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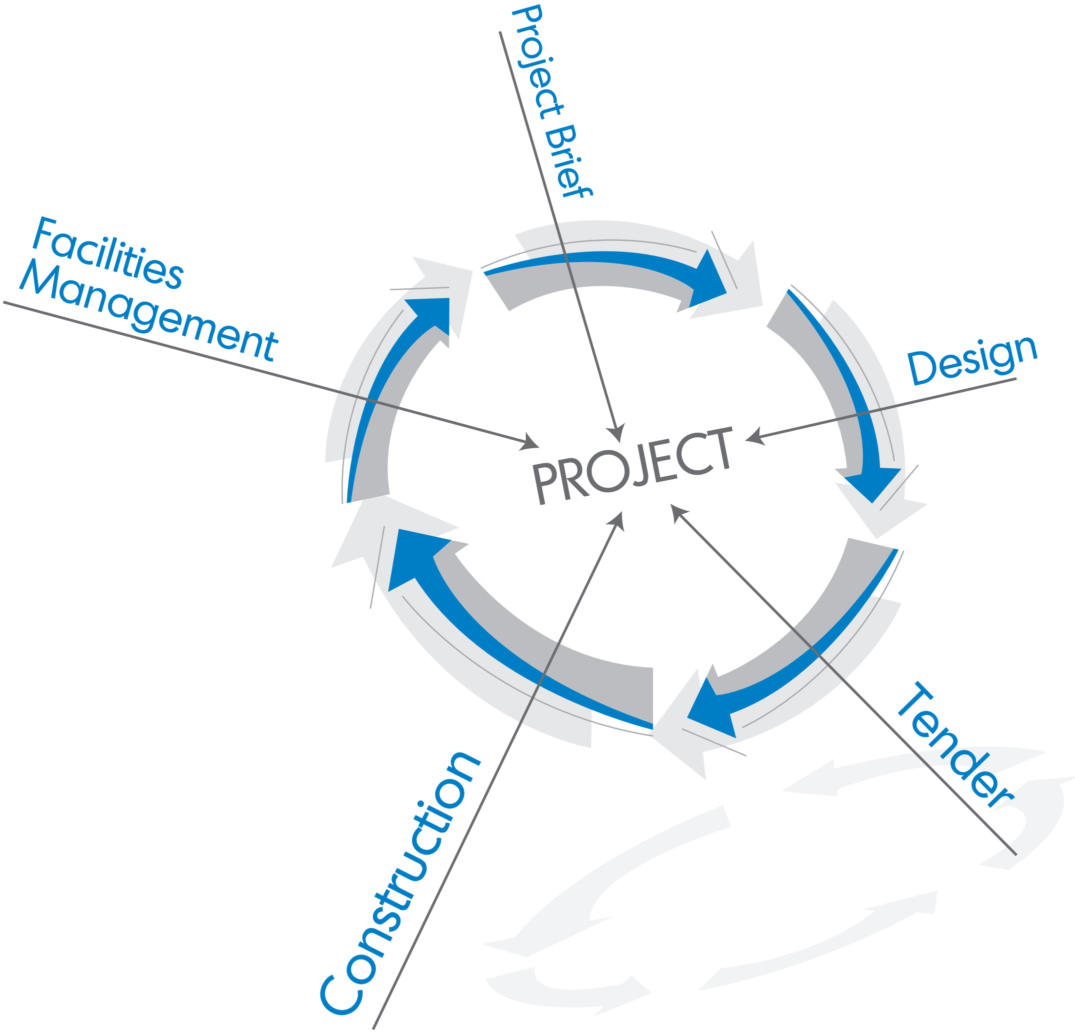

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No. 100, Jalan Putra,
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Editorial

Welcome from the Editors

Welcome to the thirty-ninth (39th) issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include nine papers that cover a wide range of research areas in the construction industry. The editorial team would like to express our sincere gratitude to all contributing authors and reviewers for their contributions, continuous support and comments.

In this issue:

Faisal Sheikh Khalid et al., discovered the optimum content of fine RCA (FRCA) as replacement sand materials for concrete through a slump, compressive strength modulus of elasticity and flexural strength tests. The overall result of concrete containing FRCA as sand replacement materials shows a significant impact as a sustainable material. It can be concluded that 20% of FRCA obtained the optimum percentage that provided significant results compared to the control and other specimens.

Ahmad Muhseen et al., investigated about the awareness of landslide risk management amongst Malaysian public. The methodology used was to select criteria based on the disaster risk management (DRM) cycle and to fashion it into a questionnaire administered to the public. The awareness of the public can be used as a yardstick in seeing the preparedness level of the community towards landslide. Via the survey done it can be it is found that the public is very much aware of landslides including some minor technical knowledge. However, the joint involvement of the civilians and authorities in the mitigation of the disaster can be improved.

Aida Atiqah Atil et al., explored the most efficient ways to enhance the geotechnical characteristics of soils by using polyurethane waste as a filler. The functional group of PU clay composite samples shows no significant changes with the drying treatment. However, from SEM image exhibited the PU waste particle was mixed successfully in clay. In summary, the risk of overheating and burning the PU waste as filler powder with the microwave processing method makes the prospective PU-CCTO the best potential in comparison to PU-CCUn and PU-CCTM. This demonstrated the effectiveness of the drying oven treatment method and its superior wettability to that of the microwave. In the future, it is recommended to utilize PU waste as filler that has been dried at a variable ratio of up to 10%.

Norhayati Abd Wahab et al., revealed the effect of curing period towards properties of cement brick made up of cement, sand, and sago fine waste (SFW) as cement replacement. SFW has a substantial impact on the compressive strength of brick in which increasing the percentages of SFW lowers the brick's value of strength. The longer the curing process takes, the stronger the brick becomes. All bricks met the requirements of class 1, 2, and 3 load-bearing bricks, according to Malaysian standard MS 1933: Part 1: 2007 which shows the potential of SFW as a revolutionary pozzolanic material for more environmentally friendly bricks.

Bismiazan Abd. Razak et al., verified IES-VE reading accuracy of naturally ventilated Royal Malaysia Police (RMP) lockup cell thermal comfort performance. The methodology used in this research is empirical comparison analysis by comparing field measurement with IES-VE simulation results. Parameter used are air temperature, mean radiant temperature, and relative humidity as thermal comfort factors, and operative temperature as thermal comfort index which were extracted from three sets of Delta Ohm HD32.3 WBGT-PMV (internal parameters), one set of Seven Elements Integrated Weather Sensor WTS700 (external parameters), and IES-VE simulation. The results showed that the range of percentage differences between field measurement and the IES-VE simulation is within the acceptable range, which support the previous studies.

Suraya Hani Adnan et al., determined the performance of concrete by flexural of the beam and compressive strength with a percentage of bamboo ash replacement from cement are 0%,5%,10%,15%, and 20%. The concrete mixture was designed by the department of environment (DOE) mix method with the flexural testing method according to ASTM C293 and compressive strength according to BS 1881-116:1983. The study's findings indicated that bamboo ash was capable of improving compressive strength performance at a replacement percentage of 5% for the BACR5 sample, and nearly the same trend happened for flexural testing at the same percentage. Thus, this study can be expanded to include a higher proportion of cement replacement, as the trend indicates an improvement for a 20% replacement rate, termed BACR20.

Nur'Ain Idris et al., investigated the performance of concrete with an additive of Semantan Bamboo Fiber (SBF) as a partial replacement of fine aggregate through a compressive strength test. This study also aims to determine the best percentage of SBF to use and compare it to previous research findings. The experiment begins with the extraction of SBF and material preparation for the design mix, followed by laboratory work, which is a concrete mix, and then common testing on concrete. This study successfully achieved its main objective, which was to investigate the strength performance of a concrete mix based on replacing fine aggregate with SBF in the concrete mix. However, the percentage of fibers used in concrete should be slight to obtain the optimum percentage more precisely.

Ayub Awang et al., critically analysed the impact of plants on heritage buildings at the Police Training Centre (PULAPOL) in Kuala Lumpur, Malaysia. Qualitative methods were employed, utilizing a case study approach and conducting interviews. The study's findings revealed that 68 out of the 143 plant species planted at PULAPOL had a negative effect on the integrity of the heritage buildings due to inadequate plant selection and less efficient maintenance practices.

Tuan Noor Hasanah Tuan Ismail et al., examined the potential of sustainable IPB by substituting Portland cement with High-Density Polyethylene (HDPE) and aggregates with Recycled Asphalt Pavement (RAP). The alternative IPB were prepared in different HDPE and RAP blends, namely 1:3, 1:4, 1:5 and 1:6. The potential of IPB was evaluated through three series of tests: density test, water absorption test, and compression test. The findings of this study showed that the highest compressive strength of 7.65 MPa was achieved by HDPE and RAP blending proportion of 1:3 (1H3R). Furthermore, the widespread use of HDPE plastic waste and RAP as new alternative building materials would help reduce the quantity of plastic waste and RAP in landfills while promoting green technology.

Editorial Committee

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THE RELATIONSHIP BETWEEN MECHANICAL PROPERTIES OF FINE RECYCLED CONCRETE AGGREGATE (FRCA) CONCRETE

Faisal Sheikh Khalid, Zahir Zaki, A. S. Mohammed Al-Hadei, Shahiron Shahidan, Syafiqa Ayob and Mohd Irwan Juki
Faculty of Civil Engineering and Built Environmental, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, MALAYSIA.

Abstract
The demand for construction materials has been growing in Malaysia. It is becoming increasing to manage and treat the solid waste generated by industry and municipal waste. A huge quantity of construction and demolition (C&D) waste has become a severe social and environmental problem. To pursue an excellent approach to sustainable issue in the construction industry and researchers focus on using the waste as a new construction material. Therefore, this study aims to discover materials such as recycled concrete aggregate (RCA) materials that can potentially serve as a substitute for natural sand. The objectives of this study are to determine the optimum content of fine RCA (FRCA) as replacement sand materials for concrete through slump, compressive strength modulus of elasticity and flexural strength tests. For this study, the concrete specimens were prepared using 20%, 25%, 30%, 35%, 40% and 45% of FRCA by volume of natural sand with a water-cement ratio of 0.5. The size of the FRCA used measured less than 5 mm. It indicates that the FRCA replacement percentage that provides the slump value within a range from 30-60mm is up until 35% replacement. The concrete specimen that contains an FRCA percentage more than that will give the slump value out of the desire range. Meanwhile, compressive and modulus of elasticity showed similar trend with the 20% FRCA replacement producing the highest strength. The values of compressive strength that are unacceptable when the FRCA replacement takes place on 45% which is lower than the characteristic strength required. The overall result of concrete containing FRCA as sand replacement materials shows a significant impact as sustainable material. It can be concluded that 20% of FRCA obtain the optimum percentage that provided significant results compared to the control and other specimens.

Keywords: *Concrete; Fine Recycled Concrete Aggregate; Replacement; Mechanical Properties.*

INTRODUCTION

Concrete is used to construct the majority of buildings today because it has numerous advantageous qualities, including acceptable compressive strength, durability, availability, adaptability, and cost-effectiveness. A new type of concrete that incorporates any waste material is currently needed by the construction sector. Waste can come from a variety of sources, including the construction and demolition process itself, the car sector, and the plantation industry. For this paper, the waste materials are coming from building construction and demolition which is concrete waste.

The notion to recycle this material came about because the government occasionally ignored the waste generated during construction and demolition (C&D). In many large cities across the world, construction and demolition debris is becoming a critical issue, especially in terms of the environment (Abid, Nahhab, Al-aayedi and Nuhair, 2018); (Azmi, Khalid, Irwan, Anting and Mazenan, 2017); (Brian, Raphael, Timothy and Zachary, 2022) and (Khongova, Chromkova and Prachar, 2022). There are several important reports about the amount of C&D trash produced annually around the world. Only 20–30% of the 136 million tonnes of C&D generated in the United States each year is recycled (Sandler & Swingle, 2006). In addition, the UK produces 70 million tonnes of C&D trash annually, and the building industry there wastes anywhere from 10% to 15% of materials (Khongova, Chromkova and Prachar, 2022) and (Department of the Environment, Transport and the Regions, DETR), 2000 China generates 29% of the MSW produced globally each year, with the building sector accounting for around 40% of this total. According to the Environmental Protection Department (EPD) of Hong Kong, 2900 tonnes of C&D trash were disposed of in landfills every day in 2007 (Wang and Tam, 2012) and (Madhu, Manoj and Rajakumara, 2022).

For instance, one of the biggest waste products from C&D is a concrete rumble. Recycled concrete aggregate refers to concrete shards made from C&D waste that has been substituted for aggregate in the manufacturing of concrete (Yang, Du and Yiwang Bao, 2011). It will make three different types of materials from the crushed RCA. The first substance is the coarse RCA (CRCA), which has a diameter of more than 5mm. Cement mortar serves as the final material. The second material is fine RCA (FRCA), which has a diameter size of 4mm or less (De Juan and Gutiérrez, 2009).

According to Senthamarai, Manoharan and Gobinath (2011), green concrete is a type of concrete that contains at least 20% of a waste product, whether it comes from daily garbage, construction and demolition waste, or agricultural waste. The ability to meet the requirements of the current generation without impeding the ability of the following generation to meet their own needs is the basic concept of sustainable development (Khalid, Azmi, Mazenan, Shahidan and Ali, 2018) and (Corinaldesi and Moriconi, 2009).

Therefore, the purpose of this study is to examine the strength potential of FRCA as a partial replacement fine material in comparison to control concrete. The percentages of replacement fine aggregates and the water-cement ratio were the study parameters utilised to determine how the two parameters related to one another. As a result, the compression test was carried out to fulfil the study's goal.

MATERIALS AND METHODS

The cement used was ordinary Portland cement (OPC), which complies with MS 522: Part 1 (2007). The composition of OPC is shown in Table 1. The coarse aggregate particle size was 14 mm and the maximum size of fine aggregates was 5 mm.

Table 1. Chemical Composition of OPC

Chemical Composition	Percentage (%)
Loss on Ignition	4.40
Silica (SiO_2)	18.08
Iron Oxide (Fe_2O_3)	2.43
Alumina (Al_2O_3)	4.72
Calcium Oxide (CaO)	61.94
Magnesium Oxide (MgO)	2.54
Sulphur Trioxide (SO_3)	2.74
Alkali-Sodium Oxide (Na_2O)	0.18
Alkali-Potassium Oxide (K_2O)	0.99

To make sure that the materials fall under the overall grade limit specified by BS 882: 1992, the size of FRCA and FNA are monitored. Figures 1 and Figure 2 for FNA and FRCA, respectively, show the size of the sieve used from 10 mm, 5 mm, 2.36 mm, 1.18 mm, 600 m, 300 m, and 150 m as well as the outcome for the grading curve. According to the results, both the FNA and the FRCA fall inside the BS 882:1992 limit, allowing FRCA to be utilised in place of the FNA. There are 6 batches of mixture with different FRCA replacement percentages which are 0%, 20%, 25%, 30%, 35%, 40% and 45%, of FRCA and the water-to-cement ratio is kept constant at 0.5 as shown in Table 2. The reference concrete mix design is calculated based on the DOE method. The desired strength is set for 35MPa, and the targeting slump is 30–60 mm which is a good slump range for structural concrete stated in Mix Suitability Factor, MSF value.

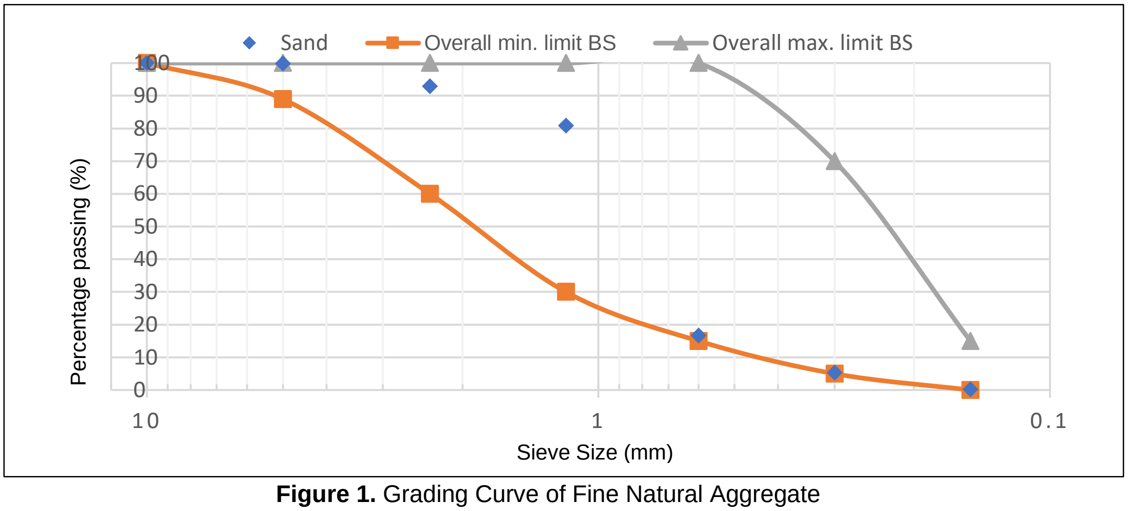

Figure 1. Grading Curve of Fine Natural Aggregate

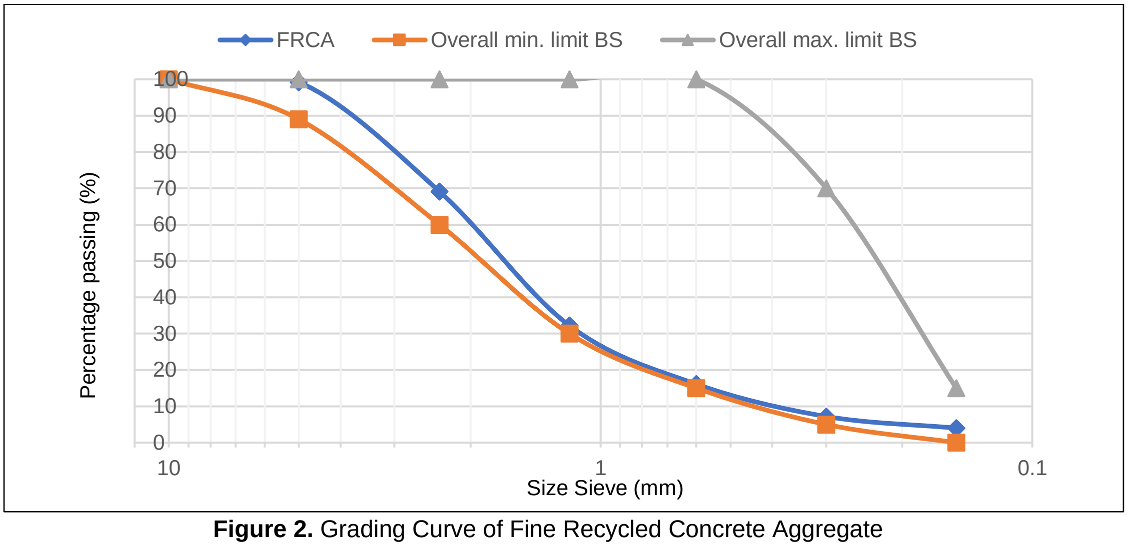

Figure 2. Grading Curve of Fine Recycled Concrete Aggregate

The compressive strength of the concrete was tested at 7 days and 28 days while for modulus of elasticity and flexural strength test was tested at 28 days of the concrete curing period. The FRCA replacement started at 20% because that is the percentage of a material that makes a concrete to be considered as sustainable concrete just as mentioned by Senthamarai, Manoharan and Gobinath (2011), concrete which contains at least 20% of waste product whether it from agriculture, daily waste or C&D waste is called green that will create sustainable development. All the concrete specimens were tested using three samples for each batch of a concrete mixture. The average of the three test results for each concrete batch was taken as the final result.

Table 2. Concrete Mixing Design (Kg/m^3)

Mix Designation	Cement (kg/m^3)	Water (kg/m^3)	Fine (kg/m^3)	FRCA (kg/m^3)	Replacement (%)	Coarse (kg/m^3)	W/C
Control	423.1	211.5	600.4	0	0	1115	0.5
FRCA20	423.1	211.5	480.3	114.2	20	1115	0.5
FRCA25	423.1	211.5	450.3	142.7	25	1115	0.5
FRCA30	423.1	211.5	420.3	171.2	30	1115	0.5
FRCA35	423.1	211.5	390.3	199.8	35	1115	0.5
FRCA40	423.1	211.5	360.2	228.3	40	1115	0.5
FRCA45	423.1	211.5	330.2	256.9	45	1115	0.5

Slump Test

A slump test is conducted according to BS EN 12350-2:2009 (2009) to determine the workability of a concrete mix before concrete is poured into moulds. A frustum of a cone with a height of 305 mm serves as the mould for the slump test. With a narrower hole measuring 102 mm in diameter at the top and a base of 203 mm in diameter, the container is set on a smooth surface and filled with three layers of concrete. A typical steel rod is tamped 25 times on each layer. Throughout the entire procedure, the mould must be tightly held to its base. Handles or footrests brazed to the mould make this easier. The slump value is determined by measuring the height of the slump cone from the tip of the concrete after the cone has been carefully lifted and filled with new concrete.

Compressive Test

The compressive strength test is the most important test that gives an overall idea of the characteristics of concrete. For this study, concrete cubes measuring 100 mm x 100 mm x 100 mm were used. The test was done according to BS EN 12390-3:2009 (2009). Firstly, the moulds were dried and later applied with a layer of oil. Next, concrete was poured in layers approximately 25 mm thick. After that, the layers were compacted with no less than 35 strokes using a tamping rod. This procedure was repeated until the third layer was poured. Lastly, the top surface was levelled and smoothed with a trowel. The specimens were stored in moist air for at least 24 hours. After 24 hours, the specimens were then taken out of the mould and kept submerged in clear tap water until the day of the compressive strength test. The specimens were cured for different periods of 7 days and 28 days. Before the test, the specimens were removed from the curing tank and wiped dry.

After that, the specimens were placed inside the compressive machine. The specimen should be placed with a smooth and clear surface at the top to avoid reading errors. Next, the specimen was aligned centrally at the base plate of the compressive machine. The load was then applied gradually and automatically. When the specimen started to fail, the final load that the specimen could withstand was recorded.

Modulus of Elasticity

The modulus of elasticity test method provides a stress-to-strain ratio value for hardened concrete regardless of age and curing conditions. Modulus of elasticity is used in the sizing of reinforced and non-reinforced structural members which establish the quantity of reinforcement and computing stress for observed strain. The modulus of elasticity values obtained are usually less than the modulus derived under rapid load application, and the MOE values under a slow load application are greater than the rapid load application. A modulus of elasticity test was conducted using a compressometer.

Suitable compressometer is used as a sensing device that measures to the nearest 5 millionths the average deformation of two diametrically opposite gage lines parallel to the axis about middle height of the specimen. It is defined by the ratio of the applied stress to the concrete to the corresponding strain within the elastic limit. This test is to determine the concrete resistance to deform when there is a presence stress applied to it. It is one of the destructive test methods to test the integrity of the concrete. The specimen is prepared using a 100 mm x 200 mm cylindrical mould. The test was conducted while loads were applied to the sample and the data was recorded manually. The data obtained were then analysed. The test was conducted according to BS 1881-121 (1997).

Flexural Test

This test is to determine the flexural strength of a concrete prism with a dimension of 100mm X 100mm X 500mm with the application of the four-point loading. Flexural strength also known as the modulus of rupture can be obtained when the maximum tensile strength of the beam is reached. This test is carried out according to BS EN 12390-5:2019 and the concrete specimens were tested after the concrete reach 28 days of age of curing.

The testing machine bearing surface is wiped clean and any loose grit is removed from the surface of the specimen that contacted with the rollers the specimen was placed on the testing machine and centred with the longitudinal axis of the specimen at right angles to the longitudinal axis of the upper and lower rollers. Bring the load-applying block in contact with the surface of the specimen and the load was applied continuously and without shock. The initial load that was applied are not more than 20% of the failure load and the load are increased continuously at constant rate between 0.04 to 0.06 MPa/s until the breaking point.

RESULT AND DISCUSSION

Slump Test

The initial slump and slump loss trend lines of all concrete mixtures are represented in Figure 3. The initial slump was reduced by the inclusion of the FRCA. The reduction increased as the FRCA percentage increased. This phenomenon could be attributed to the high specific surface area (SSA) of the FRCA compared to the fine natural aggregate (FNA). Other than that, the reduction value of the slump also triggered by the high-water absorption of the FRCA. According to Solyman (2005) results shows that higher water absorption of concrete is due to the high porosity and irregular shape of FRCA compared to fine natural aggregate. These factors will lead to an increase the specific surface area of the FRCA compared to fine natural aggregates. This property mainly comes from the old mortar in FRCA. As shown in Figure 3, the FRCA replacement percentage that provides the slump value within a range from 30–60 mm is up to 35% replacement. The concrete specimen that contains an FRCA percentage more than that will give the slump value out of the desired range.

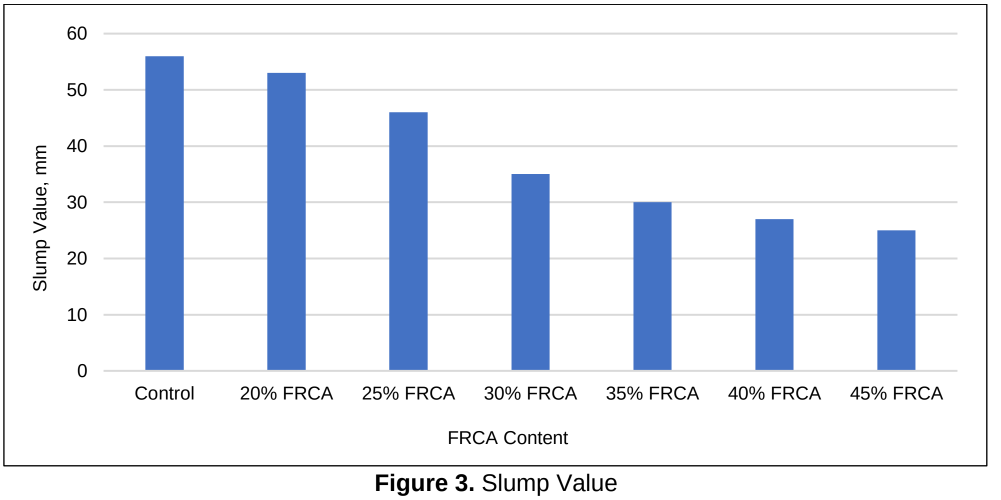

Figure 3. Slump Value

According to Ryu (2002) and Padmini, Ramamurthy and Matthews (2002), the sufficient ratio of water to cement was a significant impact when RCA collaborates in concrete. A high-water cement ratio is significant for workability but reduces the strength performances of concrete. Dhir, Limbachiya and Leelawat (1999) and Salesa, Esteban, Lopez-Julian, Pérez-Benedicto, Acero-Oliete and Pons-Ruiz (2022) stated that the compressive strength is reduced less when there is higher water to cement ratio. This occurrence is caused by the unhydrated cement present in the RCA, which changed the concrete's characteristics (Katz A., 2003). The high water-to-cement ratio is within the range of 0.5–0.7 and is best used for RCA-incorporated concrete.

Compressive Strength

The most important test for concrete is the compressive test. The compressive test indicates the quality of concrete. Figure 4 shows the compressive strength values for all the mixtures with and without FRCA at the ages 7 and 28 days of curing.

The strength of concrete is acceptable from 20% FRCA to 40% FRCA yielding values of 48.9 MPa, 40.73 MPa, 38.07 MPa, 37.2 MPa and 34.7 MPa respectively compared to the control concrete which does not contain FRCA replacement that is 42.23 MPa, the 20% FRCA replacement produce the highest in strength. The values of compressive strength that are unacceptable when the FRCA replacement takes place at 45% which is lower than the characteristic strength required. The values mentioned were obtained after a curing period of 28 days because the concrete would have achieved 99.9 % of its strength by this time which reflects the overall strength of concrete.

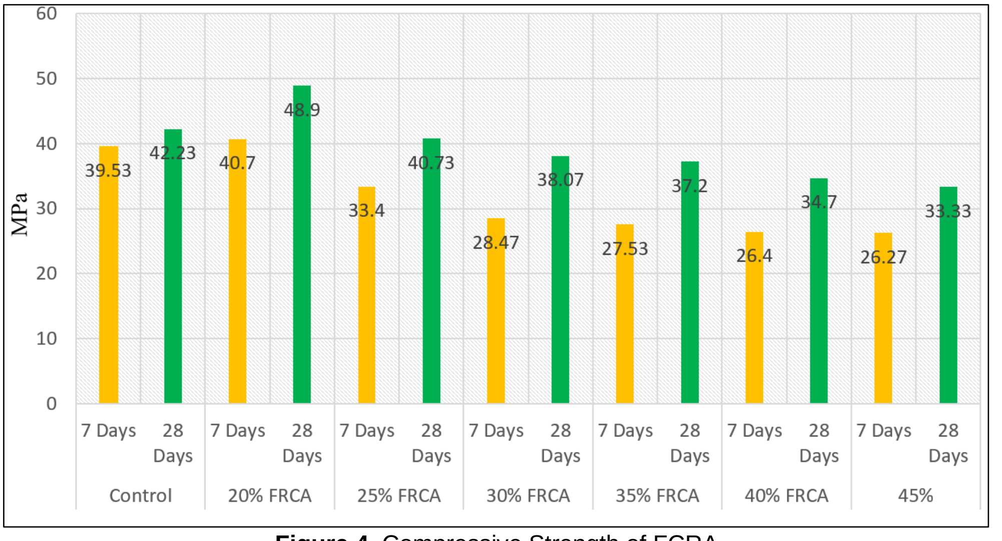

Figure 4. Compressive Strength of FCRA

The reduction in the water-to-cement ratio during mixing and the filler effects. These effects brought on properties of FRCA which is smaller surface areas to fine natural aggregate. This study found that replacement ratios between up to 40% are significant which obtained better performance in compressive strength compared to control concrete. This finding is corroborated by a study done by Evangelista and de Brito (2007) who discovered that FRCA can replace structural concrete up to 30% of the time. This is because, as long as the replacement falls within the acceptable range, the compressive strength performance of FRCA concrete is unaffected. Additionally, using FRCA in structural concrete has advantages since the original concrete's unhydrated cement and the FRCA's unique surface tend to provide a superior binder/recycled aggregate interaction (Nikmehr & Al-Ameri, 2022). Katz (2003) mentions how the high level of hydrated and unhydrated cement in the FRCA can increase the amount of cement in the mix.

Modulus of Elasticity

Modulus of elasticity is defined as the concrete ability to change and retain its shape when some forces are applied or removed respectively from it. Several factors contribute to its performance on the MOE test such as pores, voids and microcracks inside the concrete itself. The better concrete will produce a higher MOE value compared to the low-performance concrete. Figure 5 shows the data that is obtained from the MOE test between normal concrete and FRCA concrete.

The highest value of MOE was found on the 20% FRCA replacement followed by control concrete by a different of 9.33%. The readings seem to be decreasing gradually after 20% FRCA replacement. Decreasing MOE values starts from 25% FRCA replacement and the lowest value shows on the 45% FRCA replacement which is about 45% less than the value of control concrete.

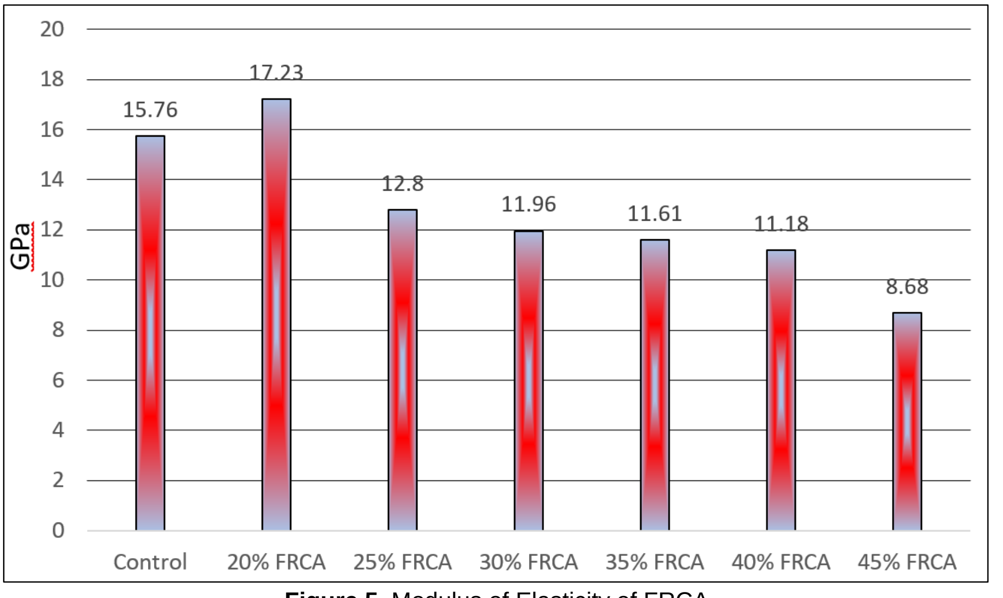

Figure 5. Modulus of Elasticity of FRCA

According to Braga, de Brito and Veiga (2012), the high MOE value is due to the fine size of FRCA that acts as a filler effect to the void that exist in the concrete. As shown in Figure 2, the grading curve of FRCA is near the lower limit of the fine aggregate graph which means that FRCA size is finer than FNA size. Other than that, the tendency of larger FRCA to break during the mixing process is higher. Braga et al. (2012), also stated that there is a possibility the unhydrated cement still exists in the FRCA. This statement also being supported by Katz (2003) stated that the old concrete consists of up to 25% of the concrete weight with both hydrated and unhydrated cement which results in the increasing amount of cement in the new mix. The presence of the unhydrated cement in the old mortar will decrease the water-to-cement ratio but with enough water, it will increase the strength of the concrete. In this research, the 0.5 water-to-cement ratio is enough for the unhydrated cement to start creating a bond and thus enhance the strength of the concrete which is also called as the increase of binder effect.

Flexural Strength

The maximum load that causes cracking can be determined through the flexural strength test. Concrete with 25% FRCA replacement shows the highest strength which is 11.02 MPa followed by 35% FRCA replacement and 45% FRCA replacement as shown in Figure 6. The lowest flexural strength was shown by the control sample which indicates that for flexural strength, all the concrete that contains FRCA in this study performed better in strength compared to the control sample. But for the displacement of concrete that took place during the test, the control sample perform the best followed by 20% FRCA replacement concrete and the values keep dropping until the 45% FRCA replacement concrete. This indicates that, even though the concrete incorporation with FRCA gives higher flexural strength, they are still brittle and easy to fail when load apply to it.

According to Braga et al. (2012), the tendency of FRCA to break during the mixing process is higher which provides the indication that the mechanical properties of FRCA are more brittle and easier to break. Other than that, a study conducted by Padmini, Ramamurthy and Matthews (2002), found that most failures in concrete occurred along the interface between cement mortar and aggregate. This indicates that the weaker interfacial zone in control concrete governs the failure. But in FRCA concrete, interfacial bond failure as well as an aggregate failure both can occur simultaneously when the concrete reaches its failure point. That is the reason why the FRCA concrete does not possess the elasticity as the control concrete.

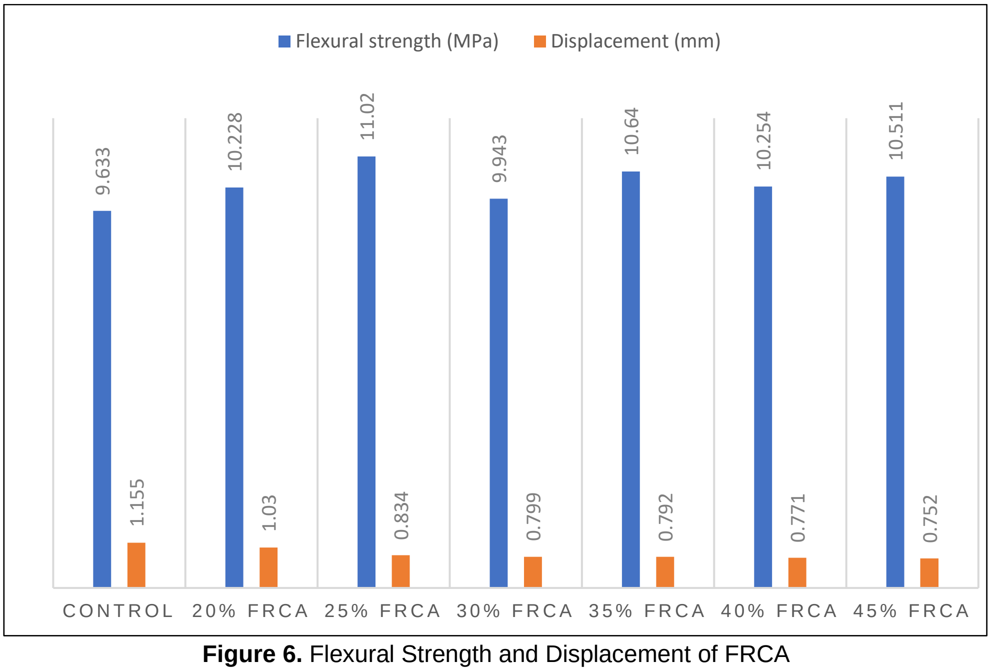

Figure 6. Flexural Strength and Displacement of FRCA

CONCLUSION

The slump starts to decrease when the percentages of FRCA increase in the mixtures. FRCA was known as a material that has la ow density which proved the replacement of sand with these materials contributed to the reduction in mass of the samples. In addition, the lower value of the specific gravity of FRCA shows that these fine aggregates as replacement materials are lighter compared to the natural fine aggregates. Hence, it reduced the slump value of each sample containing FRCA as fine aggregate replacement materials. It can be concluded that the reduction in brick density was attributed to the lower unit weight of FRCA.

The strength of concrete containing FRCA indicates significant results at 20% (compressive and modulus of elasticity) and 25% (flexural strength) compared to the control specimen. It can be concluded that the replacement of FRCA up to 35% replacement does not jeopardize the strength of concrete. It can be concluded that the concrete incorporation with 20% of FRCA shows an optimum replacement in the concrete that contributes to increasing in terms of strength and workability compared to other samples.

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AWARENESS OF LANDSLIDE RISK MANAGEMENT AMONGST MALAYSIAN PUBLIC

Ahmad Muhseen[1], Mastura Azmi[1*], Yusrin Faiz Abd Wahab[2,3] and Fauziah Ahmad[1]
[1]School of Civil Engineering, Universiti Sains Malaysia, Engineering Campus, Nibong Tebal, Penang.
[2]Malaysian Japan International Institute of Technology, Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, Kampung Datuk Keramat, Kuala Lumpur.
[3]Centre of Built Environment, Construction Research Institute of Malaysia, Sunway Putra Tower Sunway, Jalan Putra, Kuala Lumpur.

Abstract
Landslides is common in Malaysia due to the nation's all year long wet and humid conditions. The public's awareness of the disaster, or their perception of it, can be used as a yardstick for gauging the community's preparedness in face of similar disasters. This study was aimed to evaluate the public's perception of landslide risk management. The study was done via disseminating questionnaires on online platforms such as WhatsApp and Facebook to public groups of communities. The questionnaire was done according to the Disaster Risk Management (DRM) Cycle, mainly consisting of preparedness, response, recovery, mitigation, and an additional section for risk management. A total of 190 responses were recorded coming from different demographics above the age of 18. The findings show that the public is aware of landslides (over 90.6% of respondents consider landslides a threat). However, the involvement of the civilians and authorities in the mitigation of the disaster can be improved. The respondents are very much educated on the little technical knowledge such as the types of slopes, reflected from the high literacy rate of the respondents who were mainly students demographically, which shows high awareness on disasters, especially landslides among the respondents.

Keywords: *Landslides; Risk Management; Disaster; Questionnaire; Public.*

INTRODUCTION

Landslides in Malaysia are commonplace due to the annual monsoon season, torrential rainfalls, and mismanaged slopes. The condition is further worsened by climate change, which enhances the precipitation phenomenon(Abdullah, 2013; Bank Group, 2021; Gue & Tan, 2006). The public's awareness of the disaster, or their perception of it, can be used as a yardstick for gauging the community's preparedness in face of similar disasters. This study needs to be done in order to better understand the public's awareness/ perception towards disaster risk management. By doing this, better policies, for instance policies in terms of education to the public can be laid out by the government. The study contributes to the pool of knowledge regarding landslide risk management in Malaysia, and how the public as consumers and one of the stakeholders should be well informed on the landslide disaster. Data from this research can be used by policy makers to better craft the education given to the public so that they are better informed. This study was aimed to evaluate the public's perception of landslide risk management. The scope of the research is that it entails landslides present here in Malaysia; all material administered is based on the Disaster Risk Management (DRM) cycle.

The study measured public perception regarding awareness in landslide disaster risk management. The questions administered cover the disaster management cycle, including Preparation, Response, Recovery, and Mitigation. A pilot test was done involving 156 respondents and was later followed by 190 respondents from the public. The DRM covers all the fundamental aspects of disaster risk management. Through the questions asked, what is paid to attention is the public's awareness towards the risk of landslide risk management and its subsections.

LITERATURE REVIEW

Type of Landslides

A landslide occurs when a large amount of rock, earth, or debris slides down a hill (Cruden, 1991). Landslides come in a wide range of shapes and sizes, as well as movement speeds and other characteristics. We can differentiate instability in soil and rock mass based on the geological structure in which landslides occur (Geotech.hr, 2020).

For soil we differentiate according to:

1. Rotational landslide
2. Translational landslide
3. Debris flow
4. Debris avalanche
5. Earthflow
6. Creep
7. Lateral spread

For rock mass we differentiate the rock slope failure triggering mechanisms according to:

1. Block slide
2. Rockfall
3. Topple

Landslides in Malaysia

Malaysia is a Southeast Asian nation divided by the South China Sea into two regions: Peninsular Malaysia and East Malaysia, the latter of which includes the northern quarter of the island of Borneo. The country's total land area is 329,847 square kilometres, with East Malaysia accounting for 60% of that, or 198,446 square kilometres (ADPC-UNDRR, 2020; CFE-DM, 2018).

Despite its proximity to the Pacific Ring of Fire, Malaysia has mostly been safe from tectonic movement-related hazards. Despite this, it is frequently threatened by cyclones, floods, landslides, droughts, diseases, and environmental degradation that could jeopardise the country's development in the long run. The most serious problems are flooding and landslides. An estimated 29,800 square kilometres of the country flood each year, and intense tropical rainfall increases the likelihood of mass movements depending on topography and soil conditions (NIDM, 2014). Malaysia is placed naturally in the tropical region where rainfall is abundant (Abdullah, 2013; Bank Group, 2021). The country has a daily mean temperature between 26- 28 degrees Celsius. Rainfall is also high at approximately 3000mm/year, followed by two monsoon periods, usually from November till March and May till September (Bank Group, 2021). Malaysia's wet and humid climate is inducers to the nation's landslides. There were roughly 2.8 landslides per year on average, with 1.7 landslides causing human casualties and property destruction each year (CFE-DM, 2018).

Landslides in Malaysia occur especially in months of the most rainfall due to the weakened soil structure, which possibly threatens the livelihood of the local communities. From 1973 to 2007, the economic loss due to landslides amounted to about RM 4.25 billion. According to some estimates, landslides have inflicted more than $1 billion in losses since 1973, and rapid urbanisation expanding into mountainous terrain has increased the danger in many areas (Web, 2018).

As a developing country, Malaysia is also concerned about landslides. The nation's rapid development has resulted in excessive land use. This has resulted in developers opting for land at the foot of hills and developing hilly terrain and highlands (Abdullah, 2013). Without proper monitoring by the agencies responsible, hilly terrain development has resulted in various catastrophes.

Recent Landslides

One of the more recent landslides which occurred around the 13th of March 2022 is the landslide in Ampang, Selangor which required 15 houses to be vacated. Earlier that week, four individuals were killed in a huge landslide at Taman Bukit Permai 2, while a fifth victim suffered minor injuries. The incident also caused damage to fifteen houses and ten vehicles (Malay Mail, 2022). Besides, in 2021 Cameron Highlands were hit by landslides right after an intense rainstorm period which lasted over 2 hours. There were more than 12 landslides occurrences and uprooted trees, with one individual being injured. As a response to the incident, several roads were closed down (Mat, 2021). Some of the notable landslides which occurred in 2019, is the landslide which occurred in Genting Highlands, Pahang which caused a roadblock to the resort, next also in 2019 was the landslide which occurred in Jalan Lee Woon located in Ampang, Selangor which required a house to be evacuated (Majid, 2020). In 2018, three perished due to a landslide which occurred in Cameron Highlands (Apendy, 2018).

Hazard and Risk Management

Risk management can be defined as the identification, evaluation and prioritisation of risks which is accompanied by the deployment of resources in a structured and cost-effective manner or way to reduce, track, and manage the likelihood or impact of unfavourable events or to maximise the realisation of opportunities (ISO, 2021). The Disaster Risk Management Cycle begins with prevention and mitigation, preparedness, facing the actual disaster, responding to the disaster, rehabilitation and recovery, finally, back to prevention and mitigation. The administration and management of resources and responsibilities to address all aspects of emergencies and disasters emphasise disaster management. Risk management has the objective of creating and protecting value.

With reference to landslide risk management in Malaysia, there are some key actions undertaken by the authorities (Abdullah, 2013). Collectively, the actions taken pave way to better landslide risk management in Malaysia. Among the actions which are being taken includes:

1. Data collection
2. Landslide hazard and risk mapping
3. The establishment of landslide monitoring and warning systems at major hotspots
4. Slope inspection programmes
5. Having manuals and guidelines
6. Training
7. Public awareness and education
8. Setting up of Inter-governmental Committee on Slope Management (ICSM)

Risk Perception

Among the literature, risk perception is a subject that deals with the general public's perception. To gauge the public's perception, questionnaires and focus group discussions have to be made to properly see the behaviour of the public towards the risk in place (Adtiya et al., 2020; Calvello et al., 2015; Salvati et al., 2014). When using the questionnaire method, the answers are based on personal accounts related to the matter (Adtiya et al., 2020).

In the questionnaire method, the answer given is personal, depending on the respondents' demographical data. However, the limitation to this method is the lack of people participating in the questionnaire survey. Other than this, some questions within the questionnaire might be out of the participants' knowledge, leading to inaccurate answers (Thanh et al., 2021). The errors, however, are within an acceptable range. Risk perception is a key element to be understood in order for authorities and other institutional bodies to implement policies (Thanh et al., 2021). Risk evaluation can be improved tremendously by considering risk perception in the equation of managing risks (Buchecker et al., 2013).

Risk evaluation is essential for enhancing preparedness and awareness in managing the disasters such as landslides (Urbina-soria, 2016). Gauging via questionnaires and surveys and understanding the perception is essential. Without it, it would be tough to decide what to be done and what to avoid (what policy to bring forth to the public) based on the suitability of a given situation. From various studies as done by (Adtiya et al., 2020; Calvello et al., 2015; Salvati et al., 2014), an array of socio-economic, psychological and geographic characteristics can be obtained from surveys, making it uses data to be used for future actions to curb the effects of the risk (landslides for instance) in place.

Multistakeholder Collaboration

Examples of multistakeholder collaboration and cooperation involving civilians and authorities in approaches of disaster risk reduction from the side of government agencies includes the National Disaster Management or NADMA for short, the Public Works Department, the state Public Works department and not to mention the state Irrigation and Drainage Department (Chong & Kamarudin, 2018). These departments listed are responsible at every stage of the disaster risk management cycle which includes prevention, mitigation, preparedness, response and finally recovery. For instance in recent events, The National Disaster Management Agency (NADMA) and the Department of Mineral and Geosciences (JMG), in collaboration with the Public Works Department (PWD) and Malaysian Highway Authority (LLM) is taking appropriate actions on the 121 landslide occurrences which occurred nationwide during the north-east monsoon (MTL) 2021/2022 (Malay Mail, 2021).

Apart from governmental agencies, non-government agencies (NGO), with the joint forces from civilians are present in status quo in Malaysia. The NGO(s) involved include MERCY Malaysia or Malaysian Medical Relief Society, which is active in disaster risk reduction works (MERCY Malaysia, 2022). MERCY is actively doing CBDRM (Community Based Disaster Risk Management) efforts, which is a disaster risk management strategy in which at-risk communities actively participate in attempts to minimise their vulnerabilities and strengthen their capacity. The initiative is intended to stimulate community and local government participation in identifying, analysing, treating, monitoring, and evaluating potential dangers in their environment, thereby empowering them to apply solutions that they have devised.

Next, Sahabat Alam Malaysia, who is a vocal NGO on issues related to the environment including natural disasters which entails landslides. Sahabat Alam Malaysia (SAM) for instance has called out the out various stakeholders to better manage the landslide situation in various instances for example the landslide which occurred in Cameron Highlands and Selangor in recent events (Malaysiakini, 2022; Zainal, 2021).

Work Done Around the World

In Japan, a disaster-prone community due to its location has taken some steps in disaster management. One of it being the National Disaster Risk Reduction Commitment (DRR), which aim is to increase awareness amongst school children. This is to ensure the new generation of Japanese children are ready to face disaster occurrences appropriately (OECD, 2020).

Next, Indonesia aims to scale up disaster risk reduction via the application of research (Amri et al., 2017). The country also monitors disaster threats such as tsunamis via monitoring devices. These devices are actively being established and monitored to ensure the wellbeing of the local community.

In Taiwan, huge scale research and development projects are done for hazard prevention on top of the enactment of legislation (Yen et al., 2006).

In China, as part of their mitigation measures, which includes regional landslide studies and mapping, having a monitoring and warning system, landslide control works, laboratory and field research, increasing public awareness and last but not least having an insurance program (Tianchi, 1994).

Efforts for the Betterment of The Construction Industry in Malaysia

As part of the effort to improve the construction industry in Malaysia, landslides in Malaysia are governed by the National Slope Master plan which is a 15-year roadmap which outlines strategies, actions and measures which should be taken to reduce the damage (to lives and properties) due to the occurrence of landslides in Malaysia. The 15-year span starts from 2009 to 2023 (JKR, 2009).

In Malaysia for the purpose of data collection and effective slope management, slopes are catalogued. This offset possible problems related towards lack of slope data. A hazard rating or ranking system known as the Slope Management and Risk Tracking or SMART for short (Jamaludin & Hussein, 2014), mitigating the problem of the lack of data which has been a pressing issue in making informed decisions. The system uses spatial data to operate. The spatial study is separated into two which is the geomorphological mapping works and the production of hazard maps and documentation (Abdullah, 2013).

Slope inspection programs are being conducted at the federal roads in preparation for rainy seasons in Malaysia (JKR, 2006). Guidelines on slope maintenance is mentioned thoroughly in the latter document. The Malaysian slope maintenance guidelines were adapted from the Hong Kong slope maintenance guidelines with certain changes.

In Malaysia, the application of real-time monitoring systems remains limited. The early warning systems available locally use is mainly rain gauges and surface monitoring devices as the primary instruments. Most of the landslide's hazard and risk assessment work carried out by the Public Work Department (PWD) is based on the linear type of slope assessment, mainly carried out for road maintenance projects.

Apart from that, training is being at multiple levels, as simple as including the syllabus in schools throughout the nation (How et al., 2020). However, it is found that there is still improvements to be made for the syllabus, to make it more holistic and long term in nature.

METHODOLOGY

The methodology of this research starts with selecting criteria based on the disaster risk management (DRM) cycle, whereby components of the DRM were considered when designing the questionnaire. A pilot study was undertaken. It was proven to be successful to test the feasibility of the study. From the pilot test, minor corrections (structure and sequence of the questions) were made to the final questionnaire to administer to the public. In this way, the questionnaire was much more optimised. The full questionnaire was administered to the public via social media and communication platforms like local WhatsApp and Facebook groups. Once the responses had been collected, the various feedback was extracted into an excel file. Next, the extracted file was inserted into the SPSS software for further analysis. Basic statistical analysis was done by computing the mean, mode and other related criteria such as the standard deviation. Other than that, Cronbach's Alpha (the indicator for internal consistency of the data) was computed. A thorough discussion section and conclusion finally followed the statistical analysis stage.

There were mainly two software used in this research, which is as follows;

i) SPSS Software

The SPSS software was used to find the basic statistics figures such as the mean, median and mode. On top of that, Cronbach's Alpha was also computed to determine the data's reliability or internal consistency.

ii) Microsoft Excel

This software was used to convert the raw data from the questionnaire to figures such as one up to five (the Likert scale) to ease data analysis in SPSS. The other demographic data answers were also converted to figures to ease the process.

RESULTS AND DISCUSSION

General Information on Respondents

Figure 1 summarises the data from the first section of the survey questions, representing the respondents' general information. It was found that 86.2% of the respondents were between 20 to 30 years old. The probable reason that majority of the respondents came from this age group of millennials would be because of a huge chunk of social media users wherein the questionnaires were administered to were millennials. 5.3% of respondents were 30 to 40 years old, 2.6% ranged from 40 to 50 years old, while other than that accounted for 5.8%.

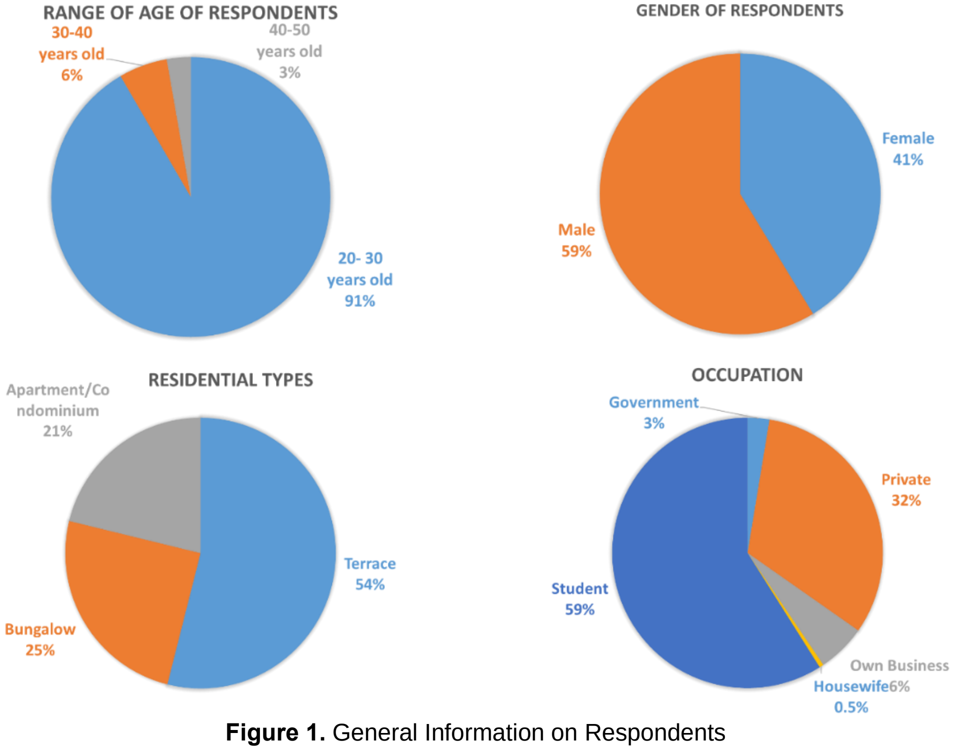

Figure 1. General Information on Respondents

For gender, it was found that 41.3% or 78 respondents were female, and the remaining 58.7% were male respondents. Of all the respondents who attended to the questions, 53.7% lived in terrace houses, 24.7% lived in bungalow houses, and the remaining lived in apartments or condominiums. From the data obtained, 2.6% of the respondents worked in the government, 32.1% were attached to the private sector, 5.8% had their own business, 0.5% were homemakers, and the largest percentile was students having 58.9% of the occupation make-up.

From the data obtained, Cronbach's alpha was calculated. The Cronbach's alpha is one of the common measures for internal consistency or the reliability of the data. The value ranges around 0.0 and +1.0. When the value approaches 1.0, the internal consistency is higher. For this dataset, the Cronbach's alpha obtained is 0.956, indicating high internal consistency.

Disaster Preparedness

Regarding questions on disaster preparedness, when asked if the respondents knew about the landslide emergency-response for their area, most of them were either neutral (41.7%) or unsure (29.4% disagreed and 9.6 % strongly disagreed respectively) about the emergency response for their area on preparedness (Figure 2). The probable reason for this might be the lack of alertness due to their area's low frequency of disaster events. Most of the respondents were unprepared for the emergency response of their area, and they were also unprepared for the evacuation plans. From the total respondents, only 2.7% strongly agreed that they had some knowledge of the evacuation plans of their area.

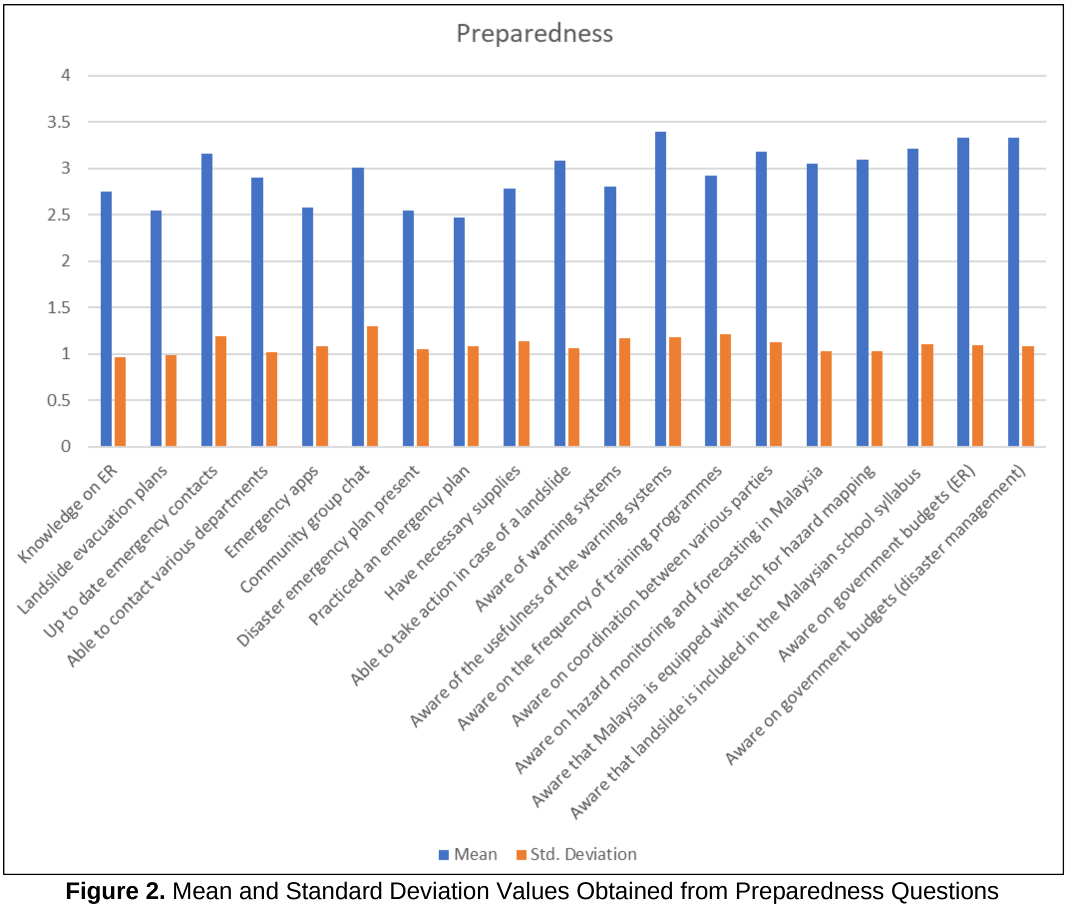

Figure 2. Mean and Standard Deviation Values Obtained from Preparedness Questions

Similar to this from the pilot study, the results were more to the neutral option. Only 2.6% strongly agreed that they had some knowledge of the evacuation plans of their area, which meant that the pilot study results and actual results were close by together and not too skewed apart. They were neutral when it came to having emergency contact numbers on their phone. The probable explanation for this is because the respondents blanket their emergency contacts to one number only.

Overall, the respondents were unprepared for the occurrence of a disaster. This is mirrored in the mean and standard deviation values obtained. The unpreparedness of the public might be due to the low alertness of the public, especially in locations of respondents who stayed in flatlands which were not necessarily susceptible to landslides. Low alertness equates to inadequate preparations by the public.

Preparedness could be one of the aspects the public could work on with the help of the careful planning of authorities in strategizing key priorities such as a systematic and laid out evacuation plan. The following finding is parallel to the objective of this study which is to find out the perception of the Malaysian public on landslide risk management.

Disaster Response

For disaster responses, most of the respondents are aware of the impact of landslides and must report the occurrence of a landslide (Figure 3). When asked about the public's awareness of the occurrences of landslides in recent years, the public is very much aware of the occurrence of landslides, with 50.3% agreeing on the statement that they are also aware of the impacts of landslides, 56.8% agree with this statement. This indicates that the public is well aware of landslides and their effects; this reflects the demographics of the respondents, who are mainly millennials either studying or working. Those in this age group received an education with the syllabus, which included basic landslide know-how in the Science subject. They too agree that a certain reliance on media, especially the internet, plays an important role during a disaster. In times of crisis, the mobile phone equipped with a data plan is most effective, according to the public, in conveying and receiving important news that could be the deciding factor of the safety of the community and the local environment. However, the public does not acknowledge or are rather neutral on local politicians and the UN. This might be due to a lack of knowledge in the role of bodies such as the United Nations. Good exposure, especially at the primary and secondary school levels and through the media such as television and newspapers on the occurrence of landslides in the recent years especially, would be why most of the respondents were aware of the impacts of landslides.

On top of that, this has also led to the respondent's familiarisation with certain search and rescue teams. Moving forward into the future, more exposure via the internet medium can lead to a better understanding on the public’s side on how to respond to the landslide disaster. To conclude, the respondents are well aware of the landslide impacts but could improve how they respond.

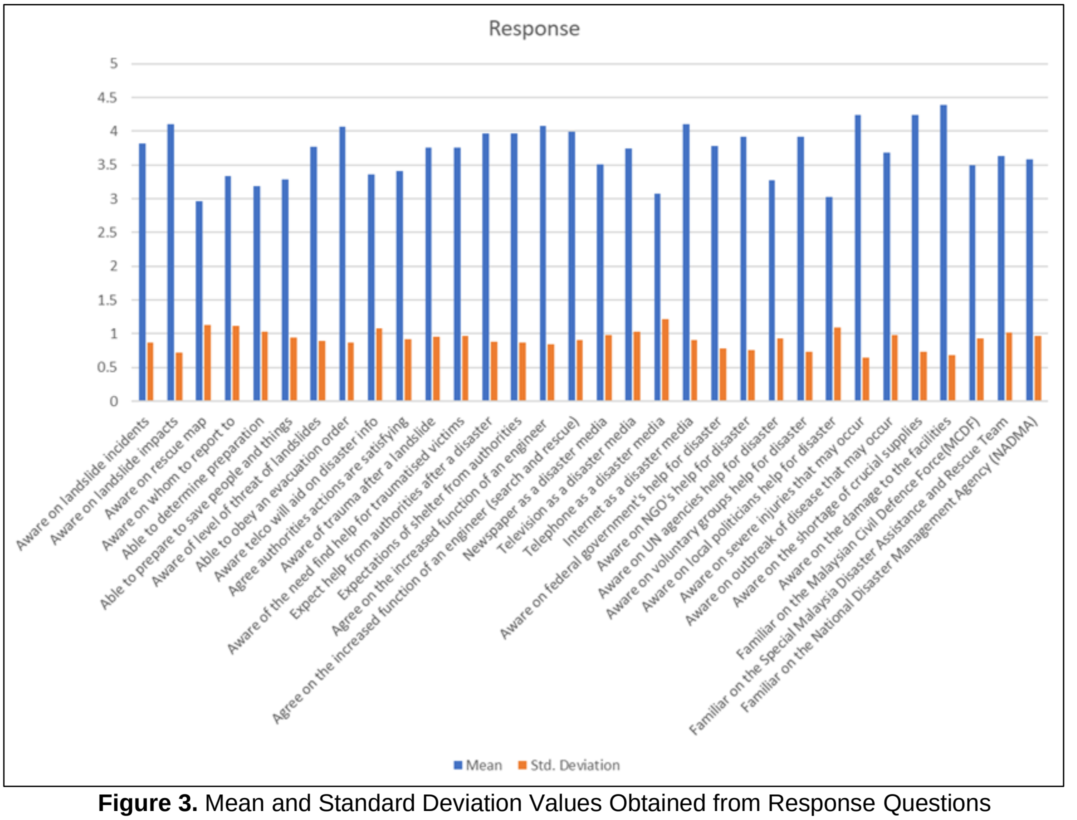

Figure 3. Mean and Standard Deviation Values Obtained from Response Questions

Disaster Recovery

In disaster recovery-related questions, the public's awareness of the disaster recovery part of disasters is high (Figure 4). They understand the importance of recovery from disasters. They, however, feel neutral towards the satisfaction with the reconstruction work efficiency after a landslide occurrence. The onset of such a response might be due to the long downtime periods attributed to repair works synonymous with landslides. The respondents also have a high awareness of which types of slopes are safe to live by. This would certainly be a useful trait when choosing housing areas to live in; respondents with the knowledge in mind would make more informed decisions at key moments. The respondents are also seen to have developed a preference for slope structures that are appealing to live by. This could be attributed to the high literacy levels of the respondents, who were majority students and working adults in both government and private agencies according to the demographics of the data. Preferences on slopes could be due to the years of observation by the respondents on slopes around hilly areas and reported cases on landslides which has led to better judgement by the respondents in making informed decisions.

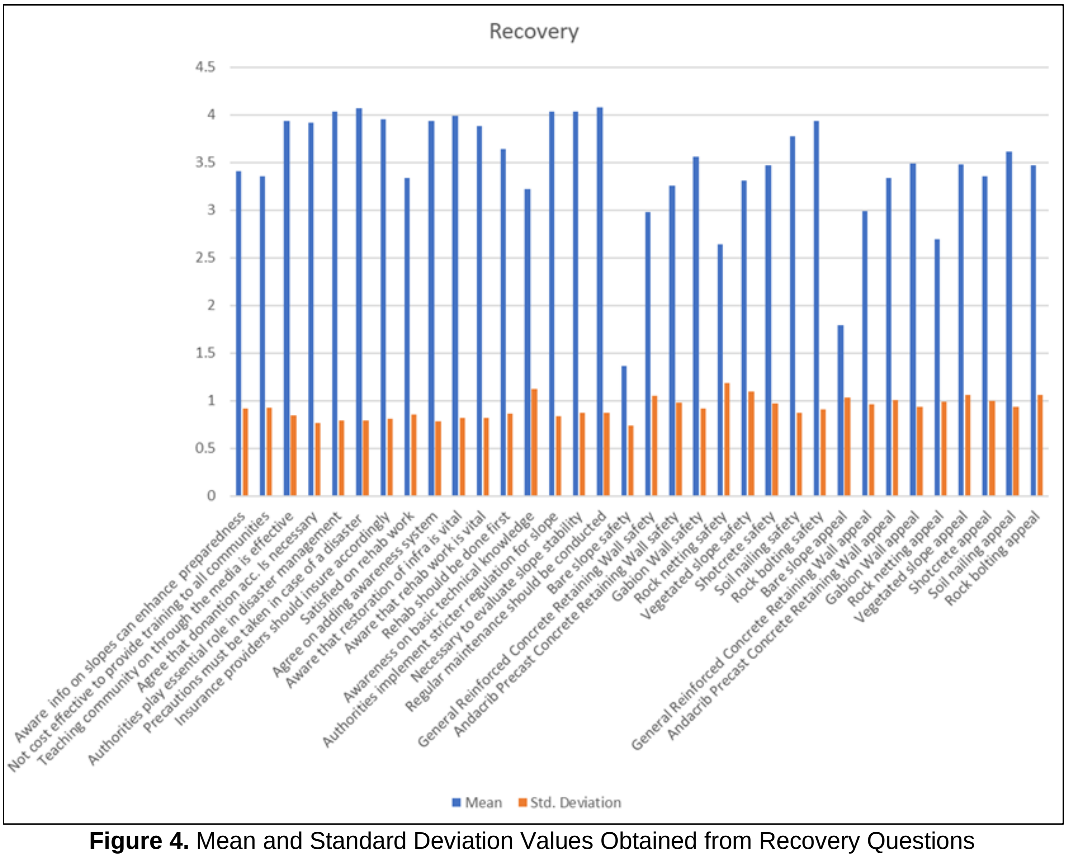

Figure 4. Mean and Standard Deviation Values Obtained from Recovery Questions

Disaster Mitigation and Perception of Risk Management

Finally, the respondents agree that mitigation should be a joint effort between authorities and the general public for mitigation and the perception of risk management (Figure 5 and 6). They are aware of taking compensation guarantees such as insurance policies to safeguard their property (Figure 5). This shows that respondents are willing to fork out the initial lump sum of money on financial aids such as insurance for a more guaranteed future, especially when dealing with volatile natural disasters, especially landslides. Respondents expressed their willingness to work with the authorities to contribute to data collection for mitigation. Although working together is not easy, especially when dealing with the masses, the public via the survey done is positive towards it, showing the maturity of the respondents towards achieving a better disaster management setting.

In conclusion, the respondents' willingness towards the betterment of their surroundings is expressed greatly via the survey done, and this means even if it means working in close hands with the authorities, which in some cases involves painstaking data collection and tallies and census. Last but not least, a majority of 90.6% of respondents consider landslides as a threat. This certainly reflects that the level of alertness towards the landslide disaster is high.

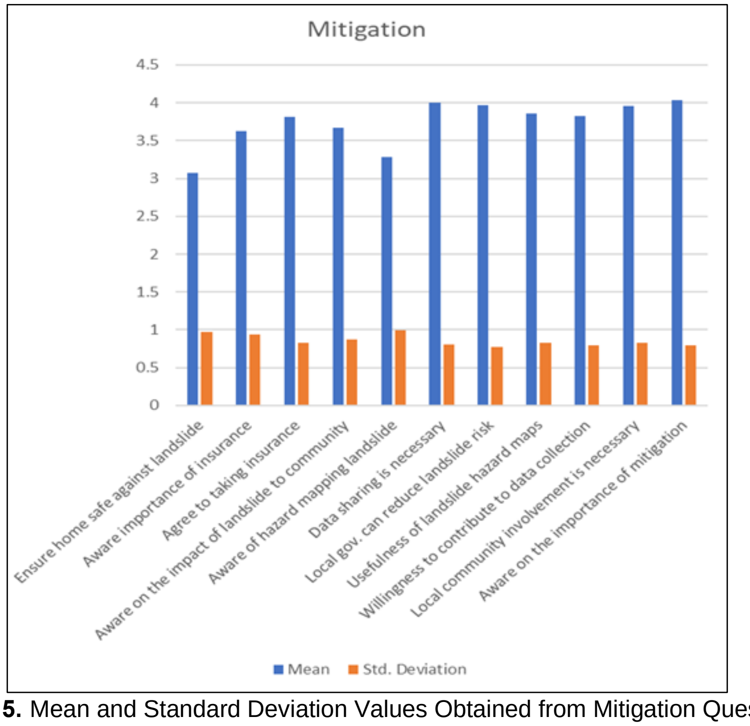

Figure 5. Mean and Standard Deviation Values Obtained from Mitigation Questions

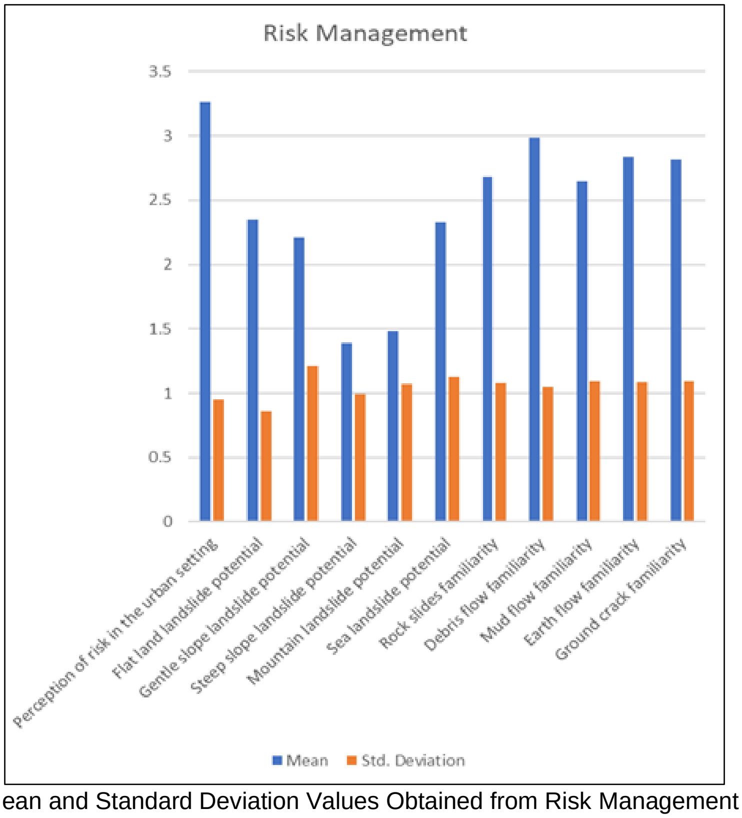

Figure 6. Mean and Standard Deviation Values Obtained from Risk Management Questions

CONCLUSION

A survey was designed to gauge the public's awareness or in other words their perception of landslide risk management, which is the main objective of this paper. The awareness of the public can be used as a yardstick in seeing the preparedness level of the community towards landslide. The data obtained from the survey was analysed using two software, mainly Microsoft Excel and the statistical analysis software SPSS, to obtain the basic statistical information and the representation of data in the form of graphs in MS Excel. Via the survey done it can be concluded that the public is very much aware of landslides (over 90.6% of respondents consider landslides a threat). However, the involvement of the civilians and authorities in the mitigation of the disaster can be improved. The respondents are very much educated on minor technical knowledge such as the types of slopes, which shows high awareness of disasters, especially landslides. The findings from this paper can be used to improve the education given to the public so that they are better informed at can cooperate better with the authorities to manage the landslide disaster in Malaysia in case of the occurrence of a disaster. For future recommendations, the period of which the questionnaires are administered may be lengthened to reach a greater audience depth therefore providing a more holistic representation of the public. The questionnaire could also be made easier and more straight forward to ease the process of data collection, for instance by reducing the time spent for answering each questionnaire therefore providing an incentive for them to answer the questions more gingerly. To sum up, closer cooperation between the public and authorities can pave way to better landslide disaster risk management in Malaysia.

ACKNOWLEDGEMENT

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PHYSICAL CHARACTERIZATION OF POLYURETHANE-CLAY COMPOSITE DOPED WITH TREATED AND UNTREATED PU WASTE AS FILLER FOR SUBGRADE LAYER APPLICATIONS

Aida Atiqah Atil[1], Nik Normunira Mat Hassan[1*], Adyla Illyana Roseli[1], Fatimah Mohamed Yusop[1], Anika Zafiah Mohd Rus[2], Noraini Marsi[1], Tuan Noor Hasanah Tuan Ismail[1] and Nur Faezah Yahya[1]
[1]Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, Pagoh, Muar, Johor, Malaysia.
[2]Sustainable Polymer Engineering, Advance Manufacturing and Material Center (AMMC), Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia.

Abstract
One of the most efficient ways to enhance the geotechnical characteristics of soils is to use polyurethane waste as a filler. In this study, the PU waste was soaked in a 0.05 M sodium hydroxide (NaOH) solution as an alkaline cleaner before being sieved to a size of 300 m. Then, the PU waste as filler was dried in microwaves and a drying oven. The PU clay composite samples were prepared at 0%, 2.5%, and 5% of PU waste filler loading namely PU waste untreated (PU-CCUn), PU waste treated by microwave (PU-CCTW), and PU waste treated by the oven (PU-CCTO), respectively. Fourier Transform Infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and water absorption was used to examine the physical characteristics of PU clay composite with treated and untreated PU waste filler loading. According to the results, the functional group of PU clay composite samples shows no significant changes with the drying treatment. However, from SEM image exhibited the PU waste particle was mixed successfully in clay. The PU clay composite shows that 12% more water was absorbed by PU-CCUn than by PU-CCTO and PU-CCTM due to the bigger pore sizes. In summary, the risk of overheating and burning the PU waste as filler powder with the microwave processing method makes the prospective PU-CCTO the best potential in comparison to PU-CCUn and PU-CCTM. This demonstrated the effectiveness of the drying oven treatment method and its superior wettability to that of the microwave. In the future, it is recommended to utilize PU waste as filler that has been dried at a variable ratio of up to 10%.

Keywords: *PU Filler; Polyurethane Waste; Drying; Subgrade Layer.*

INTRODUCTION

Polyurethane (PU) is widely used in a variety application such as furniture, insulation walls, roofs, coatings, adhesives, and automotive parts (Ya Wei, Fuming Wang, Xiang Gao, Y. Zhong, 2017). In 2022, 61.8 million tonnes were generated in Europe which produced 359 million tonnes of plastic (Agrawal, A., Kaur, R. and Walia, R.S., 2022). Other than that, there are only 47% of post-consumer plastic waste was collected, 32.5% was recycled, 42.6% was used for energy recovery and 24.9% was landfilled in Europe (Chevali, V. and Kandare, E., 2016) and PU is one of among plastics that were fifth most-produced polymer in Europe and seventh position worldwide (Samaila Saleh, 2016).

The directives of the European Union regarding as the current demand of the recycling of plastics for 2050 (A. Upadhyay, S. Kaur, 2016; Y. Yi, L. Gu, S. Liu, 2015), and the interest in recycling them suitable and efficient way has skyrocketed amongst the scientific community. However, the disadvantages of waste from PU were natural prolonged degradation times and poor disposal management posing a severe risk of environmental damage. Furthermore, PU possesses multifunctional properties such as lightweight, high mechanical properties, and impermeability (Gunturi M, Ravichandran P.T., K.D.K, Annadurai R., Rajkumar P.R.K., 2015). The variety of properties gives PU numerous possible uses in geotechnical engineering, industrial, and medical industries. It may also be used to enhance the properties of marine clay grouting (A.M.M. Fakhar and A. Asmaniza, 2016).

Expanded polystyrene (EPS) used as composite soil has played a vital part in solving additional settling issues over soft ground in geotechnical engineering. The components of EPS include EPS, soil, a binder, and water (Garcia, P.S., de Sousa, F.D.B., de Lima, J.A., Cruz, S.A., Scuracchio, C.H., 2015). EPS is an expanded polystyrene (EPS) granule that is lightweight, environmentally friendly, and high-pressure resilient. Pre-puff EPS beads, EPS shreds, and EPS strips are among the EPS materials used in the composite soil. Fly ash (As Colom, X., Faliq, A., Formela, 2016) is used as a binder to enhance the shear strength of EPSCS (Garcia, P.S. et al., 2015). This material offers an option for long-term EPS storage. EPSCS is particularly appealing in many geotechnical applications, including strong durability under dynamic stress and long-term monotonic loading, making it a great choice for pavement construction.

As a result, a variety of fillers have to be included into foam or composite samples (As Colom et al., 2016). Filler is any substance that is added to a PU-CC composition to reduce the cost or improve the characteristics. The higher the degree of the filler's surface area, the greater its stiffening ability on the PU-CC (Ahraf, M.H., 2010). Several research M. Singh, A.L.A. Musbah, D.C. Wijeyesekera, 2016; M.A. Mohammed Al-Bared and A. Marto, 2017; N.Z.M. Yunus, 2015, have been conducted in order to get access to the field use of polyurethane in ground improvement. They discovered that injecting PU into the pavement subgrade enhanced strength and stiffness, decreased volume change, and increased bearing resistance. The compressibility then rises, but the void ratio decreases.

Nitin Tiwari et. al., (A. Marto, N. Zurairahetty, M. Yunus, and F. Pakir, 2014) investigated the micro-structural geotechnical properties of expanding clay combined with EPS granules. The larger expansion and EPS were not feasible as the maximum EPS increment is 1%. The addition of lightweight EPS beads improves the engineering qualities of the expanding clay soil significantly. EPS is a non-natural ultra-lightweight aggregate with closed-cell membranes and a non-absorbent that may be easily combined with sand, clay, and chemical additives (M. W. Bo, A. Arulrajah, P. Sukmak, and S. Horpibulsuk, 2015). The issue with EPS is that it dissolves when exposed to liquid (D.K. Rao, 2011). According to M.A. Mohammed Al-Bared and A. Marto (2017), they investigated the possibility of polyurethane increasing subgrade soil strength. They noticed that grouting the soils with PU improved the soil significantly.

PU has been investigated by several researchers as a soil improvement material. In research on resin injection in clay with strong plasticity, Nawamooz et al. (2016) found that at all depths examined near the injection site, the pressure limit and soil resistance significantly increased before and after PU injection. Others conducted studies on the use of PU for reducing road flood damage. In this study, the types of soil hard soil and soft soil that are frequently used as fill for roads were explored. The clay soil was amended with polyurethane waste filler without delaying the construction process in order to create a secure and long-lasting structure (M.A. Mohammed Al-Bared and A. Marto, 2017; Atahu, M.K., Saathoff, F., Gebissa, A., 2019). Microwave treatment and drying oven treatment are two different types of polyurethane waste filler treatment. The findings of these investigations were summarised as L. Lei, L. Zhong, X. Lin, Y. Li, Z. Xia (2014); V. Ivanov, J. Chu, V. Stabnikov, B. Li (2015), looked into the impact of microwaves on andesite samples. It shown that andesite specimens melted entirely after being subjected to 900 W of power at a frequency of 2.45 GHz for 30 minutes in a multi-mode cavity, reaching temperatures in the region of 700 °C.

Stabilization is the technique of blending and mixing with soil to enhance certain properties of the soil (Z. Yang, X. Zhang, X. Liu, X. Guan, C. Zhang, Y. Niu, 2017; D.F. Grouting, 2007) to solve the problem in clay soil. The procedure may include blending soil to obtain the required gradation or incorporating commercially available additives, such as fly ash, that may modify the gradation, texture, or plasticity or function as a binder (As Colom, et al., 2016). As a result, the focus of this research has been on the characterisation of polyurethane clay composite (PU-CC) with varied polyurethane filler ratios at different treatment procedures as an alternative to soil stabilising techniques for subgrade applications.

MATERIALS AND METHODS

Preparation of PU Waste as Filler

The preparation of PU waste filler began with the preparation of raw materials and the drying process via the recycling method of the PUF waste filler. The name of the fillers is polyurethane filler untreated (PU-FUN), polyurethane filler treated by drying oven (PU-FTO), and polyurethane filler treated by microwave (PU-FTM). This process was conducted using a crusher machine at Chemical Laboratory Universiti Tun Hussien Onn Malaysia (UTHM).

Figure 1 and Figure 2 show the procedure preparation of treated PUF filler with a drying oven and microwave, respectively followed by standard ASTM D1140-14. The preparation of PUF filler treated started with the collection of PU waste from Jiang Ji Cushions. The waste PU uses part of the mechanical recycling approach by drying oven method. The 500g of PU waste was soaked in 0.05 M sodium hydroxide (NaOH) solution within 40 minutes and then rinsed thoroughly with distilled water. NaOH as a cleaning agent reacts to remove the dirt from the specimen. After that, the waste PU was treated using a drying oven from Memmert brand at 60 °C for 3 hours.

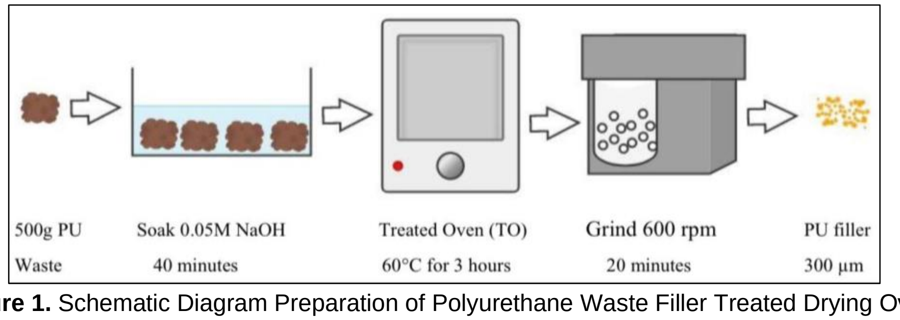

Figure 1. Schematic Diagram Preparation of Polyurethane Waste Filler Treated Drying Oven (PU-FTO)

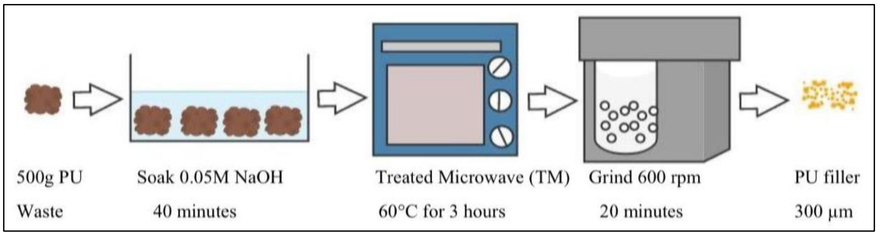

Figure 2. Schematic Diagram Preparation of Polyurethane Filler Treated Microwave (PU-FTM)

This drying process was conducted to remove the liquid content in PU waste. The process was continued with converted PU waste to particle filler size by using the grinding machine Brand Fritsch Planetary Micro Mill Pulverisette 7 made in German. The grinding condition was set up at 600 rpm and 20 minutes. The grinding bowls used is 30 pieces of grinding balls during the grinding process. The powder size of PU waste filler was sieved at 300 microns under room temperature conditions. After completing the sieving process, this powder of PU waste filler is called PU waste filler treated by drying oven (PU-FTO).

Preparation of PU-CC Sample

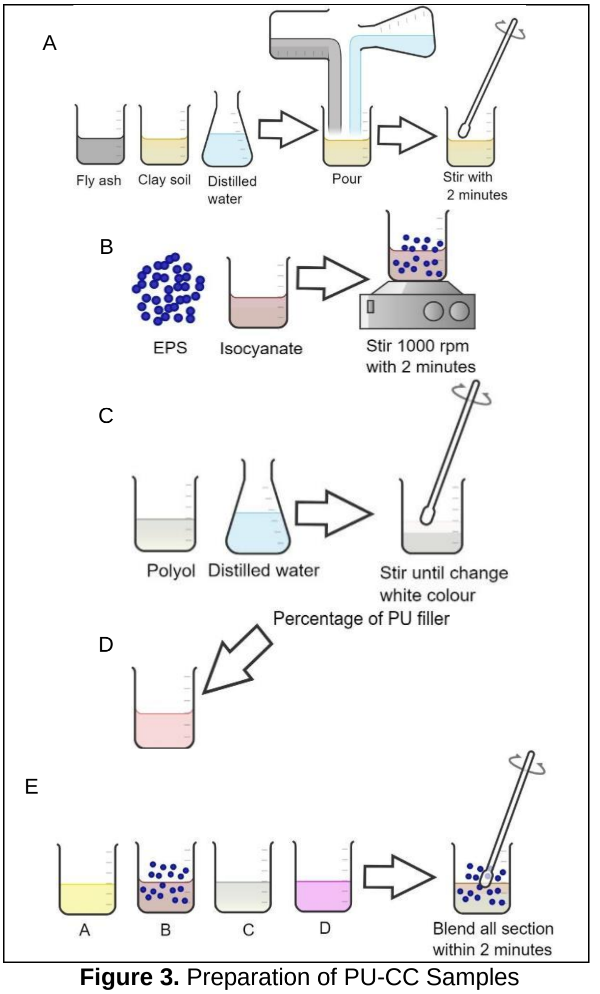

Figure 3. Preparation of PU-CC Samples

The preparation of PU-CC samples was started by sieving the soft clay at 4.75 mm as follows to ASTM 4221-18. The fabrication of the PU-CC sample was prepared by mixing 100g soft clay and PU-CC filler with different ratios of 0%, 2.5%, and 5% by weight of soft clay. The preparation was kept in an environmental chamber at 25 ± 2 µ°C and 65 ± 5% humidity to maintain the constant temperature and moisture content in the soft clay soil.

Figure 3 shows the fabrication process of PU-CC was categorized into four sections are section A the soil, fly ash, and distilled water was stirred for 2 minutes with a hand mixer. While section B, isocyanate and expanded polystyrene (EPS) bead 0.2mm were quickly stirred by magnetic stir with 1000 rpm for 2 minutes. For section C, the distilled water was stirred with polyol until turn to white colour. Then, section D is the percentage of PU waste fillers. Next, all sections (A-B-C-D) were mixed within 2 minutes, and then the PU-CC mixture was poured into containers at room temperature condition.

During the process of pouring, the containers were lightly tapped on the orbital shaker at 300 rpm within 2 hours to blend all material homogeneously. Immediately after 2 hours, the samples were covered with a lid to avoid moisture loss. The preparation of samples was namely at different ratios of PU waste filler treatment such as untreated filler PU-CCUN, treated drying oven (PU-CCTO), and Treated microwave (PU-CCTM), respectively.

PHYSICAL CHARACTERIZATION OF TREATED AND UNTREATED PU-CLAY COMPOSITE

Fourier Transform Infrared Spectroscopy (FTIR)

To verify the functional groups that appear in treated and untreated PU waste filler, the production of PU waste filler untreated and treated was evaluated by FTIR spectroscopy. FTIR spectra were collected at room temperature in ATR mode using an Agilent Technologies Cary 630 with a range of 4000 cm^{-1} to 650 cm^{-1} spectral range with background scans 20 (Kowalczuk and Pitucha, 2019; Bergamonti, Taurino, Cattani, Ferretti, Bondioli, 2018).

Scanning Electron Microscope (SEM)

The cell morphology of the flexible PU waste filler untreated and treated was examined with a Quanta FEG 250 environmental scanning electron microscope (SEM) using an acceleration of 20 kV (Choe H, Sung G, Kim JH, 2018; Chauhan, R., Kumar, R., Diwan, P. K. and Sharma, V., 2020). The result was obtained by averaging 200 µm scans at 20X magnification.

Water Absorption

The laboratory water absorption tests were conducted at 24 hours curing times in the room chosen for the treated and untreated PU-CC composites samples and ratios of the laboratory water absorption tests.

$$Water\ Absorption\ (wt.\%) = \frac{Wb-Wa}{Wa} x100\% \quad (1)$$

Wb – Weight sample before
Wa – Weight sample after

RESULTS AND DISCUSSION

Fourier Transform Infrared Spectroscopy (FTIR)

The overlay FTIR spectra of the PU-FUn, PU-FTO and PU-FTM are shown in Figure 4. The mid-IR spectrum is divided into four regions which are the single bond region (2500-4000 cm^{-1}), the triple bond region (2000-2500 cm^{-1}), the double bond region (1500-2000 cm^{-1}), and the fingerprint region (600-1500 cm^{-1}). The peak at 3274 cm^{-1} is attributed to the hydroxyl (–OH) stretching vibration of flexible PU untreated. There were no peaks observed at 2270 cm^{-1} [26]. The absence of this peak indicates that, within the detection limit of ATR FTIR, all –NCO groups reacted with the OH groups for PU waste filler untreated and treated. The presence of a hydrogen bond with carbonyl from the urethane network leads to the shifting of frequency. The typical characteristic absorption peaks of PU waste filler untreated and treated also appear, including the broad bands at approximately 3274 cm^{-1} and 1718 cm^{-1}, which are attributed to the urethane N–H stretching and C=O stretching, respectively. –OH and N-H are similar, causing surface hydroxyl groups to absorb water.

Furthermore, the peaks at around 1528 cm^{-1} and 1080 cm^{-1} are attributed to the N–H in-plane stretching and the C–N bond stretching, respectively, occur on PU filler composite for drying oven. The band at approximately 1082 cm^{-1} and 1080 cm^{-1} corresponded to the C–N groups. The peaks at around 926 ~754 cm^{-1} may be associated with the C–O stretching modes. The transmittance for PU waste filler after the treatment decreased compared with the waste flexible PU before treatment.

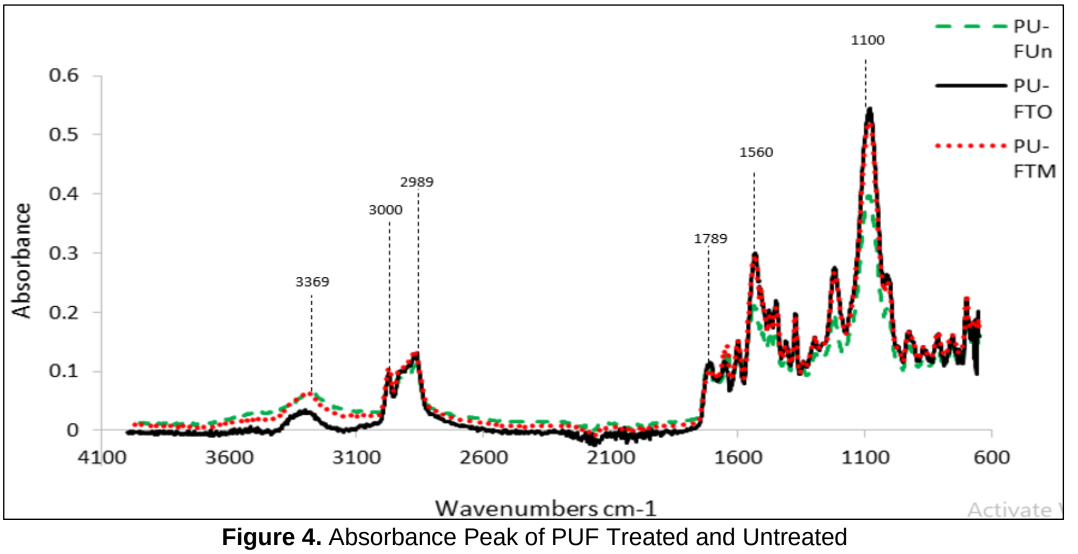

Figure 4. Absorbance Peak of PUF Treated and Untreated

According to the FTIR spectra region in Figure 5 and Figure 6, added PU filler 2.5 % of polyurethane clay soil untreated (PU-CCUn), polyurethane clay soil treated drying oven (PU-CCTO) and polyurethane clay soil treated by microwave (PU-CCTM) was 3800 to 550 cm^{-1} with similarly with Figure 5 were observed to understand the functional groups of polyurethane formation of different fabrication method.

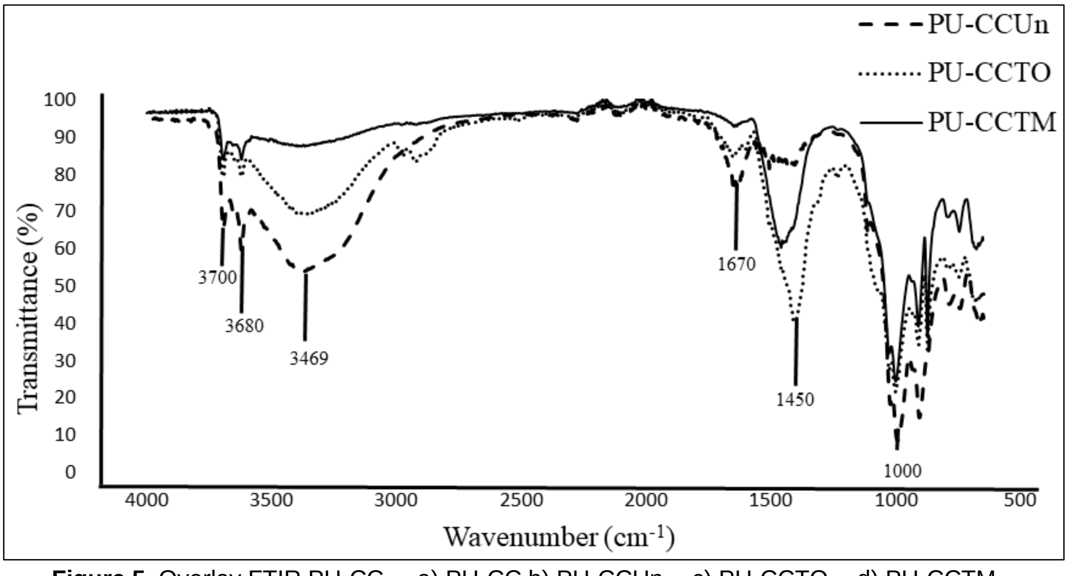

Figure 5. Overlay FTIR PU-CC $_{2.5}$ a) PU-CC b) PU-CCUn$_{2.5}$ c) PU-CCTO$_{2.5}$ d) PU-CCTM$_{2.5}$

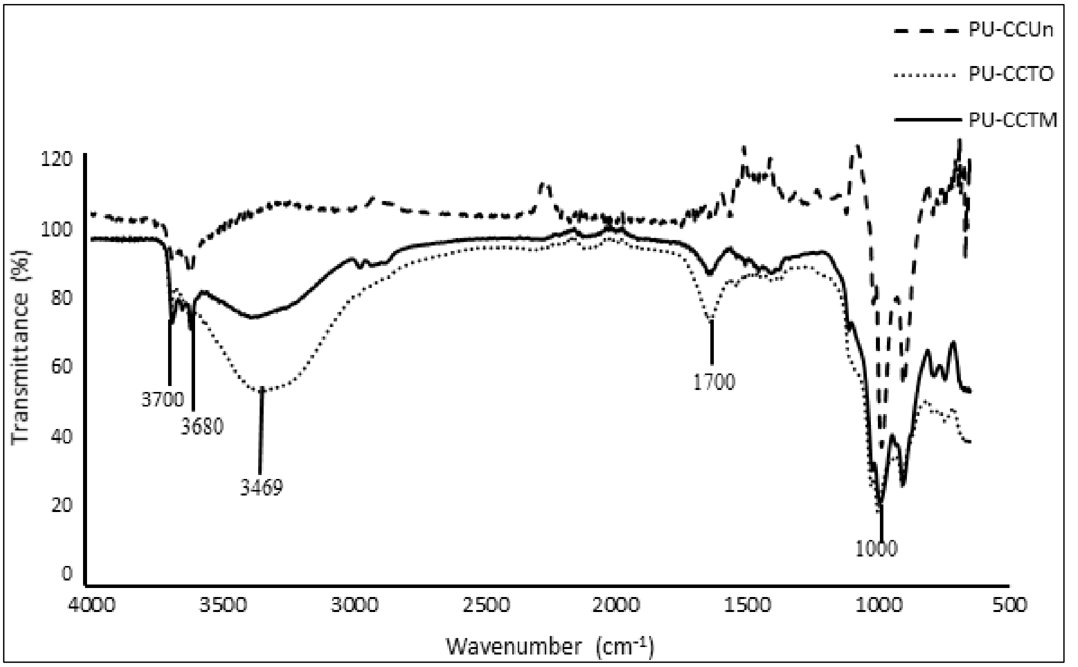

Figure 6. Overlay FTIR PU-CC $_{5}$ a) PU-CC b) PU-CCUn$_{2.5}$ c) PU-CCTO$_{5}$ d) PU-CCTM$_{5}$

The overlay spectra of all material showed interesting finding when the major absorption bands for PU-CCUn was assigned in the range of 3700 to 3680 cm^{-1}. PU-CCUn shows an intense, strong, and broad peak at 3700 cm^{-1}. It verifies the presence of hydrogen-bonded hydroxyl (O-H) stretch vibration groups in the synthesized product. The prominent peak in the region 3469-3500 cm^{-1} is attributed to the (C-H) stretch functional group with two medium peaks 3680 and 3469 cm^{-1} with symmetric and asymmetric stretching vibration (Chauhan, R. et al., 2020). The (C=O) stretching is observable in the region at 1700-1600 cm^{-1} with a maximum peak at 1670 cm^{-1}. The characteristics peak at 1670 cm^{-1} PU-CCTO$_{2.5}$ infers the N-H group bending vibrations (Chauhan, R. et al., 2020). While PU-CCTO$_5$ at a peak of 1700 cm^{-1}.

Scanning Electron Microscope (SEM)

The technique of SEM analysis is to examine the morphological structure of clay soil minerals which is a mixture of different ratios of PU waste filler namely PU-CCUn, PU-CCTO, and PU-CCTM as referred to in Figure 7 and Figure 8. The microscope process of SEM captures an image of a PU composite sample by scanning the surface of the sample with a motivated beam of electrons. From the observation on the surface of PU samples, the strength of clay soil increased with the increase of PU waste fillers on attachment among the mud elements. In the PU composite, the EPS was mixed with clay soil, and as can be seen that it does not mix homogeneously. This observation shows that the segregation and improper bond happened due to the differences in unit weights and the lack of adhesion between the clay soil and EPS.

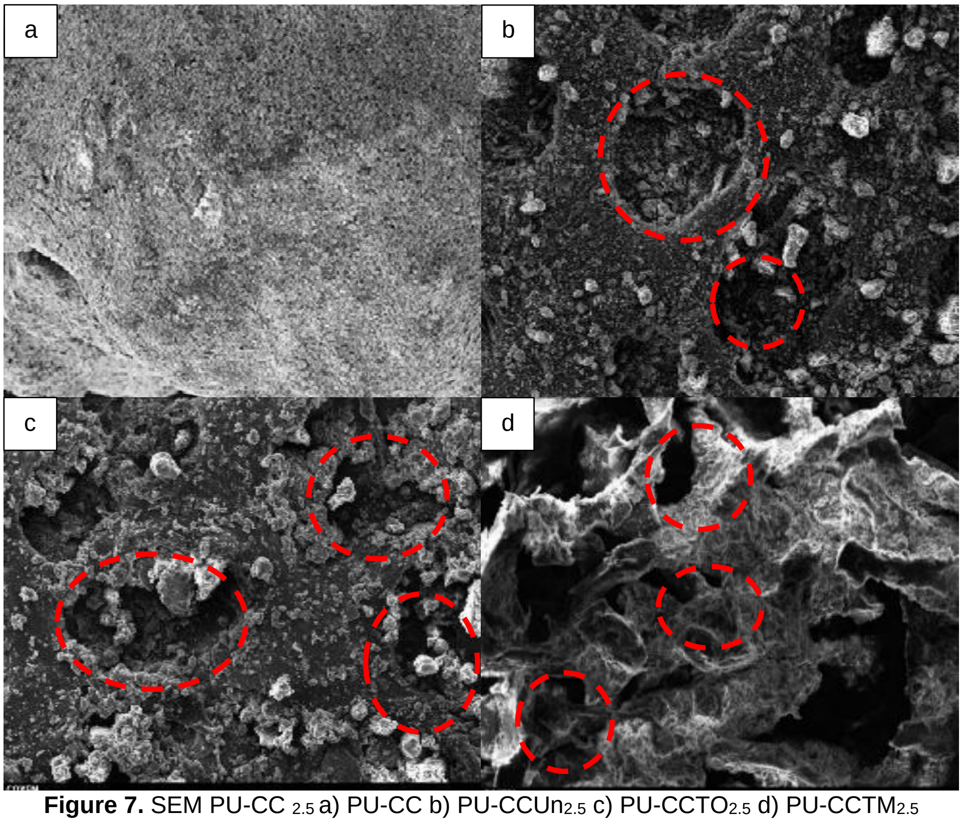

Figure 7. SEM PU-CC $_{2.5}$ a) PU-CC b) PU-CCUn$_{2.5}$ c) PU-CCTO$_{2.5}$ d) PU-CCTM$_{2.5}$

In the PU clay composite preparation process was added fly ash as a binder. This binder is used to promote the reactions bonds quickly with soil particles. This is due to the high fly ash bonding surface and evidently by the SEM analysis. In the SEM result recognized the bright colour area of the image refers to the creation of fly ash ingredients that undertake the particles and give strength to PU clay composite and turn to penetrability percentage of clay soil also decreased. The pore of PU presented in SEM image as a black hole in Figure 7 and Figure 8 state that the reaction effect of filler and clay soil with fly ash during the fabrication process promotes the chemical reaction between clay and binder as stabilizers and gets high bonding in itself particles.

Figure 8 shows the SEM of PU-CC_5 image illumination of PU clay composite was identify the components of the images at different drying treatment processes. From the SEM image, the PU filler was appeared as black spots showing as pores or cracks (Kowalczuk and Pitucha, 2019; Bergamonti et al., 2018; Choe H. et al., 2018; Chauhan, R. et al., 2020). A comparison of the images of untreated and treated PU filler is given in Figures 7 and 8. The 2 images show a significant difference, only a re-arrangement of individual particles. This means it shows evidence of the formation of a new compound due to the reaction between PU filler and clay. However, the size pore image of PU-$CC_{2.5}$ is larger compared to PU-$CC_{5.}$ The mixture percentage ratio of PU filler could be the reason that makes the sample slightly effect by the number of pores and pore sizes. This is in agreement findings by S. Saleh (2016).

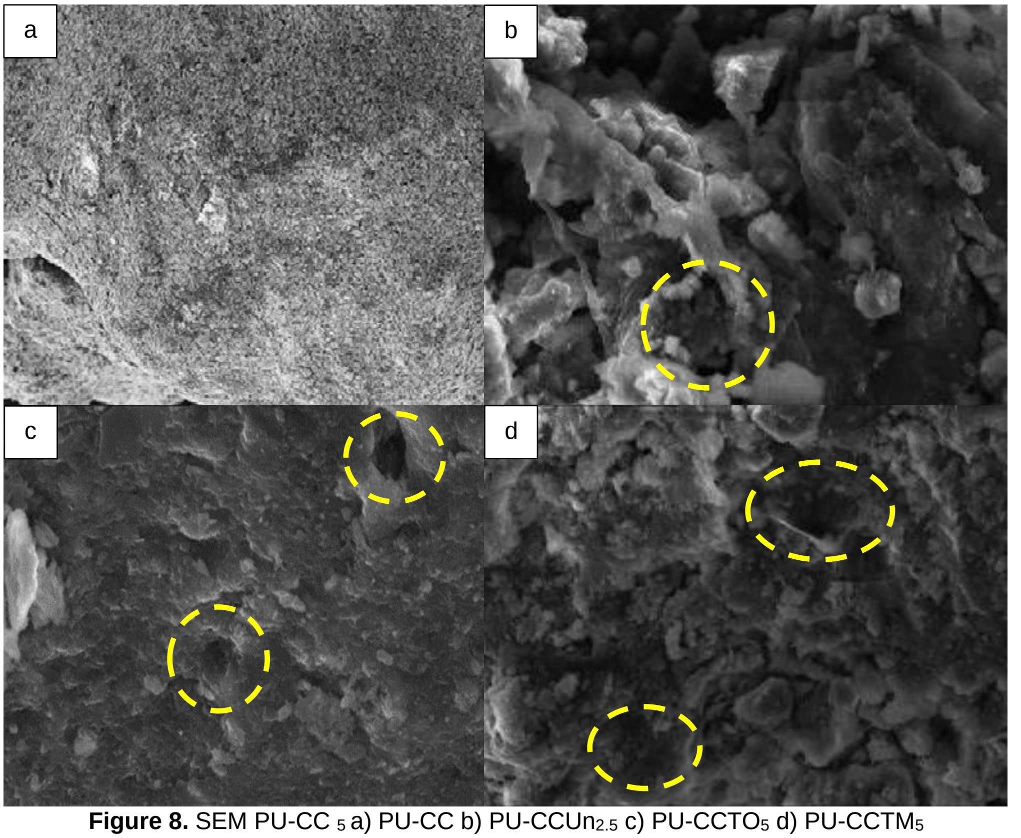

Figure 8. SEM PU-CC $_5$ a) PU-CC b) PU-$CCUn_{2.5}$ c) PU-$CCTO_5$ d) PU-$CCTM_5$

Water Absorption

The water absorption test is necessary to assess the specimen's pore volume and porosity. The estimation of water absorption is essential for determining the percentage of minimum and maximum rate of water absorption allowed in the embankment. Figure 9 illustrates the findings of each sample's water absorption test. According to Figure 9, the findings of the water absorption test showed a varying proportion of PU filler in each sample. The water absorption for a different sample where the PU filler % impacts the value of the sample's water absorption rate. This is because the PU filler has hollow properties and consequently, the PU filler absorbs more water.

The PU-CC samples were prepared by submerged for 24 hours in the water during the testing. The result shows that the value of water absorption of the PU-CC increased with the increasing with the different drying treatments of PU-CC. The results exhibited that adding the different ratios of PU waste filler influence the size of pore PU-CC and gives affected to water absorption in PU clay composites.

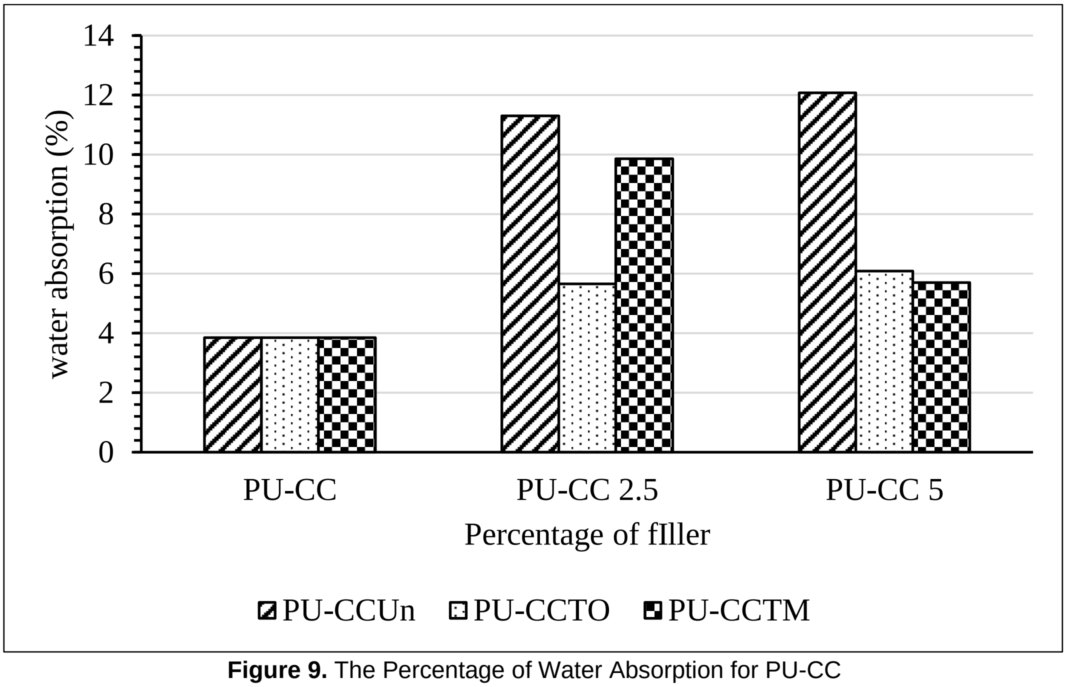

Figure 9. The Percentage of Water Absorption for PU-CC

The percentage of water absorption untreated PU-CC with the percentage of PU filler is 4. While the water absorption by adding 2.5% of PU filler increased. Based on the result, the potential for water absorption PU-CCUn is higher due to the size of the pore structure. The reason PU-CCTO and PU-CCTM are slightly different compared to PU-CCUn is due to the grinding effect of PU filler treatment. The preparation PU composites process gives influences the size of pore PU-CC connectivity by clay, EPS, and fly ash by creating the coefficient of water absorption.

CONCLUSION

This experimental study had been conducted to characterize the potential of polyurethane clay composite (PU-CC) with different ratios of polyurethane filler at different treatment methods as an alternative for soil stabilization techniques for subgrade applications. In this study, the ability of the PU waste as filler to absorb water was raised with the increasing the percentage of filler loading of PU-CCUn and PU-CCTO may increase the possible changes to absorb the water. While PU-CCTM changes to absorb the water are lowest due to the overheating effect and burning of PU filler. The use of PU waste as filler in clay composite exhibited allows the improvement in water absorption and at the same time will allow flowability and reduce the buoyancy force. This innovation modified of PU clay in subgrade soils of different percentages of PU waste fille ration can be used for controlling the nature of water absorption and prevent soil failure.

ACKNOWLEDGEMENTS

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A STUDY ON THE EFFECT OF CURING PERIOD ON THE STRENGTH OF CEMENT BRICK USING SAGO FINE WASTE AS CEMENT REPLACEMENT

Norhayati Abd Wahab[1], Suraya Hani Adnan[1]*, Abdul Hadi Izaan Ibrahim[1], Mazizah Ezdiani Mohamad[2], Mohamad Hairi Osman[1], Zalipah Jamellodin[3] and Noor Azlina Abdul Hamid[3]
[1]Department of Civil Engineering, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Campus Pagoh, Muar, Johor, Malaysia.
[2]Department of Civil Engineering, Faculty of Engineering Technology, University of Technology Sarawak, Sibu, Sarawak, Malaysia.
[3]Department of Material and Structure, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia.

Abstract
This study presents the effect of curing period towards properties of cement brick made up of cement, sand, and sago fine waste (SFW) as cement replacement. The percentage of replacement for SFW is in range between 0% to 10%. The strength of cement bricks was investigated based on curing period of 7, 28, 56, and 90 days and the density of the bricks were also recorded. Result shows the density of the brick decreases as the percentages of replacement of SFW increase. As per ASTM C55-11, bricks specimens for replacement 2 and 4% of SFW were categorized under normal brick category, while 6 to 10% as medium weight category. SFW has a substantial impact on the compressive strength of brick in which increasing the percentages of SFW lowers the brick's value of strength. The longer the curing process takes, the stronger the brick becomes. All bricks met the requirements of class 1, 2, and 3 load-bearing bricks, according to Malaysian standard MS 1933: Part 1: 2007 which shows the potential of SFW as a revolutionary pozzolanic material for more environmentally friendly bricks.

Keyword: *Sago Fine Waste (SFW); Cement Bricks; Curing Period; Pozzolanic Material.*

INTRODUCTION

Cement brick is a common building material made of sand as an aggregate, cement as a binder, and water, which hardens into a durable stone-like mass (Bustamante, Dablo, Sia, & Arazo, 2015). Cement is a common flexible material that is frequently used in the building sector for a variety of purposes. The development of the construction sector on a global scale needs an increasing amount of Portland cement for long-term development (Ashok Kumar & Velayutham, 2019). Environmental pollution generated by cement manufacturing was a major source of pollution to the environment. For example, making Portland cement requires a lot of energy and releases a lot of greenhouse gases into the atmosphere, which has an impact on the ecology of the planet (Alex, Dhanalakshmi & Ambedkar, 2016).

This can be accomplished by using appropriate, low-cost, and readily available supplemental cementitious materials (SCM), which, when used in place of some of the cement, does not affect the properties of the concrete. Many solid wastes, such as industrial by-products, natural pozzolanic materials, agricultural wastes, and so on, are classified as supplemental cementitious materials in nature (Aprianti, Shafigh, Bahri & Farahani, 2015).

The use of waste materials in today's construction is becoming increasingly popular among scholars and practitioners. As a result, numerous waste materials are used in construction bricks (Sakir, Naganathan & Mustapha, 2013).

Many researchers are investigating bricks made from agricultural waste, such as bricks produced from Palm Oil Fuel Ash (POFA) (Kadir & Sarani, 2020); (Saleh, Rahmat, Mohd Yusoff & Eddirizal, 2014); (Tarmidzi, Suraya Hani & Mohd Sufyan, 2018) bricks with Rice Husk Ash (Fetra Venny Riza, 2017), bricks with sago husk (Ornam, Kimsan, Ngkoimani & Santi, 2017) (Ornam et al., 2020) and also bricks with sago fibre (Umar, Hasan & Arsyad, 2020) (Darwis, Astriana & Ulum, 2016) (Petrus Patandung & Suroto Hadi Saputra, 2015).

Sago waste is a by-product of sago mill industries' processing of sago starch and sago flour. For a long time, sago waste was eliminated once the starch was recovered, with little effort to convert the material into a valuable commodity (Lai, Rahman & Toh, 2013).

Sarawak has the most sago palm plantations in Malaysia, especially in Mukah Division. Every day, roughly 60 tons of sago trash are dumped into rivers in Sarawak that led to many issues (Azman Zakaria, 2020). The high biological oxygen demand of about 5820 mg/L and chemical oxygen demand of 10,220 mg/L detected in wastewater have negative impacts on marine life and water quality due to the decrease of dissolved oxygen in the water (Rosli, Abdul Nasir, Takriff & Cher, 2018).

In general, previous research indicated that sago waste has the potential to be used as a replacement resource for construction materials. In this study, sago waste that has undergone physical treatment, known as Sago Fine Waste (SFW), is used as a cement replacement in producing cement bricks. The ability of SFW as a cement replacement was determined by the strength of the cement bricks in the curing period carried out.

SAMPLE PREPARATION

Material Preparation

In this study, raw materials used for brick production are ordinary Portland cement (OPC), river sand, SFW and tap water. Raw sago waste was collected from one of the sago mills in Mukah, Sarawak. Initially, sago waste was dried under sunlight for 3 days to remove its moisture content. Figure 1 illustrates how sago waste was dried before it could be used. In many industries, particularly the food business, drying is a well-known way of inhibiting bacterial and fungal growths. This helps maintain product quality attributes like colour, texture, and residual polyphenol content (Rosli et al., 2018).

Figure 1. Drying of Sago Waste

After drying, the sago waste was grinded and sieved using a 300 µm sieve to produce sago fine waste (SFW) as shown in Figure 2.

Figure 2. Sago Fine Waste (SFW)

As a binder material, blended cement containing a mixture of 2, 4, 6, 8 and 10% SFW was utilized. The chemical composition of OPC and SFW obtained from XRF analysis is shown in Table 1. Meanwhile, Figure 3 shows the scanning electron microstructure of SFW. For fine aggregate, sand with a fineness modulus of 2.7 was employed.

Table 1. Chemical Composition of OPC and SFW

Chemical Composition	OPC	SFW
Silicon Dioxide (SiO_2)	14.6	63.8
Aluminium Oxide (Al_2O_3)	3.95	0.584
Ferric Oxide (Fe_2O_3)	3.46	0.866
Calcium Oxide (CaO)	57.1	23.5
Potassium Oxide (K_2O)	0.51	1.68
Magnesium Oxide (MgO)	1.62	2.23
Sulphur Trioxide (SO_3)	3.43	0.992

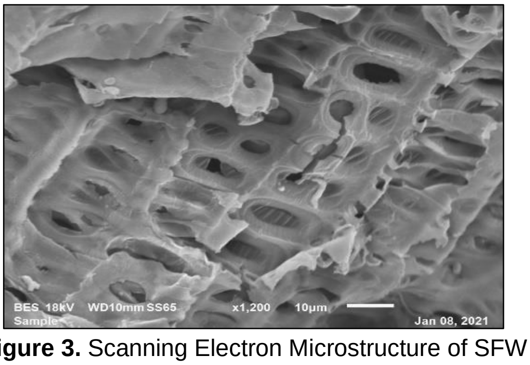


Figure 3. Scanning Electron Microstructure of SFW

Brick Sample Preparation

The components were mixed in six designs with mould sizes of 215 mm x 102.5 mm x 65 mm bricks. Cement bricks with a cement: sand ratio of 1:3 was made with cement partially replaced by SFW and water to a sand ratio of 0.6. The brick was designed to replace cement by 0, 2, 4, 6, 8, and 10%, respectively. The SFW cement bricks were cast for one day and cured for 7, 28, 56, and 90 days. The mixed proportion of the bricks is shown in Table 2.

Table 2. Mix Design Ratio in Cement Bricks

Type	Cement (%)	SFW (%)
SFW0W0.6 (c)	100	0
SFW2W0.6	98	2
SFW4W0.6	96	4
SFW6W0.6	94	6
SFW8W0.6	92	8
SFW10W0.6	90	10

*SFW-Sago fine waste, W-water-cement ratio, (c)-control bricks

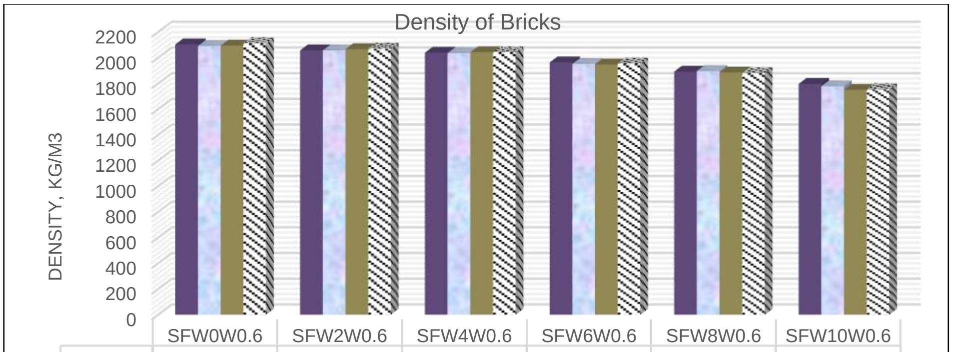
The mixing components were precisely weighed, and the moulds were lubricated. The materials were then added and stirred in a clean mixing machine until a homogeneous mixture was achieved. After that, the mixture was pressed into the mould. Finally, it was kept in a wet sack and left overnight before being demoulded (Muthusamy, Budiea, Syed Mohsin, Muhammad Zam & Ahmad Nadzri, 2021).

For each mix design, 72 specimens were prepared for compressive strength and density tests. According to BS EN 771-1:2011, 2011, the compressive strength test was conducted, and BS EN 771-3:2011, 2011 for the density test.

RESULT AND DISCUSSION

Density

The raw materials and manufacturing method affect the density of cement bricks. Based on the results in Figure 4, the density is unaffected by the number of curing days. However, as the amount of replacement materials increases, the density of the samples dropped. For example, SFW has a density of 1270kg/m^3 lower than OPC's 1454kg/m^3. This has a direct impact on reducing brick density.



	SFW0W0.6	SFW2W0.6	SFW4W0.6	SFW6W0.6	SFW8W0.6	SFW10W0.6
7 days	2103.64	2057.1	2038.48	1964.02	1891.88	1796.47
28 days	2092.01	2057.1	2036.16	1952.38	1896.53	1777.86
56 days	2094.33	2066.41	2043.14	1947.73	1884.9	1749.93
90 days	2112.95	2071.06	2043.14	1954.71	1880.24	1754.58

Figure 4. Result of the Density of The Brick

After 28 days of curing, the control brick's (SFW0W0.6) density is 2092.01 kg/m^3. The brick samples showed a reduction in density as the proportion of SFW increased. With each increment of 2%, SFW reduced around 1.02% to 6.06% of brick density. For 10% SFW, the density of brick was 1777.86 kg/m^3, which was 15% less than the standard brick. While for 90 days of curing, a density of 0% SFW was 2112.95 kg/m^{3,} and 10% SFW was 1754.58 kg/m^3, reducing 17% of density. This demonstrates the impact of agricultural waste materials like SFW can reduce the density of brick; it aligns with other researchers using agro-waste as the material in brick construction (Loong et al., 2020); (Kamarulzaman et al., 2018).

The relationship between the curing period and the density of bricks is presented in Figure 5. From the graph, the coefficient of determination R^2 shows a very strong relationship with the control sample, SFW0W0.6, which is 0.9265. While samples SFW4W0.6, SFW8W0.6 and SFW10W0.6 have a strong relationship with R^2 values of 0.6289, 0.7505 and 0.7753, respectively. For samples SFW2W0.6 and SFW6W0.6, the relationship is weak, with values R^2 are 0.2509 and 0.2798, respectively (Frisky Ridwan Aldila Melania Care, Sugeng Subagio & Rahman, 2018).

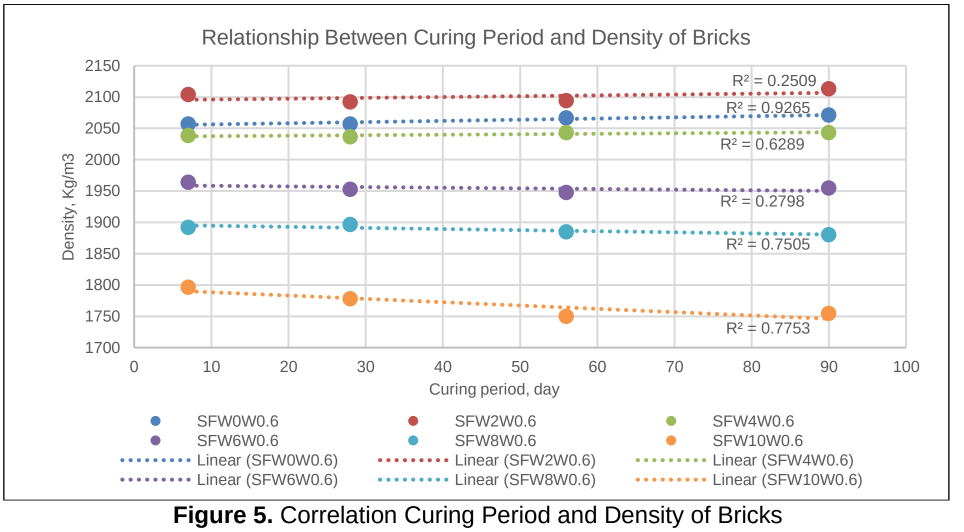


Figure 5. Correlation Curing Period and Density of Bricks

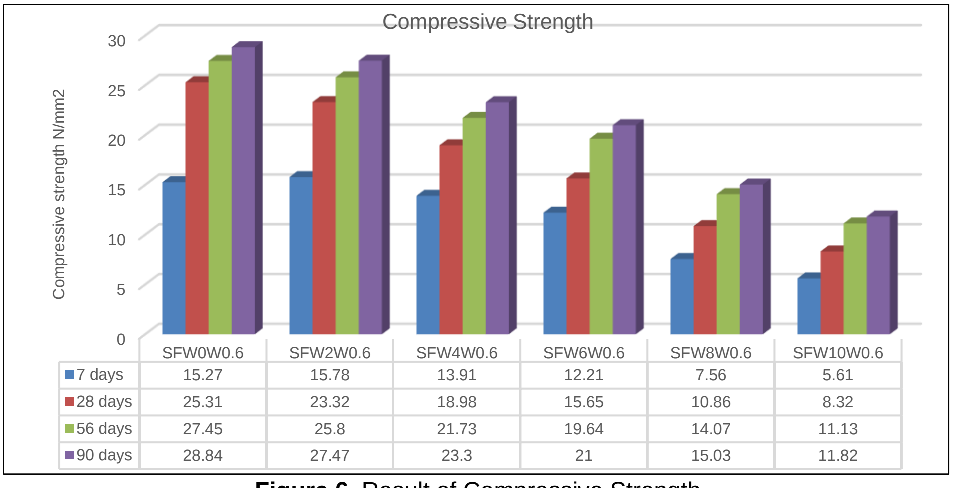
Compressive Strength

The amount of cement in the mixture, the kind of raw material and the amount of water used affect the compressive strength of a cement brick. Therefore, the compressive strength of a brick is an important factor to consider when determining its load-bearing capacity. Based on the data analyzed in Figure 6, the compressive strength of the SFW bricks meets the standards set in MS 1933: Part 1: 2007.

The value of compressive strength increases with the length of the curing period; this is evidenced by a study (Petrus Patandung & Suroto Hadi Saputra, 2015); (Rahman et al., 2018) on brick strength's effect over long curing periods. For SFW2W0.6, curing at 7, 28, 56 and 90 days are 15.78 N/mm^2, 23.32 N/mm^2, 25.8 N/mm^2 and 27.47 N/mm^2 respectively. The compressive strength increases of 44.8% from 7 days to 28 days, 10.6% from 28 days to 56 days and 6.5% increase when curing up to 90 days.

The data also shows that the greater the amount of SFW used as a cement substitute, the lesser the strength of the brick. The brick strength at 2% SFW by 7 days of curing shows a higher value of compression strength of 15.78N/mm^2 than the control brick sample of 15.27 N/mm^2. While at a different curing period with the addition of every 2% SFW, the relationship between them is inversely proportional. As a result, the brick strength decreases as the SFW replacement increases.

For example, at 28 days of curing, compressive strength of SFW2W0.6 is 23.32 N/mm^2 lower than SFW0W0.6 is 25.31 N/mm^2. While compressive strength at 56 days of curing for SFW10W0.6 is 11.13 N/mm^2 lower 59.4% than SFW0W0.6 is 27.45 N/mm^2. However, the entire design mix can be used for load-bearing structures. Based on preliminary data (Abdul Hadi Izaan et al., 2022), the value of SFW should not exceed 10% if used for load-bearing construction. Overall, the longer the curing period, the higher the strength value of the brick. The results show that the minimum strength of the brick is categorized as load- bearing for internal wall construction up to class 4, which is a strength exceeding 25.5N/mm^2.



	SFW0W0.6	SFW2W0.6	SFW4W0.6	SFW6W0.6	SFW8W0.6	SFW10W0.6
7 days	15.27	15.78	13.91	12.21	7.56	5.61
28 days	25.31	23.32	18.98	15.65	10.86	8.32
56 days	27.45	25.8	21.73	19.64	14.07	11.13
90 days	28.84	27.47	23.3	21	15.03	11.82

Figure 6. Result of Compressive Strength

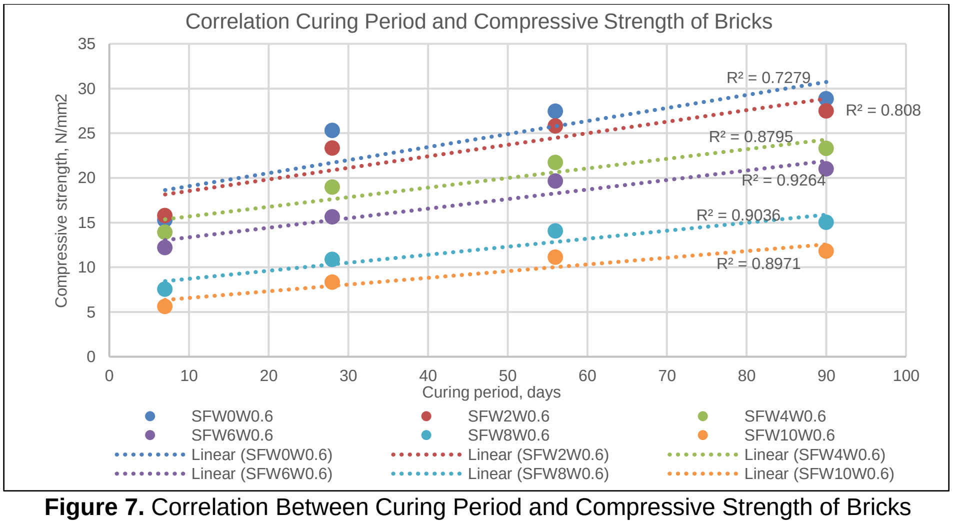


Figure 7. Correlation Between Curing Period and Compressive Strength of Bricks

The relationship between the curing period and the compressive strength of bricks is presented in Figure 7. From the graph, the coefficient of determination R^2 shows a positive correlation with a very strong relationship for all samples except the control sample. The R^2 value is 0.7279, which is a strong relationship (Frisky Ridwan Aldila Melania Care et al., 2018). This data supports the explanation stated before that increasing the curing process will increase the strength of the bricks.

CONCLUSION

The increasing percentages of SFW reduce brick density and value strength of the brick. Based on the density data obtained, more SFW can produce lighter bricks. Therefore, SFW is high potential material for making lightweight bricks. At the same time, the curing process's length shows a higher strength of brick. SFW has the potential to base on Malaysian standard MS 1933: Part 1: 2007; all bricks should satisfy the requirement of class for internal wall, class 1, 2, 3 and 4 load-bearing bricks. Therefore, the SFW has the potential to be a sustainable pozzolanic material for creating more environmentally friendly bricks. As a result, SFW as a cement replacement material could improve bricks' physical and mechanical properties as curing time increases.

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INTEGRATED ENVIRONMENTAL SOLUTIONS-VIRTUAL ENVIRONMENT (IES-VE) SOFTWARE ACCURACY VALIDATION ON NATURALLY VENTILATED ROYAL MALAYSIAN POLICE (RMP) LOCKUP'S THERMAL PERFORMANCE SIMULATION

Bismiazan Abd. Razak[1,2*], Mohd. Farid Mohamed[1], Wardah Fatimah Mohammad Yusoff[1] and Mohd. Khairul Azhar Mat Sulaiman[1]
[1]Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM), Bangi, Selangor Darul Ehsan, Malaysia.
[2]Architecture Branch of the Public Works Department, IPJKR Malaysia, Tingkat 11, Menara Tun Ismail Mohamed Ali (TIMA), Jalan Raja Laut, Kuala Lumpur.

Abstract
Along with the rapid emerging technology and research diversification, especially on the building performance simulation program, there are various programs that have been introduced by program developers, researchers and academicians in ensuring data accuracy. Correspondingly, the Integrated Environmental Solutions-Virtual Environment (IES-VE) is one of the simulation programs that is usually being used for a building performance simulation study. However, the IES-VE performance on data accuracy has often been debated and has been compared to other engineering simulation programs. Therefore, the objective of this study is to verify IES-VE reading accuracy by comparing on-site physical measurements with IES-VE simulation result using a naturally ventilated Royal Malaysia Police (RMP) lockup cell with an area of 9.0 m2 as the case study room. Using the air temperature, mean radiation temperature, and relative humidity as the thermal comfort factors and the operative temperature as a thermal comfort index, three sets of Delta Ohm HD32.3 WBGT-PMV (internal parameters) and one set of Seven Elements Integrated Weather Sensor WTS700 (external parameters) had also been used as measurement instruments. The results show that the range of percentage differences between physical measurement and the simulation is from -11.39% to 8.67%), which support the previous studies on IES-VE data accuracy percentage difference which is below 20% and the simulated data that are considered as accurate and valid for thermal performance for the targeted building.

Keywords: *IES-VE; Simulation; Thermal Performance; RMP Lockup.*

INTRODUCTION

Building performance simulation programs are often used by researchers as an alternative in validating reading data that have been obtained from field studies (Leng et al., 2012), evaluating the performance of thermal comfort (Nur 'aini, 2017), energy consumption rates and building performance (Cho et al., 2012; Nguyen et al., 2014), they are also an initiative towards energy efficient, cost effective, and sustainable building design (Ji et al., 2009). Since the 1960s, building performance simulation programs have been developed to analyse building energy consumption and are further extended to assess the dynamic thermal behaviour of buildings from brief use to complex levels (Ahmad & Szokolay, 1994). The use of the simulation program was also detected around the same year by the United States of America (USA) government who had been involved in a collapsed shelter project through the assessment of the thermal environment (Attia et al., 2009). Crawley et al. (2008) has stated that over the past 50 years, hundreds of building energy simulation programs have been developed, improved and used as indicators of building performance including its energy consumption and demand, temperature and humidity measurements as well as costs.

Building performance simulation programs are also used to determine passive systems performance of buildings with natural and hybrid ventilation as well as in optimising operating time in producing innovative and sustainable building designs (Ji et al., 2009). Apart from evaluating and analysing the performance of energy consumption, simulation programs are also used by researchers in evaluating the performance of daytime lighting and natural ventilation based on the variety of building light well designs (Ahadi et al., 2018). In recent years, the building performance simulation program has achieved a high level of maturity through the production of various programs and models that can assess building performance diversity (Attia et al., 2012). Overall, the simulation program is very important to the designers, especially to the architects, in helping to provide some alternative steps towards solving design problems in order to maximise the performance of the building.

The selected case study lockup for this validation process is one of the RMP lockup cells that have been identified to have poor ventilation system and an insufficient opening size which cause thermal discomfort to the detainees such as hot indoor environmental conditions (Abd. Razak et al., 2020; SUHAKAM, 2016). The study is purposely conducted on the RMP lockup cell since very few studies are related to thermal comfort and natural ventilation and are rarely conducted on this type of building or equivalent.

LITERATURE REVIEW

Constraints on The Existing Building Performance Simulation Programs

The development of computer technology and the world of research on the construction industry has triggered the invention of simulation programs that suit the needs of research irrespective of the field of study, professional background, expertise and industry. Rapid changes in technology and the increasing needs have caused the evolution of Building Performance Simulation (BPS) such as ECOTECT, EnergyPlus, IES-VE, TRNSYS, ANSYS and many more which are being used for data validation.

Although various improvements to the existing building performance simulation programs on the market have been made by program developers, researchers, professionals and the academia, there are still unresolved constraints. For example, there is still no ready-to-use simulation programs for the architects to analyse buildings and comfort performance in hot climate environments. The inability of some programs to support and assist the design process at an early stage is also among the constraints that have been identified (Attia et al., 2012).

According to Anand et al. (2017), 132 building performance simulation programs have been listed by the U.S. Department of Energy (US DOE) website and of that number, only about 42 programs can be used for energy simulations on buildings. According to Attia et al. (2012) most simulation programs in the current market are not user friendly, not comprehensive and produce inaccurate thermal comfort results based on the design environment and potential, with a passive or active approach that is to be used by architects in the early stages of design. She has also added that out of the 392 BPS that are listed on the DOE website in 2011, less than 40 programs have been developed for the architects use in the early stage of design.

Integrated Environmental Solution-Virtual Environment (IES-VE)

An online survey by Attia et al. (2009) has been conducted and participated by 249 respondents to understand the difference of 10 major simulation programs that are available in the market, such as ECOTECT, HEED, Energy 10, Design Builder, eQUEST, DOE-2, Green Building Studio, IES VE, Energy Plus and Energy Plus-SketchUp Plugin (OpenStudio). The purpose is to identify an appropriate program that is to be used by architects from an architectural point of view in analysing the building performance from the early stage of a building design. This is because most of the existing programs do not meet an Architectural requirement, working methods, complexity, and they are cumbersome and difficult to operate even with simple tools. The analysis was made based on two main aspects that are often prioritised by architects in the selection of simulation programs. Firstly, usability and information management, and secondly integration of intelligent design that is knowledge based. Apart from these two aspects, the handling of building modelling, the accuracy of the program and the ability to perform complex and detailed simulations of building components are also highly prioritised by architects. Based on the survey by Attia et al. (2009), three main programs are identified to be the suitable choices for architects use, especially for building simulation. They are IES-VE (85%), followed by HEED (82%) and eQuest (77%). The IES-VE was rated based on its user-friendly graphics and template-driven approach which are comprehensive and beneficial compared to the other programs which usually use text as the outcome. The IES-VE is also certified by Attia et al. (2009) as an easy program to operate and very helpful in supporting analytical advances towards thermal performance simulations which in producing rapid results for the initial design stage and detailed analysis for the later stage.

The above statements are also supported by Leng et al. (2012) through simulations of studies conducted using the IES-VE program to see the accuracy of the program through comparison with data recorded from field studies. In this study, test room was used for physical measurements with the HOBOware U-1 instrument to measure the air temperature and relative humidity of the room. The results of this field study were then verified with air temperature and relative humidity readings analysed through IES-VE simulations. The comparison between the field study results and simulation showed a very small difference which ranged from 6.99% to 13.62% for air temperature and 0.002% to 14.90% for relative humidity. Based on the previous study that has been conducted by Maamari et al. (2006), the differences between the field measurement and simulation that range from 10% to 20% is acceptable which indirectly indicate that the IES-VE usage is reliable. The study shows that the IES-VE is among the programs that have high accuracy, flexibility and is valid for the simulation of building thermal performance.

In addition, according to Zaki et al. (2012), various justifications have been expressed by previous researchers regarding the ability of the IES-VE program in the implementation of simulations on building performance as an internationally verified program for the purpose of thermal and visual comfort simulation. Notably, equip with a database designed based on ASHRAE Mohammadi et al. (2010) assist designers especially architects in solving environmental problems and building criteria through the variety of applications that have been offered by Leng et al. (2012), simulation capabilities of airflow and heat transfer Almhafdy et al. (2015), capable of predicting accurate results Ibiyeye et al. (2015) and provide an environmental environment in a detailed design evaluation of a building for the purpose of optimising comfort and energy consumption criteria Lau et al. (2016). IES-VE is also capable of producing air temperature, mean radiant temperature and relative humidity readings results through ApacheSim application which is very much in line with this study where the results are much needed in comfortable temperature setting based on previously selected equations (IES-VE, 2020).

The Integrated Environmental Solutions-Virtual Environment (IES-VE) is known as one of the recommended programs for building performance simulation study. A lot of previous studies have shown that the IES-VE simulation results are acceptable if the percentage differences between the field measurement and simulation results are within 0% to 20%. This statement has also been supported by experts in previous studies namely by Leng et al. (2012) and Qays Oleiwi et al. (2019), that have been conducted in the hot and humid climate of Malaysia. The first study is more focused on the study of software validation for one room using air temperature and relative humidity only, while the second study is more on validation for three rooms using three thermal comfort parameters which are air temperature, mean radiant temperature and relative humidity. Hence, the current study has been conducted on a naturally ventilated RMP lockup cell as the targeted room in order to be more comprehensive and to support the expert's agreement on the IES-VE data accuracy by comparing on-site physical measurements with IES-VE simulation result using four parameters, i.e., air temperature, mean radiation temperature, relative humidity as the thermal comfort factors, and the operative temperature as a thermal comfort index. Also, three sets of Delta Ohm HD32.3 WBGT-PMV (internal parameters) and one set of Seven Elements Integrated Weather Sensor WTS700 (external parameters) have been used as a measurement instrument based on the Class 1 field measurement protocol which has never been implemented by any previous studies.

METHODOLOGY

To achieve the objectives of this study, two procedures have been set, they are the field measurement and the building performance simulation, using the IES-VE software. The results from these two procedures were then compared to see the effectiveness of the IES-VE.

Case Study Room (RMP Lockup Cell)

Figure 1 shows the selected lockup, which is located in Alor Gajah District Police Headquarters, Malacca (2°38′00″ N 102°21′00″ E).

With an area of 9.0 m^2 (3.0 m (W) x 3.0 m (L) x 4.2 m (H)) as shown in Figure 2, the lockup cell has been constructed to accommodate one to three detainees at a time. The lockup cell is on the ground floor of a two-storey building and is equipped with a window opening of 0.6 m (W) x 0.6 m (H) facing south, which is parallel to the direction of the surrounding wind. The design of the existing window is in iron grilles which is conform with the design standards for a lockup cell, as shown in Figure 3a. However, the existing window only offers a 4% ventilation opening which is insufficient as stipulated by the Law of Malaysia (Act 133) (Uniform Building By Law 1986 (Ammendment, 2012), 2012) the minimum ventilation opening should be from 10% to 15% of the floor area.

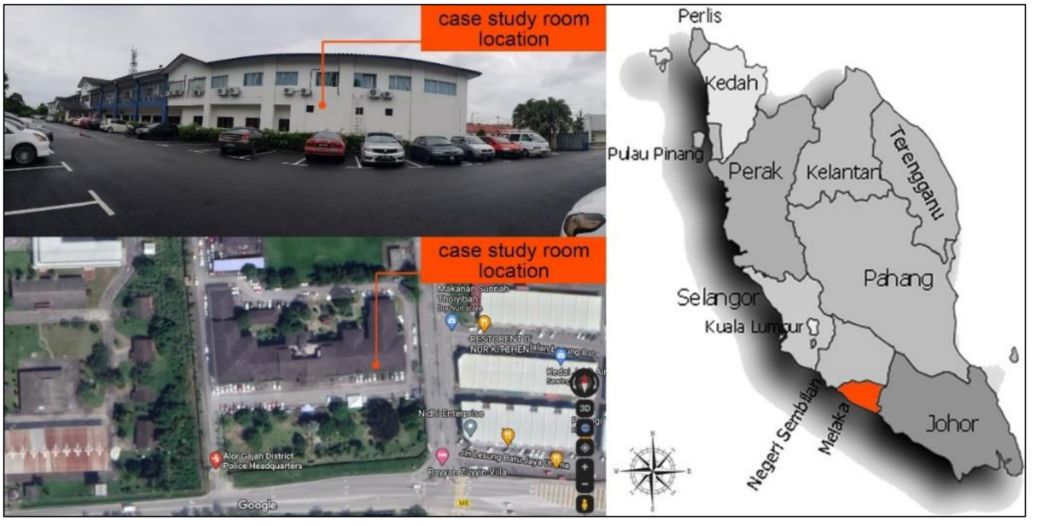

Figure 1. Case Study Room Location (RMP Lockup Cell) (Source: Author)

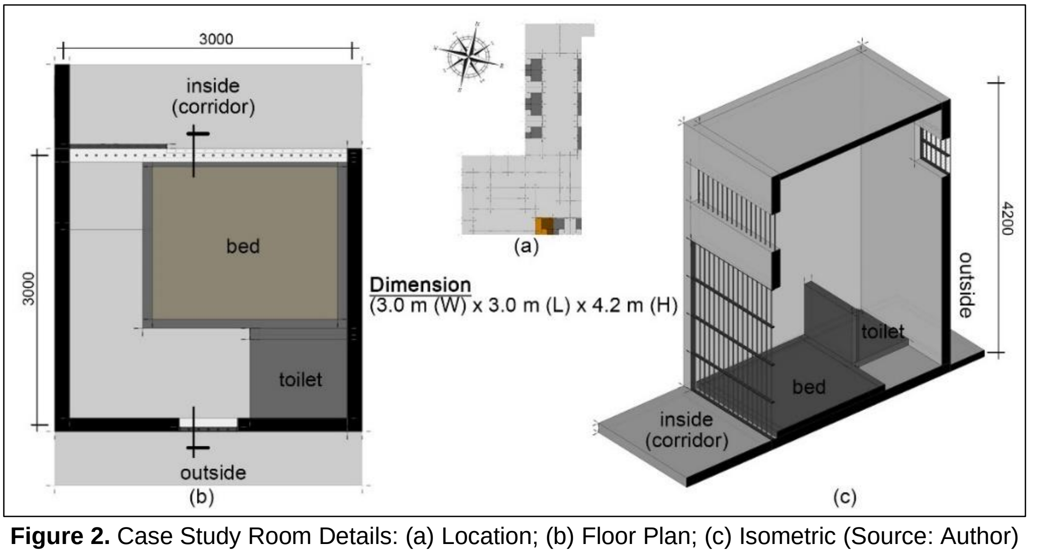

Figure 2. Case Study Room Details: (a) Location; (b) Floor Plan; (c) Isometric (Source: Author)

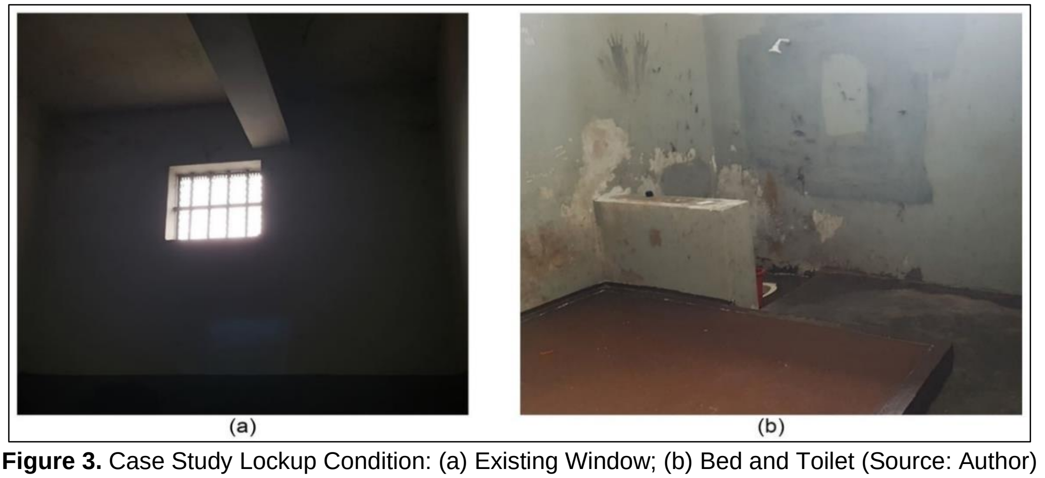

Figure 3. Case Study Lockup Condition: (a) Existing Window; (b) Bed and Toilet (Source: Author)

The lockup cell consists of a bed and a toilet as shown in Figure 3b. In general, the external walls are constructed using reinforced concrete with weatherproof paint finishing. While the internal lockup cell walls are constructed using industrialised building system concrete panel with emulsion paint finishing. The floor is made from reinforced concrete with floor hardener finishing while the ceiling is painted with emulsion paint. The finishing that is used for the toilet walls and floor is epoxy paint. For the bed area, the building material is reinforced concrete at 150 mm heights, complete with tongue and groove plank finishes. The bed and toilet are separated by a 1200 mm height partition wall to provide a bit of privacy to the detainees.

Field Measurement Procedure

Based on the Class 1 field measurement protocol, three sets of Delta Ohm HD32.3 WBGT-PMV (internal parameters) with different height above the floor level (Abd. Razak et al., 2020; Maarof, 2014) and one set of Seven Elements Integrated Weather Sensor WTS700 (external parameters) which comply with ISO 7726 requirement (ASHRAE 55, 2017) were used as a measurement instrument. The three Delta Ohm instruments were placed in the middle of the lockup cells bed with a height of 0.6 m above the floor for D1, 1.1 m above the floor for D2 and 3.2 m above the floor for D3, as shown in Figure 4. D3 was placed at a position 1.0 m inward from the centre of the existing window. The data that were obtained from these three Delta Ohm were analysed using DeltaLog10 software. For W700, the location of the instrument was in the open area outside the building without wind flow obstruction with a height of 1.8 m above the ground. It was used to record readings of the external environment of the study area. The data obtained from the W700 were then be analysed using DLG Master software. All instruments used in this field measurement have been calibrated in advance to obtain accurate and precise data.

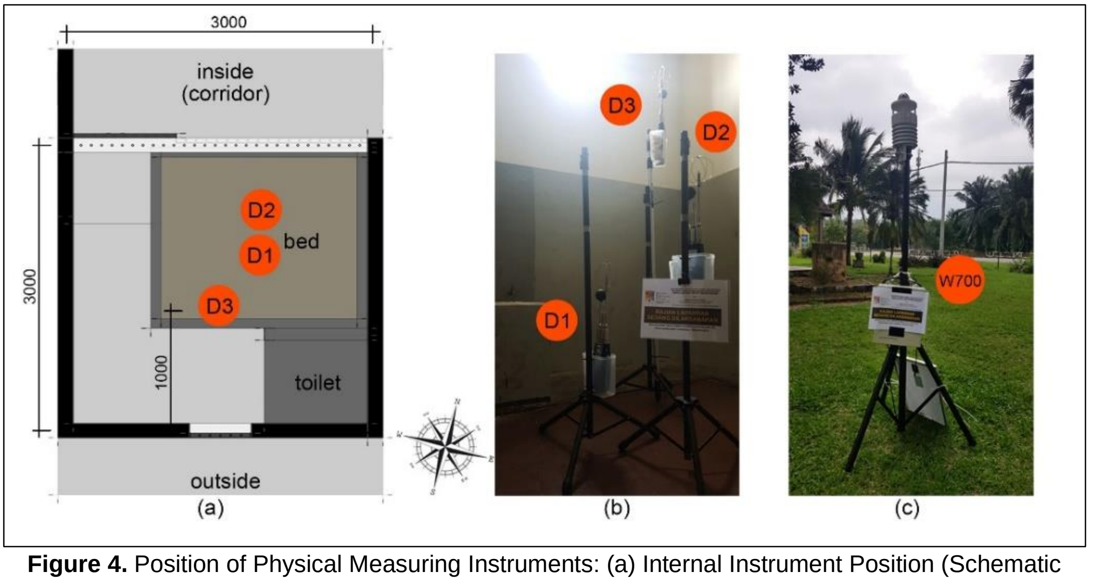

Figure 4. Position of Physical Measuring Instruments: (a) Internal Instrument Position (Schematic Floor Plan); (b) Delta Ohm HD32.3 WBGT-PMV; (c) Seven Elements Integrated Weather Sensor WTS700 (Source: Author)

Simulation Procedure

The simulation procedure started with the development of a case study room model using Sketchup Pro 2018 software. The case study room labelling was set in Sketchup Pro 2018 software with the Confinement Cells Police Station. The completed model was then exported into the IES-VE [ModelIT] program for the purpose of setting up the orientation of the case study room. The location of the case study room was then made in the IES-VE [ApLocate] program. The Design Weather Data set was based on Malaysia Standard (MS 1525:2014, 2014) with a temperature of 33.3 °C for dry bulb temperature and 27.2 °C for wet bulb temperature. Determination of the model case study room building materials and simulation duration was made through the Building Template Manager IES-VE [ModelIT and Apache] just like the actual lockup cell, as shown in Figure 5 and Table 1. Since the selected case study room was using natural ventilation with open ventilation at all times, the window openings were fixed using IES-VE [MacroFlo] as per actual condition. The whole model was then simulated using IES-VE [ApacheSim] to obtain the required reading data such as air temperature (Ta), relative humidity (RH), mean radiant temperature (Tr) and operative temperature (To) from IES-VE [VistPro].

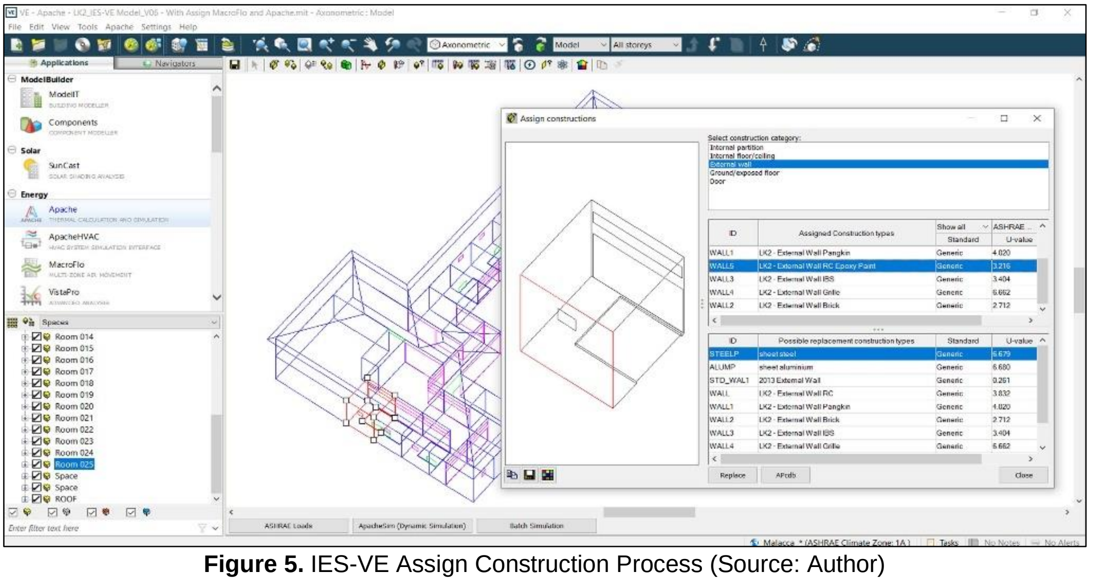

Figure 5. IES-VE Assign Construction Process (Source: Author)

Table 1. Assign Project Construction

Category	Construction	Thickness (mm)	U-Value (W/m^2-K)
External wall	Reinforced concrete c/w cement plaster and rendering	150	3.8322
Internal partition	Cast concrete (IBS) c/w cement plaster	150	2.6071
Exposed floor	Reinforced concrete c/w screed	150	3.5853
Internal ceiling	Reinforced concrete c/w cement plaster and screed	150	2.9861
Door and internal grille panel	Iron grille	20	6.6625
Window	Iron grille c/w expanded metal	25	6.6620
Bed	Reinforced concrete c/w gravel and hard wood on top (tongue and groove)	150	1.9964

(Source: Author)

Research Limitation

The case study room selected for the purpose of this study was a lockup cell with natural ventilation. Although there were wall fans and exhaust fans in some lockup cell areas, they were turned off throughout the study period. The lockup cell was also left empty without detainees in order to obtain a default reading. The field measurement was carried out in five days, 24 hours a day starting from 27th. July to 1st. August 2020 where during this period, Malaysia experienced high average daily temperature from 31.2 °C to 33.2 °C due to monsoon changes (Jabatan Meteorologi Malaysia, 2020; World Meteorological Organisation, 2020). One hour a day was allocated for data collection measurement and instrument reset. During this period, three thermal comfort factors including air temperature (Ta), relative humidity (RH) and mean radiant temperature (Tr) and a thermal comfort index of operative temperature (To) were measured and analysed. All settings implemented on the field measurements were also set in the IES-VE program as close as possible to obtain accurate variance data. However, for weather data setting, Kuala Lumpur has been chosen as the location since there are no weather data for Malacca that is available in the IES-VE, and Kuala Lumpur is the nearest equivalent. The log interval that has been set for each data reading for the field measurement and simulation is 10 minutes.

RESULTS AND DISCUSSION

The data reading results that were obtained from the field measurement and IES-VE simulation were analysed and compared to see the percentage differences in accuracy and precision. Equation (1) was used as recommended by Leng et al. (2012) and Qays Oleiwi et al. (2019) in order to calculate the reading results.

$$PD = [(SM - FM) / FM] \, x \, 100 \tag{1}$$

Where

PD = Percentage different
SM = Simulation measurement
FM = Field measurement

Maamari et al. (2006) in their previous studies had recommended that the adopted percentage difference between the field measurement and simulation program to be from 10% to 20%. This statement has also been supported through a validation study of the difference in accuracy between the field measurement and simulation programs that have been implemented by Leng et al. (2012) with the obtained percentage of difference from 0% to 15% for the studies involving air temperature and relative humidity, while Qays Oleiwi et al. (2019) have obtained a percentage from 0% to 20% for the studies involving air temperature, relative humidity and mean radiant temperature. For this study, the benchmarks that were recommended by all the three studies were used by setting the maximum accuracy difference between the field measurement and IES-VE simulation program, with not more than or equal to 20% in order to ensure the suitability and reliability of the IES-VE software for this study and in the future.

Figure 6 and Table 2 show the comparison of average air temperature differences between the field measurement and simulation for a five-day duration. The average air temperature readings that were recorded during the five days of field measurements for instruments D1-D3 ranged from 27.97 °C to 28.19 °C, while the readings produced by the IES-VE simulations over the same period were 28.77 °C. The percentage differences that were recorded for the average air temperature between the field measurements and simulations ranged from 2.06% to 2.86%. The readings for the maximum air temperature that were recorded for the field measurements were from 28.35 °C to 28.53 °C, while the readings produced from the IES-VE simulations were 29.74 °C. The percentage differences that were recorded for the maximum air temperature between field measurements and simulations ranged from 4.24% to 4.90%. For the minimum air temperature readings, the that were readings recorded from the field measurements were from 27.59 °C to 27.85 °C, while the readings produced from the IES-VE simulations were 27.73 °C. The percentage difference that was produced for the minimum air temperature was from -0.43% to 0.51%. The range of percentage differences that was recorded for air temperatures was below 20% and thus considered reliable and acceptable as recommended by previous studies and established benchmarks.

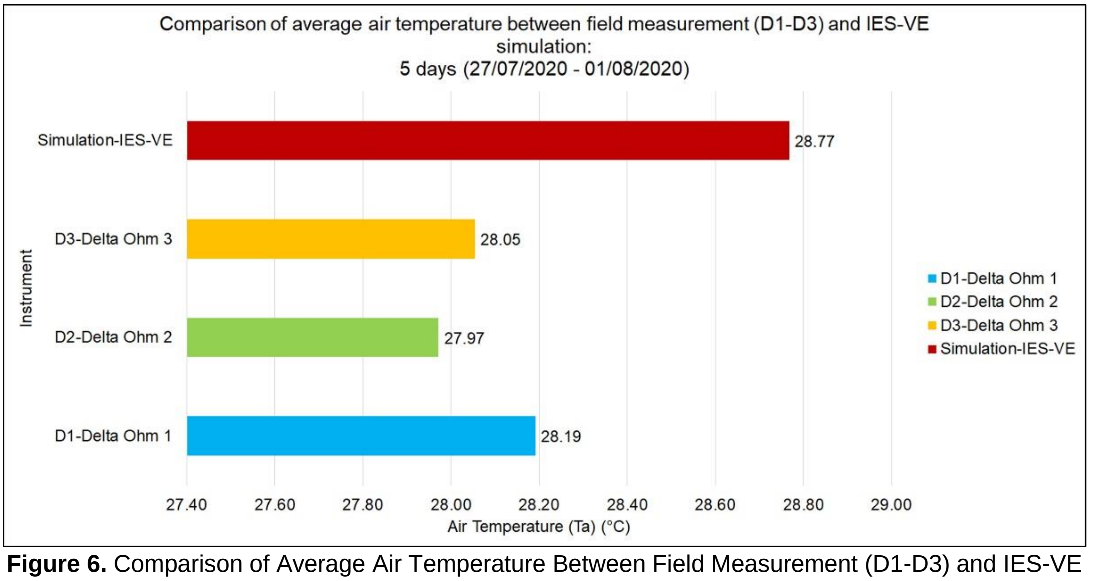

Figure 6. Comparison of Average Air Temperature Between Field Measurement (D1-D3) and IES-VE Simulation (Source: Author)

Table 2. Comparison of Average Percentage Differences of Air Temperature Between Field Measurement and IES-VE Simulation for Five Days

	Instrument Delta Ohm (F0ield Measurement) (°C)				**Simulation IES-VE (°C)**	**Percentage Differences (%)**		
	D1	**D2**	**D3**	**W700**		**D1**	**D2**	**D3**
Average	28.19	27.97	28.05	26.02	28.77	2.06%	2.86%	2.57%
Maximum	28.53	28.40	28.35	30.70	29.74	4.24%	4.72%	4.90%
Minimum	27.85	27.60	27.59	23.44	27.73	-0.43%	0.47%	0.51%

D = Delta Ohm HD32.3 WBGT-PMV; W700 = Seven Elements Integrated Weather Sensor WTS700
(Source: Author)

Figure 7 and Table 3 show the comparison of average relative humidity differences between the field measurement and simulation for a five-day duration. The average relative humidity readings that were recorded during the five days of field measurements for instruments D1-D3 ranged from 79.05% to 82.57%, while the readings produced by the IES-VE simulations over the same period were 74.21%. The percentage differences that were recorded for the average air temperature between field measurements and simulations ranged from -10.12% to -6.12%. The readings for the maximum relative humidity that were recorded for field measurements were between 81.78% to 87.56%, while the readings produced from the IES-VE simulations were 77.59%. The percentage differences recorded for the maximum air temperature between the field measurements and simulations ranged from -11.39% to -5.12%. For the minimum relative humidity readings, the readings that were recorded from the field measurements were from 75.90% to 77.44%, while the readings produced from the IES-VE simulations were 69.86%. The percentage difference that was produced for the minimum air temperature was from -11.39% to -5.12%. The negative readings might be influenced by the window opening which then caused bad internal air circulation. However, the readings were acceptable if they were below 20% as recommended by previous studies and established benchmarks.

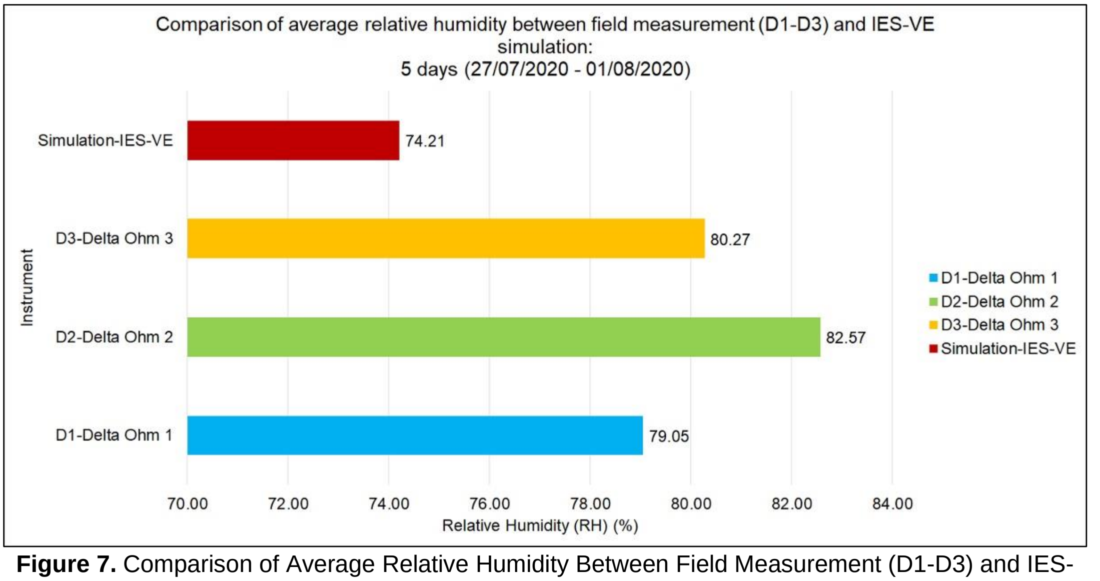

Figure 7. Comparison of Average Relative Humidity Between Field Measurement (D1-D3) and IES-VE Simulation (Source: Author)

Table 3. Comparison of Average Percentage Differences of Relative Humidity Between Field Measurement and IES-VE Simulation for Five Days

	Instrument Delta Ohm (Field Measurement) (%)				**Simulation IES-VE (%)**	**Percentage Differences (%)**		
	D1	**D2**	**D3**	**W700**		**D1**	**D2**	**D3**
Average	79.05	82.57	80.27	88.44	74.21	-6.12%	-10.12%	-7.55%
Maximum	81.78	87.56	83.25	98.42	77.59	-5.12%	-11.39%	-6.80%
Minimum	75.90	77.44	77.15	69.52	69.86	-7.96%	-9.79%	-9.45%

D = Delta Ohm HD32.3 WBGT-PMV; W700 = Seven Elements Integrated Weather Sensor WTS700
(Source: Author)

Figure 8 and Table 4 show the comparison of average mean radiant temperature differences between the field measurement and simulation for a five-day duration. The average means radiant temperature readings that were recorded during the five days of field measurements for instruments D1-D3 ranged from 27.58 °C to 27.75 °C, while the readings produced by the IES-VE simulations over the same period were 28.80 °C. The percentage differences that were recorded for the average mean radiant temperature between the field measurements and simulations ranged from 3.78% to 4.42%. The readings for the maximum mean radiant temperature that were recorded for the field measurements were from 27.87 °C to 28.08 °C, while the readings produced from the IES-VE simulations were 29.68 °C. The percentage differences that were recorded for the maximum mean radiant temperature between the field measurements and simulations ranged from 5.70% to 6.49%. As for the minimum mean radiant temperature readings, the readings that were recorded from the field measurements were from 27.21 °C to 27.42 °C, while the readings produced from the IES-VE simulations were 27.81 °C. The percentage difference that was produced for the minimum mean radiant temperature was from -1.42% to 2.21%. The range of percentage differences that was recorded for the mean radiant temperatures was from 1.42% to 6.49% which was below 20%, and thus considered reliable and acceptable as recommended by previous studies and established benchmarks.

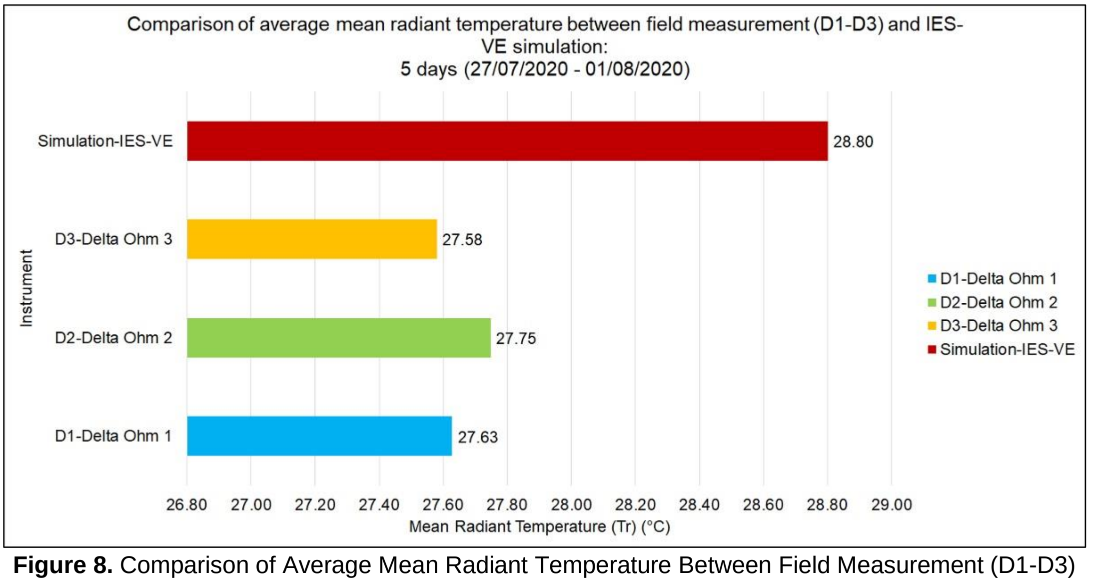

Figure 8. Comparison of Average Mean Radiant Temperature Between Field Measurement (D1-D3) and IES-VE Simulation (Source: Author)

Table 4. Comparison of Average Percentage Differences of Mean Radiant Temperature Between Field Measurement and IES-VE Simulation for Five Days

	Instrument Delta Ohm (F0ield Measurement) (°C)			Simulation IES-VE (°C)	Percentage Differences (%)		
	D1	D2	D3		D1	D2	D3
Average	27.63	27.75	27.58	28.80	4.23%	3.78%	4.42%
Maximum	27.87	28.08	27.91	29.68	6.49%	5.70%	6.34%
Minimum	27.27	27.42	27.21	27.81	1.98%	1.42%	2.21%

D = Delta Ohm HD32.3 WBGT-PMV
(Source: Author)

Figure 9 and Table 5 show the comparison of average operative temperature differences between the field measurement and simulation for a five-day duration. The average operative temperature readings that were recorded during the five days of field measurements for instruments D1-D3 ranged from 27.82 °C to 27.91 °C, while the readings produced by the IES-VE simulations over the same period were 28.69 °C. The percentage differences that were recorded for the average operative temperature between the field measurements and simulations ranged from 2.79% to 3.13%. The readings for the maximum operative temperature recorded for the field measurements were from 28.13 °C to 28.24 °C, while the readings produced from the IES-VE simulations were 30.57 °C. The percentage differences that were recorded for the maximum operative temperature between the field measurements and simulations ranged from 8.25% to 8.67%. For the minimum operative temperature readings, the readings that were recorded from the field measurements were from 27.40 °C to 27.56 °C, while the readings produced from the IES-VE simulations were 27.00°C. The percentage difference that was produced for the minimum air temperature was from -2.03% to -1.46%. The range of percentage differences that were recorded for operative temperatures was from -2.03% to 8.67% which was below 20%, and thus considered reliable and acceptable as recommended by previous studies and established benchmarks.

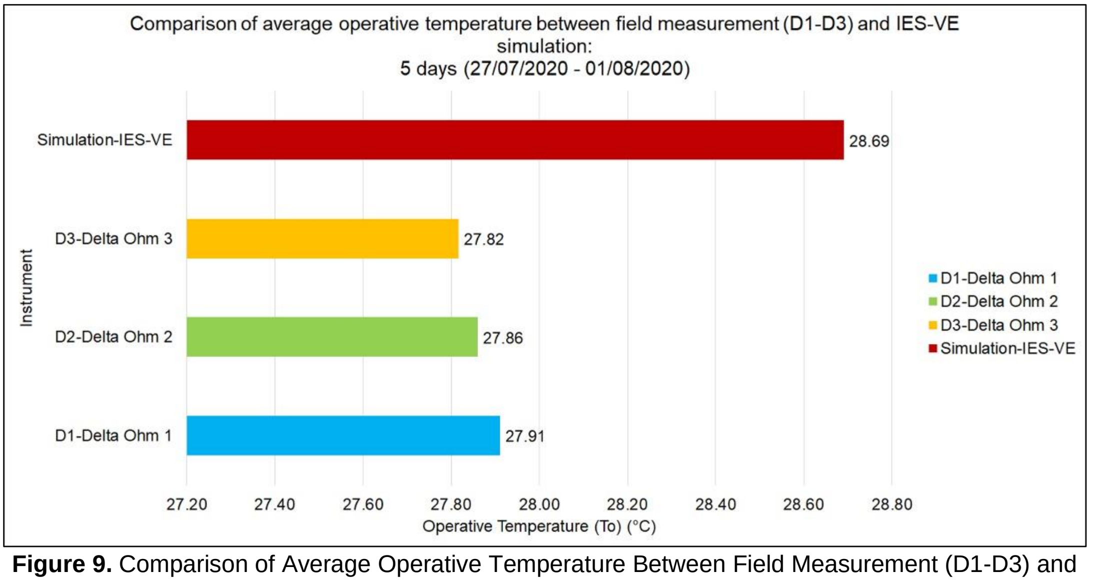

Figure 9. Comparison of Average Operative Temperature Between Field Measurement (D1-D3) and IES-VE Simulation (Source: Author)

Table 5. Comparison of Average Percentage Differences of Operative Temperature Between Field Measurement and IES-VE Simulation for Five Days

	Instrument Delta Ohm (Field Measurement) (°C)			**Simulation IES-VE (°C)**	**Percentage Differences (%)**		
	D1	**D2**	**D3**		**D1**	**D2**	**D3**
Average	27.91	27.86	27.82	28.69	2.79%	2.98%	3.13%
Maximum	28.20	28.24	28.13	30.57	8.40%	8.25%	8.67%
Minimum	27.56	27.51	27.40	27.00	-2.03%	-1.85%	-1.46%

D = Delta Ohm HD32.3 WBGT-PMV
(Source: Author)

Based on the results, the range of percentage differences between the field measurement and IES-VE simulation is from -11.39% to 8.67%. This is within the previous data accuracy, which is below 20%. In other words, the IES-VE is reliable, accurate and is valid to be used as the physical measurement replacement for building performance simulation. Moreover, the result is supported by previous studies, i.e., Leng et al. (2012), Maamari et al. (2006) and Qays Oleiwi et al. (2019).

CONCLUSION

The accuracy investigation that has been carried out on the IES-VE simulation program in accordance with the building performance, namely, for the thermal comfort performance is very important in ensuring that the program can be used in future studies. The accuracy investigation has been conducted on three thermal comfort factors which are air temperature (Ta), relative humidity (RH) and mean radiant temperature (Tr), where a thermal comfort index of operative temperature (To) is one of the alternative steps in the IES-VE program validation process for future research. The results show that:

- The difference of field measurement and IES-VE simulation is small (-11.39% to 8.67%) and is within the acceptable range which is below 20%.
- IES-VE simulation is acceptable and is able to perform effectively for simulating building performance (thermal comfort) of air temperature, relative humidity, mean radiant temperature and operative temperature based on the above statement.

ACKNOWLEDGEMENT

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PERFORMANCE OF BEAM CONTAINING BAMBOO ASH IN CONCRETE MIXTURE

Suraya Hani Adnan[1]*, Siti Nadia Syuhada Mohd Satti[2], Mohammad Ikhmal Jamali[1], Mohamad Hairi Osman[1], Zalipah Jamellodin[3] and Anizahyati Alisibramulisi[4]
[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Campus Pagoh, 81400 Muar, Johor Malaysia.
[2]Department of Pagoh Campus Laboratory Management, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh Johor, Malaysia.
[3]Department of Material and Structure, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400 Batu Pahat, Johor Malaysia.
[4]Faculty of Civil Engineering, UiTM Shah Alam, Shah Alam 40000, Selangor, Malaysia.

Abstract
The cement and construction industry's smokestacks are among the most significant contributors to poor air quality, especially in urban areas. The Portland cement production sector was currently under scrutiny due to the enormous amounts of carbon dioxide emitted. The objective of this study is to determine the performance of concrete by flexural of the beam and compressive strength with a percentage of bamboo ash replacement from cement are 0%,5%,10%,15%, and 20%. The concrete mixture was designed by the department of environment (DOE) mix method with the flexural testing method according to ASTM C293 and compressive strength according to BS 1881-116:1983. The study's findings indicated that bamboo ash was capable of improving compressive strength performance at a replacement percentage of 5% for the BACR5 sample, and nearly the same trend happened for flexural testing at the same percentage. Thus, this study can be expanded to include a higher proportion of cement replacement, as the trend indicates an improvement for a 20% replacement rate, termed BACR20.

Keywords: *Bamboo Ash; Cement Replacement; Compressive Strength; Flexural Strength.*

INTRODUCTION

Bamboo is the most commonly available material in Malaysia, and the type of bamboo that has been used affects the final results of the study. Additionally, it is dependent on the pozzolanic and cementitious characteristics of bamboo. This study used Bambusa Vulgaris owing to its manageable access to its waste. Generally, all the sources of crop rise residue come from any industry that mainly uses bamboo as a product.

Ash was produced from bamboo after it underwent physical processing. It is easier to obtain a material that helps the concrete harden due to the high presence of potassium. The existence of high potassium in bamboo ash can commit the formation of early ettringite. Thus, it can make more stability at the early stage, this innovative study will be compared with beam concrete which is always adopted in the industry.

Bamboo ash is the product of the burning of bamboo stems (Latin: Bambusa) in a furnace and was sieved with a 75µm sieve to obtain grains similar to those of cement. Mortar was a workable paste that was used to join and fill holes between building blocks. The blocks may be made of steel, mortar, cinder blocks, or other materials. Mortar hardens as it cures, forming a solid aggregate base (David & Hassan, 2018). Mineral matter in biomass and coal ash has a lot of oxide forms in their chemical compositions. In the bamboo ash, the primary components were potassium oxide K_2O (34.23 percent), silicon dioxide SiO_2 (24.32 percent), and sulfite ion SO_3 (14.05 percent). Oxocalcium CaO (3.99%) and magnesium oxide MgO were also present in little levels (6.69 percent). These major components of biomass ashes comprised potassium, silicates, carbonates, sulfates, and phosphates, which resulted in biomass ash oxidation and ripping. It was crucial in ash fusion and deposition by vaporization and condensation, especially for alkali metals (Liu et al., 2018).

The use of bamboo in concrete applications is not a new idea. Chow (1914) of MIT studied callow bamboo as a concrete reinforcement material. Later, in 1935, a researcher from Stuttgart explored the possible uses of raw bamboo in concrete. However, it was unable to incorporate full-scale applications due to issues with bamboo debonding from the concrete mixture due to water absorption and swelling. After World War II, more comprehensive research was conducted at Clemson University stated that teeny diameter bamboo culms were used as insulation in concrete structures.

Previous research has made twelve units of reinforced concrete beam for checking the impact of the percentage replacement of natural coarse aggregate and the recycled aggregate on shear loading of the recycled aggregate. The span-to-depth ratio, aggregate form, and shear reinforcement volume were all variables. Comparisons of the criteria from cracking shape and loading deflection activity were used to assess the impact of recycled aggregates. Sato et al. published a study in 2007 that compared the flexural activity of recycled aggregate concrete members to that of reinforced concrete members (R. Sato, 2007).

According to the study's hypothesis, the potential of processed bamboo ash to substitute cement in concrete mix will be evaluated to determine how well the beam performs during flexural and compression tests. The results of this study have shown how the maximum stress at the outermost fibre on the tension side of the beam. While the compressive strength test has determined the behaviour or response of a material while it experiences a compressive load by measuring fundamental variables, such as strain, stress, and deformation. Additionally, while bamboo is frequently utilized in engineering to improve the strength of concrete in the form of strips, ash leaves, and fibres, it is not currently available in the form of ash from the bamboo's main part.

MATERIALS AND METHOD

This study divided the mix proportion based on the percentages of bamboo ash used to replace the Portland Cement. It included the different types of specimens, namely 100×100×100 mm cube and 150×150×1000 mm beam.

Materials

The process of making bamboo ash started from the collection of bamboo waste material of bamboo oil (Bambusa vulgaris) which is sourced in this study from Tandom hill resort in Selangor.

The remaining used parts of the bamboo were burned in a furnace with a temperature of 600-700°C for 6 hours. The material is still in the pre-treatment phase where it has not yet been used as a substitute for cement for the manufacture of concrete. The processed raw material was brought to the laboratory, before undergoing the next process, the material is placed in a tray that fits the size of the oven because it is required for the process of drying raw material at 150-300°C for at least more than 1 hour.

The machine can grind raw materials from bamboo to produce ash with a size of <45 μm complying with the requirement of ASTM C618. The material was processed using a Ball Mill machine at a speed of 350 rpm for 10 minutes for every 100 grams of bamboo ash preparation as shown in Figure 1. After that, it was isolated into airtight plastic to ensure that it is always dry and not mixed with foreign matter.

Figure 1. Bamboo Ash After the Grinding Process

This study concentrated more on how to prepare the ingredient replacement known as Bamboo Ash Cement Replacement (BACR) by monitoring the manufacturing process to ensure the substance's quality. Physically the bamboo ash is recognized by the colour that is black-grey ashes and the size of the bamboo ash by passing through a sieve of 45 µm. This characteristic acts as the main factor to coordinate the workability to replace the cement position.

Verification testing on the material is one of the important steps to confirm that bamboo ash has the same properties as cement. There are 3 types of verification tests conducted in this study on bamboo, namely, Scanning Electron Microscope SEM, X-ray Fluorescence Spectroscopy XRF, and particle size analysis by CILAS.

Methods

The hardened concrete samples were prepared in the size of 100mm cubes plus with 1000mm span length of the beam with 150mm both in height and width. Three cube samples of concrete with sizes 100mm x 100mm x100mm have been prepared for each mix and the total sample is 30 units. Then, the sample of 1000mm span length of the beam with 150mm x 150mm for height and width is prepared for flexural testing on 28 days. These samples are duplicated for three units at each mix design and the total sample is 15 units. The mixing of cubes refers to the standard of BS 1881-108:1983.

The DOE method approach was used for concrete mix design, and it was first published in 1975 and then improved in 1988. The weight of cement was calculated using the DOE method and divided by the percent of BACR. The mix design proportions of OPC and BACR are shown in Table 1. From the table, sample control used 100% of OPC, and sample 1 is a replacement of 5% by weight of BA. Sample 2 is a replacement 10% of OPC and sample 3 replaced about 15% of OPC. For the last sample, the design is BACR20 was replaced by 20% of BA which is the maximum percent of cement replacement in this study.

Table 1. The Mixed Design Proportion of OPC and BA

No.	Sample/Mix Design	Percentage of OPC (%)	Percentage of Bamboo Ash (BA) (%)
1.	Sample Control	100	0
2.	Sample 1 (BACR5)	95	5
3.	Sample 2 (BACR10)	90	10
4.	Sample 3 (BACR15)	85	15
5.	Sample 4 (BACR20)	80	20

Following the end of the concrete mixing process, each concrete mix must pass a slump test to assess the workability or texture of the cement mortar created in the laboratory or on the job site. A concrete slump test is performed from batch to batch to ensure that the quality of the concrete is consistent throughout the building process. Generally, the concrete droop value is used to determine workability, which reflects the water-cement ratio, however, the concrete slump value is affected by a variety of elements such as material qualities, mixing techniques, dosage, and admixtures, among others. Figure 2 shows the slump test execution handled every mix design in the laboratory.

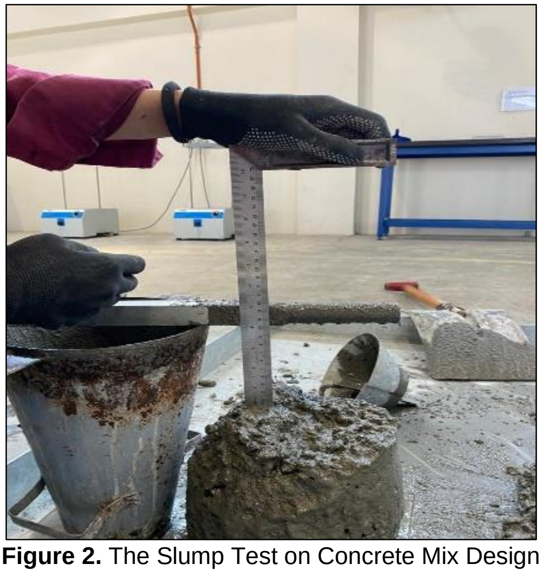

Figure 2. The Slump Test on Concrete Mix Design

Testing of Sample

The test on the sample has been carried out initially as the verification test on the material by conducting Scanning Electron Microscope (SEM) test, X-ray fluorescence Spectroscopy (XRF) test, and Size analysis by CILAS after Bamboo Ash is prepared. Cube and Beam samples were also tested with assessments focusing on the performance of compressive and flexural strength.

Compressive Strength Test

After 7 days and 28 days of curing, a compressive strength test (cube test) has been performed on grade 30 concrete to improve the accuracy of the flexural test results. This test is conducted according to BS 1881-116:1983.

Flexural Strength Test

The flexural strength test was conducted according to ASTM C293 standard. This test method used a simple beam loaded from the centre to assess the flexural strength of concrete specimens. It was operated after a 28-day maturation period. The specimen was continually loaded. The load must be applied continuously until failure. Invert the test specimen and centre it on the support blocks. The loading system should be cantered. Bring the load-applying block into contact with the specimen's central surface and apply 3–6% of the ultimate load. The dial gauges measure the distance between the specimen and the load-applying or support blocks over a one-inch length.

RESULTS AND DISCUSSIONS

The compressive strength of BACR concrete is tested by the cube test method after 7 days and 28 days of curing. A flexural test was performed on a sample beam that had attained maturity after 28 days. All examples for 100mm cube and beam use a concrete mix including a proportion of 5 percent, 10%, 15%, and 20% bamboo ash as cement substitution.

Several tests were conducted to determine whether bamboo ash is suitable for use as a cement substitute in concrete mixes. Scanning Electron Microscope (SEM) testing is used to identify the elements and morphology of bamboo ash, while X-ray Fluorescence Spectroscopy (XRF) is used to determine the chemical composition of bamboo ash. The particle size analysis CILAS test is used to determine whether the particle size in the cement is comparable.

Verification test of Bamboo Ash Cement Replacement (BACR)

In general, by SEM, it can be claimed that bamboo ash has a similarity in the proportion of atomic weight elements with ordinary Portland cement. The description of the element can be seen in Figure 3 which is the morphology of bamboo ash by SEM when detecting the particle size at a size of 25 μm.

As for the partial proportion of chemical composition silica of bamboo has a value of 3% greater than Portland cement by XRF test as shown in Table 2. This indicates that pre-study for element detail, chemical composition, and particle size has verified that bamboo ash has pozzolanic capabilities for concrete replacement material of cement referring to the standard ASTM C618 of the chemical requirement for pozzolanic material (ASTM C618, 2012).

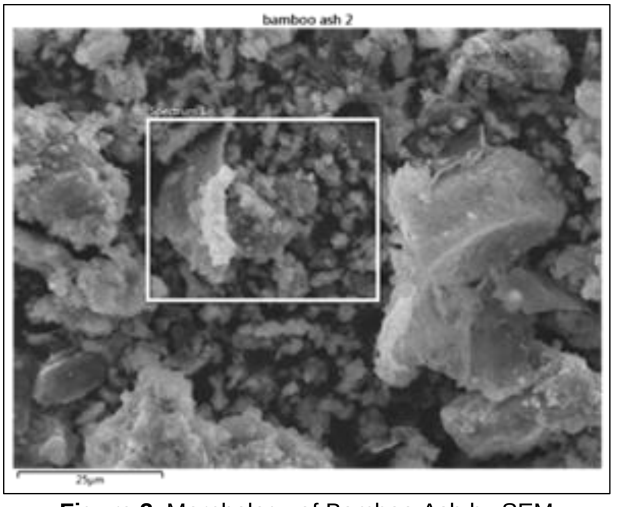

Figure 3. Morphology of Bamboo Ash by SEM

Table 2. Chemical Composition of BACR and OPC

Sample	BACR (%)	OPC (%)
SiO_2	37.4	34.4
Al_2O_3	1.43	9.96
Fe_2O_3	9.91	3.78
MgO	2.5	1.63
CaO	4.35	44.5
Na_2O	ND	ND
K_2O	27	0.977
SO_3	4.83	3.12
P_2O_5	2.53	0.0687
MnO	0.197	0.0513
ZnO	0.0758	0.0224
Al_2O_3	1.43	9.96

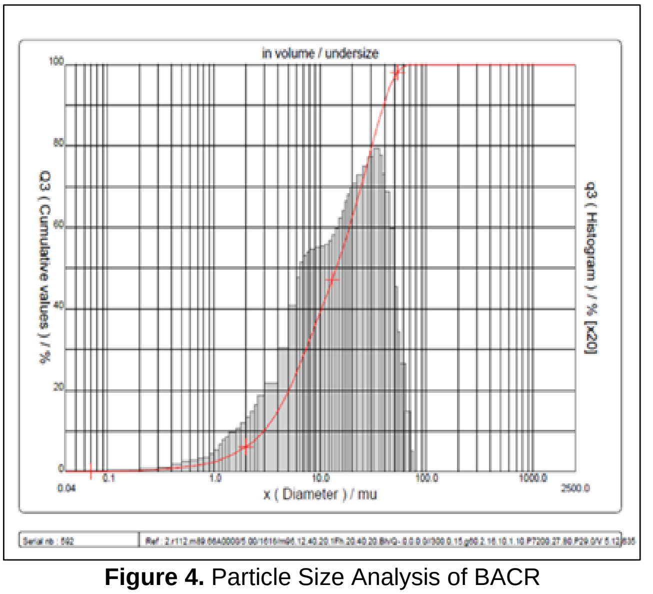

Figure 4. Particle Size Analysis of BACR

Additionally, an investigation of the particle size on bamboo ash by the particle analyser using CILAS, as shown in Figure 4, further demonstrated that the majority size particle of bamboo ash maximizes on 45 µm. The investigation showed that the maximum particle size for 45µm was 94.33 percent cumulative percentage Q3 and that the greatest differential distribution for Q3 was 2.98 percent. This shows that most of the bamboo ash samples have reached the desired particle size of 45 µm. But in general, the particle size for bamboo ash is below 100 µm.

Compressive Strength Test

Compressive tests were conducted to determine the specimen's maximum compressive strength following British Standard BS 1881-116: 1983. Although each mix designation was tested with three specimens, the average compressive strength results were reported for analysis. Then the compression test result is shown in Figure 5.

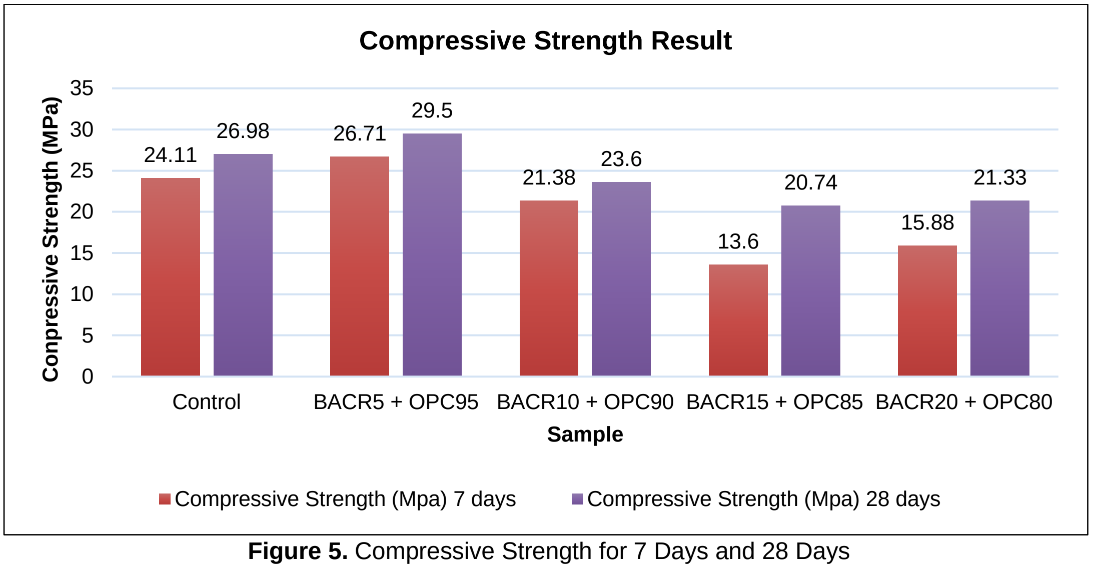

Figure 5. Compressive Strength for 7 Days and 28 Days

At day 7 of concrete maturity, BACR5 obtained 26.71 MPa, while the control sample obtained 24.11 MPa. The figure shows that only the control sample and BACR5 achieved 65% strength of the designed strength at 7 days. BACR10's compressive strength dropped to 16.93 MPa, whereas BACR15 was 13.60 MPa. Comparatively, BACR20 has a higher compressive value than that BACR15, but not achieving 65% of its original strength which is 15.88 MPa. For the data for 28 days, the concrete can achieve 98 to 100% of the compressive aim of 30 MPa. Each sample showed a 7-28 day increase in compressive strength. However, the bar graph in Figure 5 shows that it exceeded the required BACR5 when it reached 29.5 MPa at 28-day concrete maturity from 24.11MPa at 7 days. The control sample is 26.98 MPa. BACR10 is 5.9 MPa weaker than BACR5. This was evident when 15% bamboo was used in place of cement in a 28-days concrete mix, which could only withstand stresses up to 20.74 MPa. The data increases when BACR20 was used in concrete design, which is 21.33 MPa, or 71% of the targeted strength. When the compressive strength of the concrete is equal to or greater than the design value, the concrete attributes are achieved (Hidayat et al., 2018). So, BACR5 shows the compressive strength greater than the control which proves the properties of concrete are achieved.

Flexural Strength Test

The flexural strength test was conducted following the ASTM C293 standard. The purpose of this test method is to determine the flexural strength of concrete specimens using a simple beam loaded from the centre. Table 3 illustrates the results of flexural strength. From the table, it can be seen that the highest load of 190.5 MPa is obtained for the control sample compared to samples that have containing bamboo ash as a substitute for cement. Furthermore, for BACR5, the data showed a slight decrease when as much as 5% of cement replacement using bamboo ash which is 180.6 MPa. The closest difference was 9.9 MPa between the control sample and BACR5.

Table 3. Flexural Test Result and The Deflection Value

Sample	Percentage of BACR (%)	Flexural Strength (MPa)	Deflection Result (mm)
Control	0	190.5	9.46
BACR5 + OPC95	5	180.6	9.97
BACR10 + OPC90	10	150.9	10.53
BACR15 +OPC85	15	143.8	12.65
BACR20 + OPC80	20	125.5	12.94

On the other hand, Figure 6 shows the Flexural Beam Test Result. As shown in this figure, it behaves similarly to a graph plot when displayed in linear form. Essentially, this study is conducted to determine the ideal quantity of bamboo ash to utilize to achieve a load almost comparable to that of standard concrete. When the load of flexural increasing, the more percentage of substitution Bamboo ash reduce the strength to maintain the rigid shape of the beam could be the reason for this contrasting result between flexural and deflection. It was demonstrated that relevant bamboo ash was utilized as a replacement for cement. The graph depicts a decreasing plot, nevertheless, BACR5 was the closest since it has the least difference and is comparable to the control sample performance.

To further strengthen the analysis in the study on the performance of this reinforcement beam, as shown in Figure 7, the deflection value was found using a dial gauge to obtain the maximum level of flexibility during load. Thus, the distance between the original shape and after being loaded will indicate how much bending changes on the concrete beam. In general, the best performance is when the control sample is subjected to a high load and gets the lowest deflection value of 9.46 mm.

Then, the most relevant maximum load is for BACR5 because when applied the second highest load and close to normal concrete and gets a deflection value of 9.97 mm. For BACR15 and BACR15, the deflection value is increasing by 10.53mm and 12.65mm respectively. BACR20 on the other hand shows failure when the maximum load reaches only 125.5MPa and the highest deflection value of 12.94 mm. Therefore, in the presence of data on flexural and deflection. It is proved that BACR5 can behave with higher stiffness compared to the number of cement substitutes for BACR10, BACR15, and BACR20.

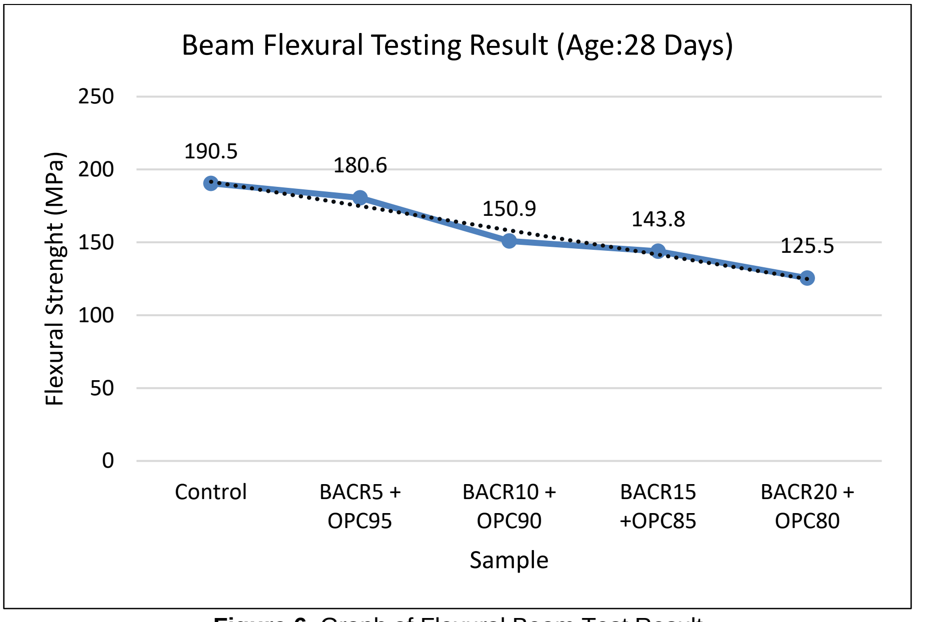

Figure 6. Graph of Flexural Beam Test Result

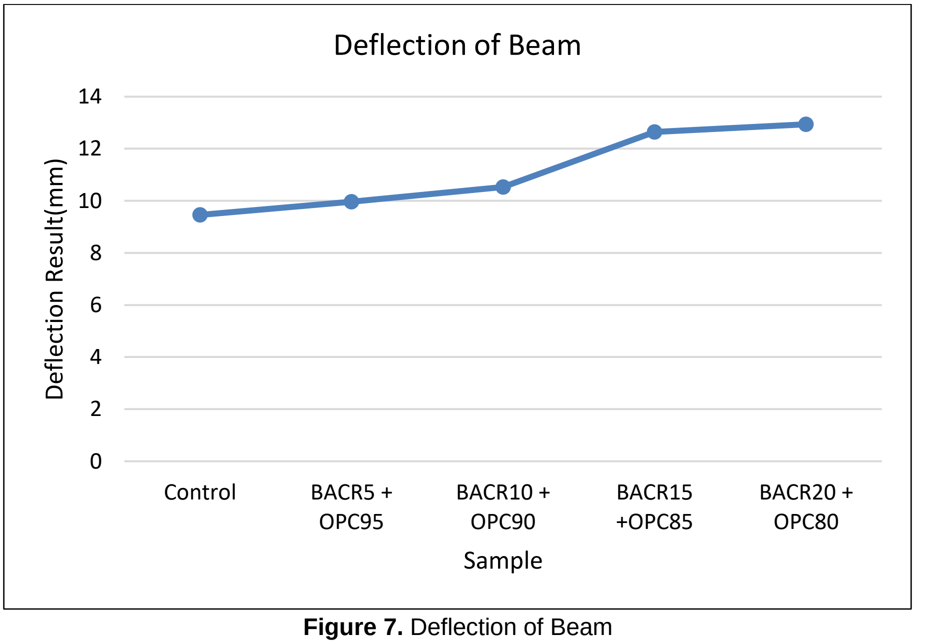

Figure 7. Deflection of Beam

CONCLUSION

Bamboo ash in concrete as a substitute for cement has the potential to significantly reduce greenhouse gas emissions by boosting the possibility of obtaining a greater number of carbon credits. The compressive strength of concrete containing bamboo ash with BACR5 recorded the best result of a compression value of 29.50 MPa. There was a modest improvement on the BACR20, but it was still unable to achieve the appropriate strength at 80 percent of the target. This means that the substitution rate BACR5 may be used to get the highest possible strength levels from other sample percentages. According to the results of the flexural test, it can be concluded that the performance of the reinforcement beam for BACR5 is the best possible and is the closest to that of a conventional concrete reinforcement beam. Essentially, the beam for BACR5 was chosen as the strongest possible since it is capable of withstanding the maximum flexural stress of 180.6 MPa while exhibiting the lowest deflection value of 9.97mm when compared to the other samples. The BACR5 beam, in particular, can reach the target stage. Overall, Bamboo Ash Cement Replacement (BACR) performed well as the optimal percentage of Bamboo ash in cement was 5% in terms of compressive strength with an optimum strength is 29.5 MPa and flexural strength is 180.6 MPa.

ACKNOWLEDGEMENTS

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THE PERFORMANCE OF SEMANTAN BAMBOO FIBER (SBF) IN CONCRETE MIX

Nur'Ain Idris[1,3,5]*, Hamidun Mohd Noh[2], Muhammad Illias Mohd Ullwi[1], Faris Izwan Shah Afzainizam[1], Wan Amizah Wan Jusoh[4,5] and Nurul Anisah Kasran[1]
[1]Department of Civil Engineering, Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, Pagoh, Johor, Malaysia.
[2]Department of Construction Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, Malaysia.
[3]Spatial Technology for Civil Engineering, Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, Pagoh, Johor, Malaysia.
[4]Department of Civil Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, Pagoh, Johor, Malaysia.
[5]Bamboo Research Centre, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, Pagoh, Johor, Malaysia.

Abstract
Recently, bamboo has become one of the most popular species with its uniqueness and potential as a commercial product in Malaysia. There is much intensive research into its anatomical, physical, and mechanical properties, with the goal of contributing to the expansion of the bamboo industry in the country. The source of bamboo is huge and widely cultivated. The harvesting of bamboo is also easy, which leads to a low manpower cost. The shortage of raw materials for construction has been discussed for years. Hence, this study is conducted to overcome this issue by investigating the replacement of raw materials to overcome this issue, especially concrete. Semantan Bamboo Fiber (SBF) is the chosen fiber used in this research, and the type of bamboo used is Semantan Bamboo (G. scortechinii Gamble). This study aims to investigate the performance of concrete with an additive of Semantan Bamboo Fiber (SBF) as a partial replacement of fine aggregate through a compressive strength test. This study also aims to determine the best percentage of SBF to use and compare it to previous research findings. The experiment begins with the extraction of SBF and material preparation for the design mix, followed by laboratory work, which is a concrete mix, and then common testing on concrete. Four percentage levels of fibers are compared with standard concrete: 5%, 10%, 15%, and 20%. The optimum percentage of SBF is 5%, which gives the best performance; at 10%, it drops drastically. This study successfully achieved its main objective, which was to investigate the strength performance of a concrete mix based on replacing fine aggregate with SBF in the concrete mix. However, the percentage of fibers used in concrete should be slight to obtain the optimum percentage more precisely.

Keywords: *Bamboo; Fiber; Semantan Bamboo; Concrete Mix; Performance; Sand Replacement.*

INTRODUCTION

Nowadays, a country's development is parallel with its economic and political stability. As a developing country, Malaysia is currently constructing several large-scale infrastructure projects. Because the number of projects is increasing, the amount of material used has also increased. Fibers are one of the additions employed. The concrete industry has entered a period of sustained growth. Sustainable development is demonstrated by using environmentally friendly resources in the construction sector. Natural fiber has been used in the concrete industry for years. Fibers such as cane fiber, sisal fiber, coconut fiber, bamboo fiber, banana fiber, and pineapple fiber have all been tested for the use of fiber in concrete. Synthetic fibers, such as glass, polypropylene, and steel fiber, have also made concrete significantly stronger (Roselin & Ravikumar, 2018). Malaysia is developing well in this era, so many construction projects are underway. Over the last decade, fast development has led to an increased demand for construction materials, particularly in the construction of high-performance concrete. The recent discussion of replacing those resources reveals many interesting findings (Bindu, Narendra, & Manjunatha, 2016). Bamboo was chosen for this study as it is easily obtainable with strength characteristics. Semantan bamboo is the most commercially exploited bamboo species in Malaysia, and it is currently the subject of intensive research into its anatomical, physical, and mechanical properties to expand the bamboo industry in this country (Azmi, Sulaiman, Razak, & Rokiah, 2011).

This research is limited to using fibers as a minor replacement for fine aggregate in concrete mixes as an additive. Semantan bamboo fiber (SBF) is the only fiber used in this investigation. The scientific name of Semantan bamboo is *G. scortechinii Gamble*. Results from this study are compared with those obtained by other researchers using different fibers in the discussion section. This study aims to observe and investigate the performance of SBF additives in concrete at various fiber percentages. In order to determine whether the concrete cube is strong enough to withstand a load, a parameter has been determined, which is the compressive strength test. Using natural fibers is environmentally friendly because bamboo is a natural resource that can be found easily, grows quickly, is easy to harvest, and does not produce chemical reactions. Good compressive and tensile strength characteristics for safety are the main factors required in the construction industry. In addition, this product also promotes a green environment in construction as it is a renewable source.

This study investigates the performance of concrete with the additive of SBF as a partial replacement of the fine aggregate through a compressive strength test. In addition, this study also determines the optimum percentage of SBF used compared to the previous research. This study is critical for future research because it will assist the construction industry in moving toward more environmentally friendly innovations while still providing good concrete performance. Besides, this study can significantly improve the green building index, leading to reduced carbon emissions.

MATERIALS AND METHODS

This section explains the materials used in the experiment and the method employed to successfully complete this investigation by referring to the standard.

Materials

This investigation used Ordinary Portland Cement (OPC) as raw material source. OPC has a medium hardening rate and is suitable for a wide range of applications. According to BS 4550, the minimum compressive strength of OPC concrete cubes for seven days and 28 days are 13 N/mm^2 and 29 N/mm^2, respectively. The material for the concrete mixture used in this study is shown in Figure 1. The coarse aggregates used have a nominal dimension of 20 mm, a specific gravity of 2.47 mm, and a water absorption of 0.5%, respectively. Sand is used as fine aggregate, with a specific gravity of 2.63, and it absorbs water at a rate of 1%. Meanwhile, the SBF was extracted from raw bamboo (*G. scortechinii Gamble*). Before the extraction process, the water retting method was applied, whereby the bamboo bundle was submerged in the water to ease the extraction process.

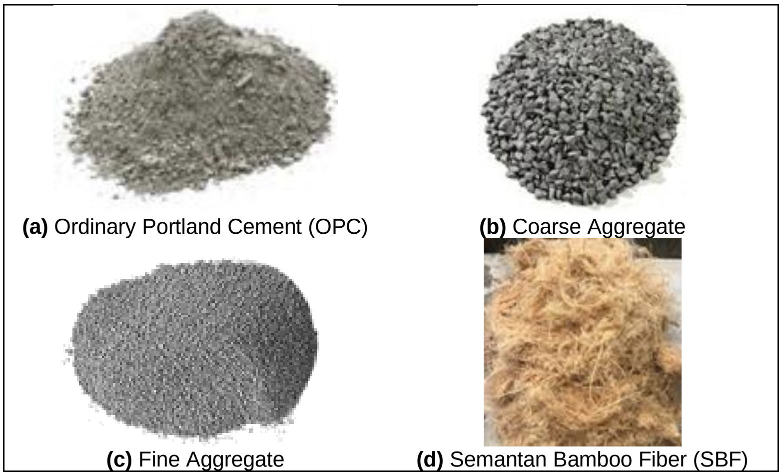

Figure 1. Material for Concrete Mix

Methods

In this chapter, the methodology and procedures used to achieve the goal of this research are described in detail. Figure 2 shows the flow chart of the methodological process.

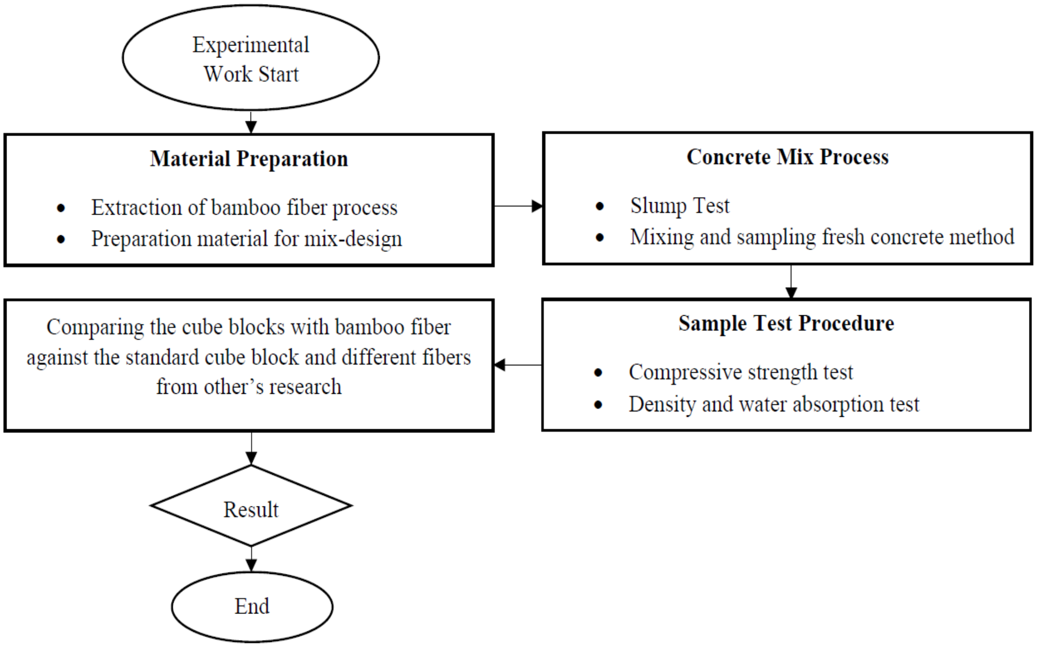

Figure 2. Research Methodological Flow Chart of This Study

Concrete Mix Design

The materials needed, such as OPC, SBF, fine, and coarse aggregate, were prepared to produce 3 concrete cubes for each percent of replacement. A cube mould of 100 mm × 100 mm × 100 mm is used to produce cube-shaped concrete.

Table 1. Mass of Each Material Used for Each Mixture

No. of Mixture	Percent of Replacement (%)	Water (kg)	Cement (kg)	Fine Aggregate		Coarse Aggregate (kg)
				Mass of Sand (kg)	Mass of SBF (kg)	
1	0	1.26	2.4	3.240	0	7.53
2	5	1.26	2.4	3.078	0.0234	7.53
3	10	1.26	2.4	2.916	0.0468	7.53
4	15	1.26	2.4	2.745	0.0702	7.53
5	20	1.26	2.4	2.592	0.0936	7.53
Total of 30 concrete cubes		6.3	12.0	14.571	0.2340	37.65

Table 1 shows the proportion for water, cement, and fine aggregate divided by two: sand and SBF as the minor replacement in concrete. The mass of coarse aggregate and the total mass for each material are also presented.

Extraction Process

The extraction of SBF consists of several steps. The machine used for the SBF extraction process is the bamboo fiber extraction machine (BfEM).

Table 2. SBF Extraction Process

Figure	Description
	a) The bamboo stick was prepared with dimensions of 1000 mm in length and 25 mm in width. Then, it was immersed in the water for 24 hours before the next process (Subash, Stanly Jones Retnam, & Edwin Raja Dhas, 2017).
	b) A fiber extraction machine, which is a bamboo fiber extraction machine (B*f*EM), was used in the SBF extraction process.
	c) Next, the bamboo sticks were inserted into a fiber extraction machine to crush and grind the bamboo stick into a fibrous matter.
	d) This machine can produce fibers from bamboo sticks mechanically.

Figure	Description
	e) Fiber produced by the machine has bamboo nodes and epidermis that need to be removed.
	f) A combing process was performed on the SBF. The purpose is to remove the bamboo node and epidermis (Muhammad, Rezaur, & Sinin, 2019). This process maintains the quality of the SBF.
	g) The fibers were washed with water before the drying process.
	h) Before being used in the concrete mixture, the bamboo fibers were allowed to dry at room temperature.
	i) Then the fibers were cut into small pieces. The SBF dimension used was 2cm long (Ade Sri, Fepy, Elhusna, & Agustin, 2014).

The extraction is done by using a machine to produce a long strip and manually process it for finishing, as depicted and described in Table 2. The mass of fine aggregate and SBF for each mixture can be obtained using the density formula.

RESULTS AND DISCUSSION

This section presents the experimental data. The data set includes results of the compressive strength, slump test, density, and water absorption. Data has also been simplified in graph form for easier comprehension. As for the data validation, the results from this experiment have been compared with the results from Composite Cement Reinforced Coconut Fiber by Alida, Shamsul, Mazlee, and Kamarudin (2011), as a supportive finding.

Slump Test

Concrete slump tests are carried out to determine the consistency of new concrete before it is put into use. This test is carried out to determine the workability of freshly mixed concrete. It can also be used as an indicator to determine whether a concrete mix was used correctly. True slump is the term used to describe when concrete collapses evenly. Meanwhile, shear slump is when one-half of the concrete structure collapses to the bottom. A collapsed slump is when the concrete completely collapses, while concrete that remains according to the conical mould is a zero slump.

Table 3. Workability of SBF Concrete

Sample	Slump Value (mm)	Percentage of Difference Between Control (%)	Slump Type
0%	78	-	Shear
5%	25	67.95	True
10%	0	100.00	Zero
15%	0	100.00	Zero
20%	0	100.00	Zero

Table 3 shows the workability of SBF concrete. The slump value was 78 mm for a control mixture in which there was no substitution of sand for the SBF additive. A shear slump was observed in the case of zero percent replacement. The shear slump indicates sufficient water in the concrete, and the workability of this concrete was high. Meanwhile, the true slump was observed in 5% replacement with a 25 mm slump value. A zero slump was observed for bamboo replacements ranging from 10% to 20%. Concrete with zero shears can be defined as concrete that stiff consistently and dry. There was no concrete collapsing in this type of slump; thus, the slump value was zero. This is because SBF is naturally dry and capable of absorbing water, as SBF are uncoated. The workability of the sample SBF replacements at 10%, 15%, and 20% is poor, respectively. Because of the low workability of the concrete, it was difficult to shape the concrete into a mould.

Density and Water Absorption

Concrete's mechanical characteristics are highly influenced by its density. Denser concrete typically has higher strength and fewer voids and porosities. Concrete becomes less permeable to water and soluble substances as its spaces within decrease. As a result, water absorption was reduced, and this concrete form lasted longer. The results obtained from the SBF sample after 7 days of curing were compared with coconut fiber employed by Alida et al. (2011).

Table 4. Results Of Density and Water Absorption for Each Percent of SBF Sample After 7 Days of Curing

No	Percentage of SBF (%)	Number of Samples	Concrete Age (days)	Average of Density (kg/m^3)	Average of Water Absorption (%)
1	0	3	7	2243	1.86
2	5	3	7	2330	1.70
3	10	3	7	2292	1.19
4	15	3	7	2185	0.78
5	20	3	7	2163	1.03

Table 4 presents the results of density and water absorption for each percent of the SBF sample after 7 days of curing. Figure 3 shows the density values for SBF and coconut fiber composites after 7 days of curing by Alida et al. (2011). The graph in Figure 3 indicates that the density value decreased as the percentage of coconut fiber increased. It was observed that the highest value of density of composite concrete mixture for SBF is 5%, which is 2330 kg/m^3 while coconut fiber is the control sample, which is 2243 kg/m^3. The lowest value of density of composite concrete mixture for SBF is 20%, which is 2163 kg/m^3 while coconut fiber is 15%, which is 1893 kg/m^3.

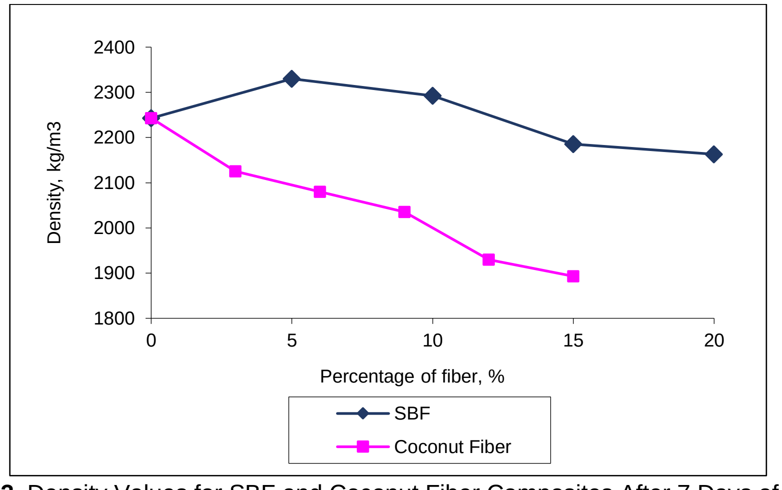

Figure 3. Density Values for SBF and Coconut Fiber Composites After 7 Days of Curing

Figure 4 shows the results of water absorption for SBF and coconut fiber composites after 7 days of curing (Alida et al., 2011). The graph indicates that the water absorption value for SBF decreased as the percent of fiber increased, and otherwise for coconut fiber. It was observed that the highest value of water absorption for SBF is the control sample, which is 1.86%, while for coconut fiber is 15%, which is 4.79%. The lowest value of water absorption of composite concrete mixture for SBF is 15%, which is 0.78%, while coconut fiber is the control sample, which is 1.34%.

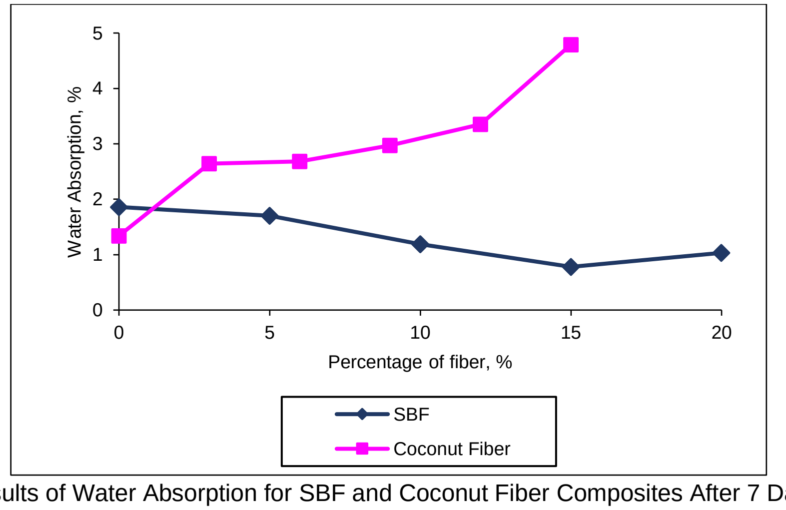

Figure 4. Results of Water Absorption for SBF and Coconut Fiber Composites After 7 Days of Curing

The results of the density comparison for this study have found similarities between SBF and coconut fiber because the density value decreases as the percentage of fiber increases. This study's overall result of water absorption found differences between SBF and coconut fiber, as shown in Figure 4. The control sample without SBF shows the highest percentage of water absorption compared to the composite, while the control sample without coconut fiber shows the lowest percentage of water absorption compared to the composite. In this research, the optimum percent of SBF, which is 5%, in the composite produced a higher density and lowest water absorption. A higher percentage of coconut fiber content in the composites resulted in low density but high-water absorption value.

Compressive Strength

The compressive strength of concrete is affected by various aspects, including the water-cement ratio, cement strength, admixture, concrete material quality, and quality control during the manufacturing process. For this study, 15 concrete cubes with the same dimensions of 100 mm × 100 mm × 100 mm were tested in a compression test machine after 7 days of curing.

Table 5. Results of Compressive Strength for Each Percent of SBF Sample After 7 Days of Curing

No	Percentage of SBF (%)	Number of Samples	Concrete Age (days)	Average of Compressive Strength (MPa)
1	0	3	7	24.47
2	5	3	7	26.63
3	10	3	7	11.73
4	15	3	7	12.60
5	20	3	7	14.37

Table 5 shows the compressive strength results for each percent of the SBF sample after 7 days of curing. The results are depicted in Figure 5 for a clear view of the compressive strength. From the graph, it was observed that the maximum compressive strength of the composite concrete mixture for SBF is 5%, which is 26.63 MPa, while for coconut fiber, it is 9%, which is 31.08 MPa. The lowest compressive strength of composite concrete mixture for SBF is 10%, which is 11.73 MPa, while for coconut fiber, it is 15%, which is 22.47 MPa.

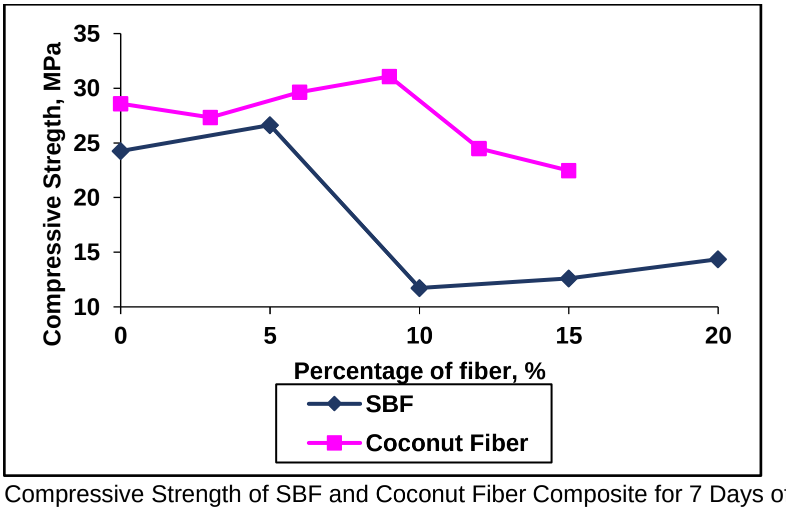

Figure 5. Compressive Strength of SBF and Coconut Fiber Composite for 7 Days of Curing

Based on Figure 5, the compressive strength results differ between SBF and coconut fiber. For SBF, the highest compressive strength, 26.63 MPa, was recorded for the composite concrete mixture with 5% of SBF. While for the coconut fiber, the highest compressive strength, 31.08 MPa, was recorded for the composite concrete mixture with 9% of coconut fiber. The lowest compressive strength, which is 22.47 MPa, is given by the composite concrete mixture with 10% of coconut fiber. In this study, the optimum content of SBF is 5%, while coconut fiber is 9%. The compressive strength value decreases when the percentage of fiber exceeds the optimum value.

Table 6. Results of Compressive Strength at 7 Days and 28 Days

No	Percentage of SBF (%)	Average of Compressive Strength 7 days (MPa)	Expected Compressive Strength 28 days (MPa)
1	0	24.47	37.65
2	5	26.63	40.97
3	10	11.73	18.05
4	15	12.60	19.38
5	20	14.37	22.11

Table 6 shows compressive strength results at 7 days and 28 days. As expected, the strength for 28 days after curing was 35% higher than the 7 days' results. Figure 6 shows the compressive strength of SBF for 7 days and 28 days of curing. The graph indicates that the compressive strength value after 28 days of curing is higher than 7 days.

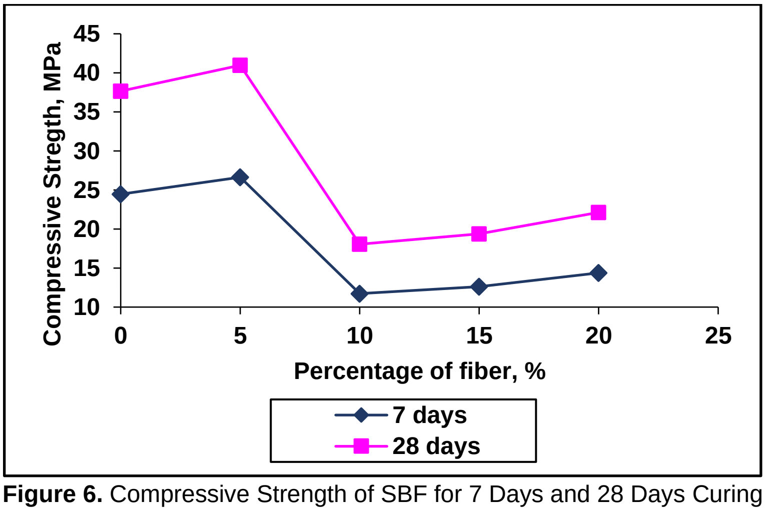

Figure 6. Compressive Strength of SBF for 7 Days and 28 Days Curing

The overall result of compressive strength for this study shows similarities between 7 days and 28 days of curing. The similarities where 5% of SBF produces the highest compressive strength, and 10% of SBF produces the lowest compressive strength for each curing time. The highest compressive strength of SBF after 7 days is 26.63 MPa, while after 28 days, it is 40.97 MPa. Meanwhile, the lowest compressive strength of SBF after 7 days is 11.73 MPa, while after 28 days, it is 18.05 MPa, as shown in Figure 6. In this study, the optimum content of SBF found is 5%, and the compressive strength value decreased when the fiber percentage exceeded the optimum value.

CONCLUSION

In summary, this study has successfully achieved its main objective: to investigate the strength performance of a concrete mix based on the replacement of fine aggregate for SBF in the mix. By conducting this experiment, the study was able to ascertain what percentage of SBF replacement was optimal. All the testing procedures were based on the British Standard BS 1881. The batching and mixing of the material were according to BS 1881: Part 125: 1983. Determining the workability of the designed mix by slump test was in reference to BS 188: Part 102: 1983. Based on the result from the laboratory testing, the workability of concrete with SBF 10%–20% decreased proportionally to the percent added. The same goes for the density, water absorption, and compressive strength, where the value of the testing procedure drop after a 10% replacement of SBF. However, among the samples containing SBF, the best results were obtained when 5% of the SBF replacement was used.

Following the completion of this research and analysis of the data obtained some recommendations are made to future researchers as a precaution. Primarily, the percentage of SBF used as a replacement for fine aggregate must be increased by a narrow percentage. It is necessary to use a percentage multiplied by 3, that is, 3%, 6%, 9%, and 12%, to ensure the optimum result is valid and comparable, as the highest value might be between 3%–15% of fiber. Secondly, during the preparation of SBF, proper treatment or coating techniques might be approached to ensure the SBF is in a hydrophobic condition, whereby it does not absorb water. One of the best ways to treat bamboo is to use epoxy, as it avoids water absorption while improving tensile, flexural, and impact properties (Maheswari, Reddy, Muzenda, & Shukla, 2012). Epoxy adhesives provide water resistance, durability, chemical resistance, and thermal resistance (Nur'Ain, Hamidun, Fahmi, & Shazrina, 2021).

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VEGETATION AND THEIR IMPACTS ON HERITAGE BUILDINGS AT POLICE TRAINING CENTRE (PULAPOL) KUALA LUMPUR, MALAYSIA : A CRITICAL ANALYSIS

Ayub Awang[1], Mohammad Rusdi Mohd Nasir[1], Wan Saiful Nizam Wan Mohamad[1], Ramly Hasan[1], Izati Nabila Marzuki[2] and Nurzuliza Jamirsah[3]
[1]*Faculty of Architecture and Ekistics, Universiti Malaysia Kelantan, Bachok Campus, Bachok, Kelantan, Malaysia.*
[2]*Faculty of Technology Creative and Heritage, Universiti Malaysia Kelantan, Bachok Campus, Bachok, Kelantan, Malaysia.*
[3]*Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia.*

Abstract
Police Training Centre (PULAPOL) Kuala Lumpur has been gazetted as a heritage site since the year 2004. Since its inception, this academy houses various species of landscaping plants sheltering the area away from the sun and in turn giving it a refreshing atmosphere. However, the study found that the heritage buildings at PULAPOL have been affected by the surrounding vegetation. Although the previous studies stated that the damages on the heritage buildings were caused by several different factors, the damage caused by the vegetation factor is less studied and highlighted. Therefore, this study aims to identify the type of plants that contribute to the damages of the heritage buildings at PULAPOL as well as to analyze the damages based on the plants' characteristics. This qualitative study has been carried out through the employment of a case study approach that involves site observation and interview. The study found out that out of the 143 species of plants that have been planted at PULAPOL, 68 of them carry the potential to damage the heritage buildings due to inefficiency in management and their unsuitability.

Keywords: *Landscape Plants; Heritage Building; Conservation; PULAPOL.*

INTRODUCTION

Kuala Lumpur Police Training Centre (PULAPOL) is the oldest police academy in Malaysia. The academy was established in 20 November 1904 established by Captain Graham who is a former Malay States Guides Officer and has been coordinating the police system in the country to date. It has also been recognized as a heritage site in Malaysia since 2004. The construction work of PULAPOL started around the 1930s and the construction was fully completed in 1936. To date, a total of 27 buildings and a monument were gazetted as heritage site making the academy as a historical building complex (Abu Bakar, 2017). This makes the PULAPOL building complex in Kuala Lumpur distinctive compared to any other heritage sites in Malaysia due to their large number of buildings in one area. Therefore, it is the Facility Management's responsibility to run the maintenance task on the heritage buildings since the management ought to be carried out by the proprietor.

Even so, the buildings listed as national heritage found in PULAPOL are also facing the threat of damage considering that the 27 buildings are old buildings that existed before independence. Most of the the buildings are using fair faced bricks and cement plastered walls. While the roof part uses clay tiles and wood finish as fascia board (Awang et al., 2021). The damages to buildings in PULAPOL were reported such as cracked aprons, rotting wooden finishes, roof damage, cracked walls and pillars, most of which were caused by the threat of the surrounding vegetation (Awang et al., 2021). The issue of plants that threaten heritage buildings, whether they are planted or grow naturally, is not taken very seriously because the solution that is often taken during building conservation works is to cut down or prune. This situation is to preserve the heritage building from being continuously threatened in the future. Therefore, the study of the characteristics of plants found around heritage buildings is to identify the causes of damage to heritage buildings. Next, this will help conservators, building owners and local authorities take appropriate action to solve problems and reduce the impact on heritage buildings, especially in handling existing plants so as not to threaten heritage buildings and help in the selection of plants that want to be planted in the future.

OBJECTIVES AND METHODS OF STUDY

This research aims to identify the type of plants or trees that could affect the heritage buildings at PULAPOL as well as to analyze the damages in the buildings based on the plants' characteristics. This study is carried out using qualitative case study approach. PULAPOL Kuala Lumpur is selected as the research subject because this location is the only site that consists of clustered buildings in one place which are 27 buildings in total. The building involved is a masonry type built in the 1930s, which is when this area was established. Its management is coordinated by the Management and Facility Unit led by an assistant manager who has been working there for 30 years. Instrumentally, the study is carried out through the employment of field observation method and interviews with the PULAPOL'S Facility Management. The observation method is carried out on all buildings in this academy that are listed as the heritage site by the National Heritage Department (JWN). Observations are made using plant inventory form combined with a dilapidated study form for building damage. Meanwhile, the interview method is carried out as purposive sampling by identifying the background of the sample; - the individual who is known to manage the organization of the buildings and landscape area in PULAPOL. The use of an interview candidate is because PULAPOL is a non-public area that conducts policing training activities. The buildings in this area are fully under the responsibility of PULAPOL management and do not involve conservators and other interested bodies. To conduct research in the PULAPOL area also requires some strict procedures where the number of visitors is also limited. The data then analyzed using content analysis from both instruments of the research method. This study has also been sent to the Official Administration Deputy Commander (General Police), PULAPOL Kuala Lumpur as a research procedure required for the government building as well as to be reviewed for data validation before being published to the public.

LITERATURE REVIEW

Many studies state that heritage buildings often face physical damage because of their ages, reaching to hundreds of years old. The damages are usually caused by various factors such as weather, pests, traffic, and plants (Awang et al., 2021; Ahmad, 2018; Ahmad & Rahman, 2010; Hanafi et al., 2018; Salleh & Ahmad, 2009; Talib et al., 2014; Tan et al., 2016). Moisture is found to be the main issue that threatens the heritage buildings especially in the tropical area (Jim, 2018; Jim & Chen, 2010). This moisture issue is not only caused by the weather but also due to the presence of the trees in its surroundings (Awang et al., 2021; Ahmad, 2018). Similarly, other damages such as fractures, termite issues and structural damage also occur as a result of the existence of plants in the vicinity (Awang et al., 2020). The presence of termites poses a threat to the building structures, especially for areas with tropical climate (Muvengwi et al., 2017; Verma et al., 2018).

Plants are able to live longer than the buildings next to them, which can damage the building and pose a threat to its occupants (Catt, 1993). Hitchhiking plants are more likely to grow on old buildings such as palaces, fortresses, tombs, places of worship and archaeological sites (Caneva et al., 2009; Ceschin et al., 2016; Giulia et al., 2018; Awang et al., 2021). The tropical climate gives plants the advantage to grow easily no matter where they are, including on buildings such as walls (Jim, 1998, 2013, 2018). The presence of plants around the building causes moisture on the walls and interior spaces to activate the growth of moss and the formation of green stains (Ahmad, 2018; Kayan, 2006; Ayub et al., 2021). As in the case of the buildings of Angkor, Cambodia, the canopy of plants was found to prevent sunlight from reaching the building and creating a mossy area, always dim and humid. (Giulia et al., 2018). Plants that have sparse leaves are more suitable than plants that have dense foliage because they do not block the sunlight from penetrating them and also do not block the visual view of the building. (Catt, 1993). In addition, the moss or fungus that grows releases spores into the air that can affect the health of the building's occupants (Bakri dan Mydin, 2014).

The stone wall is the main habitat for some plants to live which then spread on the wall of the building (Ceschin et al., 2016). Plants that have a strong root system and the ability to grow quickly such as Ficus spp. tends to damage brick walls and structures (Caneva et al., 2009). In addition, plant roots can cause cracks in walls and pavements (Ahmad 2004; Caneva et al., 2009; Catt, 1993; Halwatura et al., 2013; Kayan, 2006; Satriani et al., 2010; Yadav, 2015). The damage is caused by plants planted or plants close to the building (Catt, 1993; Mattheck et al., 2003; Young dan Ellsmore, 2008). Most cases of insurance claims against insurance companies against building damage often involve the attack of tree roots that are adjacent to the building which eventually causes the plant to be removed and cut down to reduce damage to the building structure (Biddle, 1979). Plant roots are able to lift heavy loads which this attack will cause vertical cracks, horizontal cracks and lateral forces (Mattheck et al., 2003).

FINDINGS

In general, the landscape design at the academy focuses on beautification and brightening the environment with no specific concepts applied (Zahari, 2020). This can be observed in terms of the selection of different species of plants that display different shapes and functions. Meanwhile, the management and maintenance work of the landscape are more concentrated at the entrance and main management buildings such as the Commander's Office building, the Financial Office Building, around the marching field, the main road, and Gurdwara Sahib. The management unit gives the least attention to the landscape in the area of the Men's and Women's hostel barrack as this area is not a place of interest and not the main area.

The damaging impact of plants identified in PULAPOL Kuala Lumpur creating untidy surrounding, causing plant remains pollutants on the roof, gutter, drainage, and leading to formation of moss as well as stain (Table 1). The study has found that there are 143 species of landscape plants that have been planted throughout the area of PULAPOL Kuala Lumpur which are 51 species of trees, 35 species of woody shrubs, 25 species of herbaceous plants, 11 species of palms & cycads, 9 species of cacti & succulents, 6 species of epiphytes & lithophytes, 3 species of bamboo, grass & sedge plants, 2 species of climbers & creepers plants, and 1 species of fern & allies. Meanwhile, Overall, the study has found that there are 68 out of 143 species of these plants that are capable of affecting the heritage buildings in

PULAPOL which consist of 43 trees species, 8 palm species, 13 woody shrub species, 3 herbs species and 1 species of climbers & creepers. From that number, the findings concluded that there are 25 species of plants threating the heritage building which involve 21 species of trees, 3 species of woody shrubs and 1 species of palms & cycads (Table 2).

Table 1. List of Heritage Buildings in PULAPOL Kuala Lumpur by Type of Damage Caused by Plants

NO	CODES	LIST OF BUILDINGS Building category: Listed as a Heritage Site by Jabatan Warisan Negara Building type: Masonry	IMPACTS CAUSED BY PLANTS TO HERITAGE BUILDINGS				
			Untidy Surrounding	Waste on Rooftops	Waste in the Gutter	Waste in the Drainage	Moss and Stain
1	JKR 341	Male Barrack	/	/		/	/
2	JKR 342	Male Barrack	/	/		/	/
3	JKR 386	Female Barrack	/	/		/	/
4	JKR 394	Female Barrack	/	/		/	/
5	JKR 817	Commander's Residence	/	/			
6	JKR 1331	Adjutant Residence	/			/	
7	JKR 1332	Assistant Commander’s Residence (Training)	/				
8	JKR 1333	Assistant Commander’s Residence	/				/
9	JKR 1541-44	Class F Family House	/	/			
10	JKR 1744-55	Women Police’s Children Dormitory	/	/		/	/
11	JKR 1874	Office of The Art of Self-Defense Building (SMD)	/			/	
12	JKR 1875	Physical Intelligence Test Building (UKF)	/			/	
13	JKR 1876	Cyberpool Building	/			/	
14	JKR 1877	Sports Building (Gymnasium)	/	/		/	
15	JKR 1878	Marching Band Building	/			/	
16	JKR 1879	Diner Building	/			/	/
17	JKR 1786	Commander's Office Building (Guard Hall)	/		/		
18	JKR 1896	KEMAS Kindergarten Building	/			/	/
19	JKR 2003	Male Police's Children Dormitory	/	/	/	/	/
20	JKR 2004	Finance Office Building					/
21	JKR 2005	Central Weapons & Armament Workshop	/		/	/	/
22	JKR 2006	Hall One	/		/	/	
23	JKR 2006	Batu Lama School Building	/		/	/	
24	JKR 2019	Commander's Office Building	/				
25	JKR 2076	Sport Building	/			/	
26	JKR 2078	Gurdwara Sahib PULAPOL	/		/	/	/
27	JKR 2085	Musolla/Mosque PULAPOL	/				

The study has identified that there are a total of 21 plants that cause the environment of the building areas to be untidy. This condition is caused by leaves, twigs and flowers that often fall and accumulate at the corners of the buildings that are difficult to clean. These types of plants are identified as *Hopea odorata, Loropetalum chinensis, Mangifera indica, Peltophorum pterocarpum, Pterocarpus indicus, Samanea saman, Terminalia mentaly, Juniperus chinensis, Spathodea campanulata, Phyllanthus acidus, Moringa oleifera, Artocarpus heterophyllus, Artocarpus integer, Dalbergia latifolia, Syzygium campanulata, Syzygium aqueum,* and *Averrhoa bilimbi*. While plants like *Bougainvilliea spectabilis* and *Veichia merillii* which produce flowers and fruits, although not much, have been found to affect the buildings due to lack of maintenance.

There are six (6) species of plants that cause the accumulation of plant residues on the buildings' roof such as *Dalbergia latifolia*, *Durio zibethinus*, *Juniperus chinensis*, *Mangifera indica*, *Peltophorum pterocarpum* and *Spathodea campanulatum*. The existence of these plants have made the surrounding area untidy because they produce and drop their leaves, fruits and twigs. As these plants are planted near the buildings, the physical condition of the plants is higher than the buildings and such location is less suitable due to wind factor that causes leaves to accumulate and get trapped on the roof. Plants from the species of *Dalbergia latifolia* and *Peltophorum pterocarpum* are found to be far from the building but still, their small leaves have been found to be carried by the wind and trapped on the roof.

There are six (6) buildings that are found to have the problem of waste accumulation in the gutter channel such as Commander's Office Building (Guard Hall), Male Police's Children Dormitory, PULAPOL Central Weapons and Armament Workshop, Hall One, Batu Lama School Building and Gurdwara Sahib PULAPOL. The accumulation of plant waste such as leaves and twigs is from *Juniperus chinensis*, *Mangifera indica* and *Syzygium campanulatum*. Other buildings are not affected by this problem because there is no tall plant near the building and there is no gutter channel attached to the buildings. These buildings are administrative buildings such as the Commander's Office and Finance Office buildings which only house flowering shrubs.

While 17 species of plants have been found to cause the accumulation of waste in the drains, 15 of them are plants that shed leaves, 1 species drop flower and 1 species drop fruit. The affected buildings are 20 out of 27 buildings where the type of plants that cause this problem are *Anacardium occidentale, Artocarpus heterophyllus, Averrhoa bilimbi, Bougainvillea spectabilis, Hopea odorata, Juniperus chinensis, Mangifera indica, Oleiferous moringa, Peltophorum pterocarpum, Phyllanthus acidus, Platycladus orientalis, Pterocarpus indicus, Samanea saman, Syzygium aqueum, Syzygium campanulatum, Terminalia mentaly* and *Veitchia merrillii*.

Moss growth and stain effects have been found to result from the existence of shady plants and tall trees that are planted closely along the roads and near the buildings. This condition provides prolonged moisture to the area. The contributing plants are *Peltophorum pterocarpum*, *Juniperus chinensis* and *Mangifera indica.* On the other hand, woody shrubs that are used as a hedge and topiary namely *Ficus microphylla* 'Golden', *Loropetalum chinense and Phyllanthus myrtifolius* also provide moisture due to the density of their leaves. As its fallen fruits and flowers are not cleaned, *Veitchia merrillii, a palm species*, also gives a shady effect on the building apron.

For plants that are planted in the pot, one common issue that often occurs is moss and stain formation in their surroundings. The moss formation exists because the pots have no plant saucer at the bottom part and also are arranged too close to each other. The employment of the pots without their saucer has caused some white and yellow stains to form on the floor which then lead to sediment accumulation in the drains. The sediment is actually resulted from the water residues during plant watering work. Species of plants that are planted in the pot are *Aloe arborescens, Bougainvillea spectabilis, Bulbophyllum* spp., *Calathea makoyana, Codiaeum* Cultivars, *Cordyline terminalis, Cordyline fruticose, Costus woodsonii, Dendrobium crumenatum, Dendrobium* Hybrids, *Dieffenbachia amoena, Dischidia nummularia, Dracaena angustifolia, Dracaena braunii* 'Lotus', *Dracaena draco, Guzmania lingulata, Ficus lyrata, Premna corymbosa, Sansevieria trifasciata* 'Laurentii', *Tabernaemontana divaricata, Tradescantia spathacea,* and *Wrightia religious.* However, the formation of moss and stain is not associated with the type or species of plant but caused by the usage of the pot that is less practical as well as excessive watering.

In addition, many plants that could risk the buildings are also planted in the area. However, due to their position that is quite far from the buildings, these plants are seen to have no impact on the building but based on the characteristics indicated, these plants are seen to have potential risks of damaging the structures if they are planted close to the buildings. The plants that are identified to have destructive roots are *Anacardium Occidentale, Artocarpus altilis, Cinnamomum iners, Fagraea fragrans, Ficus benjamina, Ficus microphylla* 'Golden', *Hopea odorata, Lagerstroemia floribunda, Peltophorum pterocarpum, Psidium guajava, Pterocarpus indicus, Samanea saman, Terminalia catappa* and *Terminalia mentaly.* While *Vanilla planifolia* that is a climber type with aerial root may also affect the building surface if it is planted on the wall of the building.

Plants that are identified to have a seasonal leave falling or deciduous, crowded crown types, possess flowers and fruits are capable of damaging the buildings if the remnants are stuck on the gutter, drainage and roof. The identified plants are *Azadirachta indica, Caesalpinia ferrea, Cinnamomum iners, Ficus benjamina, Lagerstroemia floribunda, Naphelium lappaceum, Vitex trifolia, Naphelium mutabile, Terminalia catappa, Tabebuia pentaphylla* and *Ziziphus maitian.* Many of these species should be given more attention because they often drop their leaves in large numbers *such as Azadirachta indica, Caesalpinia ferrea* and *Terminalia mentaly*. Plants that drop flowers in large quantities such as *Tabebuia pentaphylla* should also be avoided to be planted too close to the building because the flowers will produce stain if they are not cleaned immediately and will cause clogged gutters if they accumulate in the channels. Plants that need to be avoided due to their risk of causing serious damage to the building are *Ficus benjamina, Vitex trifolia, Terminalia mantaly, Terminalia mantaly* 'Variegata', and *Fagraea fragrans*.

Plants that have dense crown and a high number of leaves carry the risk of making the surrounding area moist as they obstruct the sunlight from penetrating the ground floor. The palm and shrub plants such as *Rhapis excelsa, Dypsis lutescen and Heliconia psittacorum* are found to have a crowded-like appearance due to its cluster-grown properties and wide fan-shaped leaves. It is the same with *Rhodomyrtus tomentosa* and *Osmoxylon lineare* plants which are the woody shrub species with a crowded-like appearance that are often used as a fence and planted close to drains and buildings. Other woody shrub plants with the same feature are *Streblus asper, Duranta* sp., *Ficus microphylla* 'Golden', *Hibiscus rosa-sinensis* and *Ixora sunkist. All of these plants* can't be planted too close to the buildings. These plants are often employed for topiary which will leave remains such as leaves and twigs. Some trees like *Cinnamomum iners and Ficus benjamina* do not only drop their leaves, but also cause a damp surrounding because they have dense round-shaped crown. Typically, maintenance practices that are insufficient will leave the remains in the surrounding area as mulch. Besides making the environment a bit messy, these remnants if not properly managed will invite termite attack because plant's remains is their food source.

The palm plant, *Roystonea regia that is* planted in the building area of the Office of Martial Arts (SMD) is seen not in good condition and exhibits a withering appearance. Its shoots have been attacked by insects and at risk of dying if not treated. If the plant dies, it will be attacked by wood-feeding insects and termites. However, palm plants such as *Wodeyetia bifurcata* that are planted in some places in this area, are seen as fertile but the location of their cultivation should also be given attention as the plants are at risk to be attacked by pest. Pest like termites are usually attracted to plants that are easy to die because they have decaying parts and high cellulose content. Therefore, the selection of plants needs to be suitable or precise by identifying the characteristics of the plant.

Table 2. Summary of Plants in PULAPOL Kuala Lumpur and Its Characteristics Affecting Heritage Buildings

NO.	PLANTS	FEATURES OF PLANTS THAT AFFECT HERITAGE BUILDING						
		Drop Leaves	**Drop Twigs & Branches**	**Bear Fruits**	**Drop Flowers**	**Destructive Roots**	**Compacted Crown & Shed**	**Easy to Rot or Die**
1	*Acalypha siamensis* (Wild Tea)	- **Dry leaves from prunning (topiary) trapped in drainage & surrounding	- **Dry twigs from prunning (topiary) trapped in drainage & surrounding	-	-	-	- **Moisture on wall & apron - **Dry leaves in drainage	-
2	*Alpinia galanga* (Lengkuas)	-	-	-	-	-	- **Moisture on wall, apron and drainage	-
3	*Anacardium occidentale* (Cashew)	- *Dry leaves stucked in drainage & surrounding	-	-	-	- *Roots attack on floor and apron	- *Moisture on wall & apron	-
4	*Annona muricata* (Soursop)	- **Dry leaves stucked in drainage	-	-	-	-	-	-
5	*Annona squamosa* (Sweetsop)	- **Dry leaves stucked in drainage	-	-	-	-	-	-
6	*Artocarpus heterophyllus* (Nangka)	- *Dry leaves in gutter, roof, drainage surrounding	-	- **Fruits attract civet/ monkey - **Roof damage due to fruits fall	-	-	- *Moisture on wall & apron	-
7	*Artocarpus altilis* (Breadfruit)	- *Dry leaves in gutter, roof, drainage & surrounding	-	-	-	- **Roots attack on wall, floor and apron	- **Moisture on wall & apron	-
8	*Artocarpus integer* (Cempedak)	- *Dry leaves in gutter, roof, drainage surrounding	-	- **Fruits attracts civet/ monkey - **Roof damage due to fruits fall	-	- **Roots attack on wall, floor and apron	- **Moisture on wall & apron	-
9	*Averrhoa bilimbi* (Belimbing)	- *Dry leaves in drainage surrounding	-	-	-	-	-	-
10	*Azadirachta indica* (Neem)	- *Dry leaves in gutter, roof, drainage & surrounding	-	-	-	- *Roots attack wall, floor and apron	- *Moisture on wall & apron	-

Table 2. Summary of Plants in PULAPOL Kuala Lumpur and Its Characteristics Affecting Heritage Buildings (continued)

11	*Bougainvillea spectabilis* (Bunga Kertas)	-	-	-	- *Dry flowers fall in drainage	-	-	-
12	*Caesalpinia ferrea* (Brazialian Ironwood	- *Dry leaves in drainage surrounding	-	-	-	-	-	-
13	*Calathea lutea* (Cuban cigar)	-	-	-	-	-	- *Moisture on wall and apron	-
14	*Cinnamomum iners* (Kayu Manis)	- *Dry leaves in drainage & surrounding	-	-	-	- **Roots attack wall, floor and apron	- *Moisture on wall & apron	-
15	*Cocos nucifera* (Coconut)	- **Roof damage due to fronds fall	-	- **Roof damage due to fruits fall	-	-	-	-
16	*Codiaeum* cultivars (Croton)	-	-	-	-	-	- *Moisture on wall & apron	-
17	*Cyrtostachys renda* (Lipstick Palm)	-	-	- **Floor stain due to ripe fruits fall	- **Flowers accumulate in drain	-	- **Moisture on wall, apron & drainage	-
18	*Dalbergia latifolia* (Indian Rosewood)	- *Dry leaves in gutter, roof, drainage & surrounding	-	-	-	-	- *Moisture on wall & apron	-
19	*Duranta erecta* L. (Golden Dew-Drop)	- - *Dry leaves from prunning (topiary) trapped in drainage & surrounding	- **Dry twigs from prunning (topiary) trapped in drainage & surrounding	-	-	-	- **Moisture on wall & apron	-
20	*Durio zibethinus* (Durian)	- *Dry leaves in gutter, roof, drainage & surrounding	- *Roof damage due to fragile branches & fruits fall	- *Fruits fall in gutter, roof, drainage & surrounding	- **Flowers accumulate in gutter roof and drain	-	- *Moisture on wall & apron	- **Rotten branches attract termite
21	*Dypsis lutescens* (Golden Cane)	-	-	-	-	-	- **Moisture on wall, apron & drainage	-
22	*Etlingera elatior* (Torch Ginger)	-	-	-	-	-	- **Moisture on wall, apron and drainage	-
23	*Euodia ridleyi* (Euodia)	-	-	-	-	-	- **Moisture on wall, apron and drainage	-

Table 2. Summary of Plants in PULAPOL Kuala Lumpur and Its Characteristics Affecting Heritage Buildings (continued)

24	*Fagraea fragrans* (Tembusu)	- **Dry leaves in gutter, roof, drainage & surrounding	-	-	-	- **Roots attack walls, floor, apron and drainage	- **Moisture on wall & apron	-
25	*Ficus benjamina* (Jejawi)	- **Dry leaves in gutter, roof, drainage & surrounding	-	- **Fruits attract birds	-	- ** Roots attack on wall, column, roof & floor - Strangler species	- *Moisture on wall & apron	-
26	*Ficus microphylla* 'Golden' (Golden Fig)	- **Dry leaves in gutter, roof, drainage & surrounding	-	- **Fruits attract birds	-	- **Roots attack on wall, column, roof & floor - Strangler species	- *Moisture on wall & apron	-
27	*Hibiscus rosa-sinensis* (Bunga Raya)	-	-	-	-	-	- *Moisture on wall & apron	-
28	*Heliconia psittacorum* (Sepit Udang)	-	-	-	-	-	- **Moisture on wall & apron	-
29	*Hopea odorata* (Chengal Pasir)	- *Dry leaves in gutter, roof, drainage & surrounding	- **Dry twigs in gutter, roof, drainage & surrounding	-	-	- ** Roots attack wall, floor and apron	- *Moisture on wall & apron	-
30	*Ixora sunkist* (Ixora)	- - **Dry leaves from prunning (topiary) trapped in drainage & surrounding	- **Dry twigs from prunning (topiary) trapped in drainage & surrounding	-	- **Dry flowers in drainage	- ** Minor from roots to apron and drainage	- **Moisture on wall & apron	-
31	*Juniperus chinensis* (Chinese Juniper)	- *Dry leaves in gutter, roof, drainage & surrounding	-	-	-	-	- *Moisture on wall & apron	-
32	*Lagerstroemia floribunda* (Bungor)	- **Dry leaves in gutter, roof, drainage & surrounding	- **Dry twigs in gutter, roof, drainage & surrounding	-	- **Dry flowers in drainage	- ** Roots attack walls, floor, apron and drainage	- *Moisture on wall & apron	-
33	*Lagerstroemia indica* (Crepe Myrtle)	- **Dry leaves from prunning trapped in drainage & surrounding	- **Dry twigs from prunning trapped in drainage & surrounding	-	- **Dry flowers in drainage	-	-	-

Table 2. Summary of Plants in PULAPOL Kuala Lumpur and Its Characteristics Affecting Heritage Buildings (continued)

34	*Lansium domesticum* Corr. (Dokong)	- **Dry leaves in gutter, roof, drainage & surrounding	- **Dry twigs in gutter, roof, drainage & surrounding	-	-	-	-	- **Rotten branches attract termite
35	*Livistona chinensis* (Serdang)	-	-	- *Floor stain due to ripe fruits fall	-	-		-
36	*Loropetalum chinense* (Chinese fringe)	- **Dry leaves in drainage & surrounding	-	-	-	-	- *Moisture on wall & apron	-
37	*Macaranga tanarius* (Pokok Mahang)	-	-	-	-	-	- **Moisture on wall & apron	-
38	*Mangifera indica (Mangga)*	- *Dry leaves in gutter, roof, drainage & surrounding	- *Dry twigs stuck in gutter, roof, drainage & surrounding	- **Fruits stuck in gutter, roof, drainage & surrounding - Fruits attract bats and chivet	-	-	- *Moisture on wall & apron	-
39	*Moringa oleifera* (Munggai)	- *Dry leaves in drainage & surrounding	-	-	-	-	-	-
40	*Naphelium lappaceum* (Rambutan)	- **Dry leaves in gutter, roof, drainage & surrounding	- **Dry twigs stuck in gutter, roof, drainage & surrounding - **Fruits attract bats and chivet	- **Ripe fruits stuck in gutter, roof, drainage & surrounding - **Fruits attract bats and chivet	-	- **Roots attack on floor	- **Moisture on wall & apron	-**Rotten branches attract termites
41	*Naphelium mutabile* (Pulasan)	- **Dry leaves trapped in gutter, roof, drainage & surrounding	- **Dry twigs in gutter, roof, drainage & surrounding	- **Ripe fruits stuck in gutter, roof, drainage & surrounding - **Fruits attract bats and chivet	-	- **Roots attack on floor	- **Moisture on wall & apron	-
42	*Osmoxylon lineare* (Aralia)	-	-	-	-	-	- *Moisture on wall & apron	-

Table 2. Summary of Plants in PULAPOL Kuala Lumpur and Its Characteristics Affecting Heritage Buildings (continued)

43	*Peltophorum pterocarpum* (Batai)	- *Dry leaves trapped in gutter, roof, drainage & surrounding	- *Dry twigs trapped in gutter, roof, drainage & surrounding	- *Dry fruits trapped in gutter, roof, drainage & surrounding	- **Small flowers accumulate in guttern roof and drain	- **Roots attack on floor, apron and drainage	- *Moisture on wall & apron	-
44	*Phaleria marcocarpa* (Mahkota Dewa)	-	-	- **Fruits trapped in drainage & surrounding	-	-	-	-
45	*Phyllanthus acidus* (Cermai)	- *Dry leaves trapped in drainage & surrounding	-	- *Fruits trapped in drainage & surrounding	-	-	-	-
46	*Phyllanthus myrtifolius* (Mousetail Plant)		-	-	-	-	- *Moisture on wall & apron	-
47	*Plumeria obtusa* (Kemboja Putih)	- *Dry leaves trapped in drainage & surrounding	-	-	- **Flowers accumulate in drain	- **Roots attack on floor, apron and drainage	-	-
48	*Plumeria rubra* (Kemboja Merah)	- *Dry leaves trapped in drainage & surrounding	-	-	- **Flowers accumulate in drain	- **Roots attack on floor, apron and drainage	-	-
49	*Platycladus orientalis* (Chinese Aborvitae)	- *Dry leaves trapped in drainage & surrounding	-	-	-		- *Moisture on wall & apron	-
50	*Psidium guajava* (Guava)	-	-	- *Fruits attract civet and other animals	-	- **Roots attack on floor, apron and drainage	-	-
51	*Pterocarpus indicus* (Angsana)	- *Dry leaves trapped in gutter, roof, drainage & surrounding	- *Dry twigs trapped in gutter, roof, drainage & surrounding	- *Dry fruits trapped in gutter, roof, drainage & surrounding	- **Small flowers accumulate in drain	- ** Roots attack on floor, apron and drainage	- *Moisture on wall & apron	- **Building damage due to easy to rot and fall
52	*Rhapis excelsa* (Palas)	-	-	-	-	-	- *Moisture on roof, wall & apron	-

Table 2. Summary of Plants in PULAPOL Kuala Lumpur and Its Characteristics Affecting Heritage Buildings (continued)

53	*Roystonea regia* (Royal Palm)	-	-	- **Floor stain due to ripe fruits fall	-	-	-	- **Attract termites due to rotten trunk
54	*Samanea saman* (Hujan-hujan)	- *Dry tiny leaves trapped in gutter, roof, drainage & surrounding	- *Dry twigs trapped in gutter, roof, drainage & surrounding	-	-	- ** Roots attack on floor, apron and drainage	- *Moisture on roof, wall & apron	-
55	*Schizolobium parahyba* (Tower Tree)	** Dry leaves trapped in gutter, roof, drainage & surrounding	** Dry twigs trapped in gutter, roof, drainage & surrounding	-	-	-	-	-
56	*Spathodea campanulata* (African Lily)	- *Dry leaves trapped in gutter, roof, drainage & surrounding	- *Dry twigs trapped in gutter, roof, drainage & surrounding	-	-	-	-	- *Moisture on wall & apron
57	*Streblus asper* (Kesinai)	- **Dry leaves from prunning (topiary) trapped in drainage & surrounding	- **Dry twigs from prunning (topiary) trapped in drainage & surrounding	-	-	-	- ** Moisture on roof, wall & apron	-
58	*Syzygium aqueum* (Jambu Air)	- *Dry leaves trapped in gutter, roof, drainage & surrounding	- *Dry twigs trapped in gutter, roof, drainage & surrounding	- **Ripe fruits trapped in gutter, roof, drainage & surrounding - **Fruits attract bat and chivet	-	-	- *Moisture on wall & apron	-
59	*Syzygium campanulatum* (Kelat Paya)	- *Dry leaves trapped in gutter, roof, drainage & surrounding	- *Dry twigs trapped in gutter, roof, drainage & surrounding	-	-	-	- *Moisture on wall & apron	-
60	*Tabebuia pentaphylla* (Trumpet Tree)	- *Dry leaves, flowers & twigs trapped in gutter, roof, drainage &	- **Dry twigs untidy the surrounding	-	- **Flowers accumulate in drain	- ** Roots attack on floor, apron and drainage	- *Moisture on wall & apron	-
61	*Terminalia catappa* (Ketapang)	- **Dry leaves untidy the surrounding	- **Dry twigs untidy the surrounding	-	-	- ** Roots attack on floor, apron and drainage	- **Moisture on wall & apron	-

Table 2. Summary of Plants in PULAPOL Kuala Lumpur and Its Characteristics Affecting Heritage Buildings (continued)

62	*Terminalia mentaly* (Doa Tree)	- *Dry leaves trapped in gutter, roof, drainage & surrounding	-	- *fruits trapped in gutter, roof, drainage & surrounding	-	- ** Roots attack on floor, apron and drainage	- *Moisture on wall & apron	-
63	*Terminalia mantaly* 'Variegata' (Doa Tree)	- *Dry leaves trapped in gutter, roof, drainage & surrounding	-	- *Fruits trapped in gutter, roof, drainage & surrounding	-	- ** Roots attack on floor, apron and drainage	- *Moisture on wall & apron	-
64	*Vanilla planifolia* (Vanilla)	-	-	-	-	- **Roots attack on wall surfaces	-	-
65	*Veitchia merrillii* (Manila Palm)		-	- *Floor stain due to ripe fruits fall	- *Flowers accumulate in drain	-	-	-
66	*Vitex trifolia* (Lemuni)	- *Dry leaves trapped in drainage & surrounding	-	- *Fruits trapped in drainage & surrounding	-	-	-	-
67	*Wodyetia bifurcata* (Foxtail palm)	-	-	- **Floor stain due to ripe fruits fall	- **Flowers accumulate in drain	-	-	- **Trunk that easy to rot attract termites
68	*Ziziphus mauritiana* (Bidara)	- **Dry leaves trapped in drainage & surrounding	-	- **Fruits trapped in drainage & surrounding	-	-	- **Moisture on wall & apron	-

Note: *Plants that already threat the buildings;
**Plants that potentially threat the buildings.

FACTORS THAT CAUSE PLANT IMPACTS ON BUILDINGS

In general, there are three factors that contribute to plant impacts towards the heritage buildings which are building factor, plant factor, and landscape management factor. The building factor can be identified based on three elements which are building age, building design, and building material. The age of the building that has reached hundreds of years have made some structures prone to damages and they need to be fixed. That state of the buildings with some already damaged structures will become more vulnerable to the plant's threats such as cracks on the drain part which also encourage the root to grow across the structures. Besides, the architectural design of the building that is too complicated at some parts such as the roof has caused the leaves, fruits, and twigs to be easily trapped. The building material factor also could affect how the plants impact the buildings. Buildings with the employment of facing brick materials are shown to have less damage. Most damages occur on building structures that employ plaster, moisture-prone materials, painted wall, and wood materials with no weather-resistant element. The damages that occur are mostly associated with the moisture problem in which the plants are one of the active agents. Masonry building with the employment of lime plaster and clay brick has been providing mineral source to the plants. Some materials can maintain or preserve the moisture longer than other types of materials encouraging the plants to grow on them. Because of this factor, epiphyte plants such as ferns and strangler, *Ficus sp*. for example, can easily grow on the material surface due to wind pollination and bird dissemination (Zahari, 2020).

The second factor is the plant factor which can be identified into two elements namely the species of plant and the planting location. These two factors are seen as interconnected because each species has different impacts. Some plants are planted in an area far from the building but still contribute to the damage of the building. Some of the plants are *Peltophorum pterocarpum, Pterocarpus indicus, Samanea saman, Terminalia mantaly, Schizolobium parahyba* and *Hopea odorata* which are categorised as deciduous plants in which their leaves are easily scattered due to wind gusts. Among these plants, some plants have fine leaves such as *Peltophorum pterocarpum, Samanea saman, Schizolobium parahyba and Terminalia mantaly* and their leaves could scatter at a far distance from the trees. Due to their small size, there will be some difficulties in cleaning work. This situation will become more complicated if the leaves are stuck in hard-to-reach places such as gutter channels (Zahari, 2020). This location factor concerns more on the threats from the roots beneath the soil that are difficult to detect with naked eyes. The practice of tree planting is usually based on the spread of roots through observation of the widening of the crown. If the plant’s crown reaches the building, most likely the roots have also touched the structure of the building in the soil. Plants that could reach the building could also build a connecting way for insects and dangerous animals to get through to the building.

Furthermore, the landscape management factor should also be given attention because inefficient management will negatively affect the building. Inconsistent maintenance with no planned schedule will expose the building to the plants’ threats (Zahari, 2020). In this academy, the maintenance work is only seen to be done consistently in the Commander's Office, Guard Hall, Finance Office, Gurdwara Sahib, and Hall One. This situation can be seen through the condition of plants that are maintained only in those areas and the selection of plant species such as flowering and decorative plants is only focused on the main area. The most under-performed maintenance is in Men & Women’s Barracks, Deputy Commander's

Residence (Training), Deputy Commander's Residence (Administration & Garage), and Sports Building. This inconsistent landscape management is seen as a factor causing serious damage to the buildings. The maintenance work at the administrative building and the main entrance is excellent because the concerned buildings act as a welcoming landmark to the visitors. However, the buildings that are located at hidden location with less attraction to the visitors are somewhat ignored. Some trees have been planted not for beautification purposes but more towards medical purposes and providing fruits and other supplies for kitchen such as *Durio zibethinus, Capsicum annum, Carica papaya, Jatropha curcas, Mangifera indica, Manihot utilissima, Musa* Cultivars, *Oroxylum indicum, Artocarpus altilis, Artocarpus integer* and so on. These plants can be found around the buildings of Men and Women's Barracks, Sports Building, KEMAS Kindergarten Building, and behind the Office of Martial Art Building (SMD). These types of plants could make the maintenance work more difficult not just because of the high production of leaves, but also unattended rotten fruits that will contribute to a dirty environment as well as attracting insects and animals such as bat and civet. The most worrying situation is the existence of termite colonies due to poorly cleaned environment with an abundance of its food source even though the treatment of insects has been done. Therefore, plants that drop leaves, twigs, branches, fruits & flowers, have destructive roots (hard and rising roots) and dense shade causing prolonged shading are characteristics that need attention due to the excessive moisture and structural damages that they have caused.

CONCLUSION

In conclusion, not all plants affect the condition of heritage buildings at PULAPOL Kuala Lumpur. Plants that drop leaves & branches, produce fruit, flower heavily, pest roots, thick stems and plants that rot or die easily are characteristics that need to be paid attention in preserving heritage buildings. In building conservation works, identifying the plants in the surrounding area is very important in order to prevent repeated damages in the future. In addition, the types of vegetation that threaten heritage buildings can be avoided for landscape design after the conservation project is fully completed. This is especially important for the Management and Facilities Unit of PULAPOL as the academy has the greatest number of heritage buildings in one area. Therefore, the botanical knowledge in identifying the characteristics and types of appropriate plant species is essential to ensure that the beautiful landscape and scenery of the academy can be maintained without any restrictions. Besides, the academy location is situated in the centre of Kuala Lumpur city which requires it to follow the National Urbanisation Policy (2016) 2nd edition which is in Principle 5 of Green Development and Clean Environment emphasising that the landscape in municipalities should be intensified to reduce carbon dioxide intensity to 45% by 2030. Therefore, the landscape design in this area cannot be ignored simply to preserve the heritage buildings but a more efficient approach should be implemented so that the landscape and preservation of heritage buildings are balanced and interdependent.

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DEVELOPMENT OF SUSTAINABLE INTERLOCKING PAVEMENT BLOCK (SIPB) USING HIGH-DENSITY POLYETHYLENE (HDPE) AND RECYCLED ASPHALT PAVEMENT (RAP)

Tuan Noor Hasanah Tuan Ismail[1], Muhammad Fariz Abdul Wahab[2], Suraya Hani Adnan[1], Andri Kusbiantor[3], Nik Normunira Mat Hassan[4], Faezah Yahya[5], Harina Md Amin[1] and Wan Amizah Wan Jusoh[3]
[1]Sustainable Engineering Technology Research Centre (SETechRC), Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Malaysia.
[2]Cergas Setia Construction, Taman Pinggiran Putra Seksyen 1, Selangor, Malaysia.
[3]Bamboo Research Centre (BambooRC), Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Malaysia.
[4]Integrated Engineering Simulation and Design (IESD), Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Malaysia.
[5]Intelligent Construction Centre (ICONSTC), Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Malaysia.

Abstract
Interlocking pavement block (IPB) has been extensively used in many countries for many years as a specialized problem-solving technique that provides pavement in areas where conventional types of construction are less durable due to many operational and environmental constraints. In developing IPB, cement, sand, and aggregates are frequently utilised, which at present these resources are limited and leading to many environmental impacts. This study attempts to examine the potential of sustainable IPB by substituting Portland cement with High-Density Polyethylene (HDPE) and aggregates with Recycled Asphalt Pavement (RAP). The alternative IPB were prepared in different HDPE and RAP blends, namely 1:3, 1:4, 1:5 and 1:6. The potential of IPB was evaluated through three series of tests: density test, water absorption test, and compression test. The findings of this study showed that the highest compressive strength of 7.65 MPa was achieved by HDPE and RAP blending proportion of 1:3 (1H3R). Furthermore, the widespread use of HDPE plastic waste and RAP as new alternative building materials would help reduce the quantity of plastic waste and RAP in landfills while promoting green technology.

Keywords: *Sustainable Interlocking Pavement Block (IPB); High-Density Polyethylene (HDPE); Recycled Asphalt Pavement (RAP); Compressive Strength.*

INTRODUCTION

Interlocking Pavement Block (IPB) is an accepted engineering product used mainly as an alternative to asphalt and concrete pavements. The IPB offers several benefits, including fast assembly, replacement, and transportation, high drainage capacity, ease of handling, and fast manufacturing (Kassim & Rohim, 2017). Furthermore, IPB is utilised globally as it is durable, non-skidding and dimensionally accurate, available in many sizes; and has good structure and colour. Additionally, IPB can also be installed by unskilled labours and can be re-used at the same site or elsewhere.

Unfortunately, cement, sands and aggregate are frequently utilised in the development of IPB, which is currently limited resources, costly, and causes many environmental impacts arising from its productions such as global warming and greenhouse effect. Moreover, cement production significantly contributes to carbon dioxide and greenhouse gas emissions (Ganjian, Jalull & Sadeghi-pouya, 2015; Jamellodin et al., 2021). One tonne of cement generates one tonne of carbon dioxide (CO_2). Cement output currently stands at 337.32 million tonnes from 2018 to 2019 (Patil & Sathe, 2021), accounting for 7 to 8 % of global CO_2 emissions (Patil & Sathe, 2021; Andrew, 2018). In addition, sand is the most in-demand resource in the construction sector; due to natural aggregates shortage caused by rapid urbanisation. An estimated 1.4 billion tonnes of sand would be required in 2020, up from 630 million tonnes in 2010 (Patil & Sathe, 2021). These numbers demonstrate public enthusiasm for increasing global warming as well as resource scarcity and environmental scarcity (Ganjian et al., 2015). As a result, researchers are seeking alternate building materials while keeping in mind the needs and breadth of future development.

Thus, this study was carried out to develop a sustainable IPB (SIPB) using by-product, which are plastic waste, and recycled asphalt pavement (RAP). Apart from reducing reliance on natural resources, it can be a long-term solution to solid waste problems that consists of non-disposable plastics requires a long time to decay, dumping of waste in landfills and threats the environmental sustainability (Patil & Sathe, 2021; Yasmin et al., 2021).

The idea of using plastic waste as a binder to replace Portland cement in the production of conventional IPB is due to its properties as well as reducing its volume in our environment. Plastic waste is one of the greatest issues affecting environmental sustainability (Patil & Sathe, 2021). In fact, it takes up to billion years for the waste to degrade naturally. Furthermore, RAP was used to replace aggregate as it contains 90 to 95% aggregate (Jebur & Abedali, 2020). RAP is a combination of aggregate and bitumen from existing old asphalt pavement. According to Saboo, Prasad, Sukhija, Chaudhary and Chandrappa (2020), it is generated in large quantities annually which becomes waste to landfills. Therefore, the reuse of by-products as an alternative to construction materials should reduce the consumption of natural resources.

Thus, the present study aimed to assess the potential of using HDPE plastic and RAP waste as new alternative materials to substitute cement and aggregate content in IPB based on its weight performance, water absorption and compressive strength. In this study, four different HDPE to RAP blend proportions of 1:3, 1:4, 1:5, 1:6 was used to develop the Sustainable IPB (SIPB). The significant findings of this research can benefit construction industry in optimising by-product resources in developing innovative, economical, and sustainable IPB for Malaysian market.

MATERIALS AND METHODS

Materials

In this study, SIPB was fabricated from a mixture of HDPE plastic waste and RAP where HDPE was used to replace cement contents while RAP substituted the fine aggregate contents. The HDPE used in this research was collected from UTHM Residential College. HDPE is a thermoplastic that can be melted into a liquid and remoulded into a solid-state. According to Ragaert, Delva, and Van Geem (2017), HDPE is tough, comparatively cheap, and has good process capabilities. The HDPE plastics were cut with a scissor into smaller pieces with dimensions of 1 cm × 1 cm to ensure uniform burning and facilitate melting of the plastics. Then, the cut HDPE plastics were rinsed with water to eliminate any pollutants and left to dry completely in the open air. The HDPE density varies between 940 and 970 kg/m^3, while the commonly used standard density is 950 kg/m^3 (McKeen, 2016).

The RAP used in this research was obtained from Sime Darby Berhad, Pagoh and Muar Municipal Council (MPM) in Johor. The RAP comprises high-quality, and well-qualified aggregates with high humidity asphalt cement. The RAP aggregates were heated evenly in the oven at 80^{o}C for 30 – 40 minutes before being crushed into individual fine aggregates by CBR hammer. The same method was used by Saboo et al. (2020). This study used RAP as fine aggregate that passed through a sieve size of 4.75 mm, as shown in Figure 1.

Figure 1. RAP That Passed Through a Sieve Size of 4.75 mm

SIPB Mix Proportion

The SIPB was made from four different HDPE:RAP blends proportions of 1:3, 1:4, 1:5 and 1:6. Both HDPE and RAP were mixed up to a total amount of 1400 g per sample. Table 1 shows the mixed proportion of SIPB used in this study. The HDPE and RAP were prepared separately before the fabricating process.

Table 1. Mix Proportion of SIPB

Sample ID	Mix Blend (HDPE:RAP)	Material Replacement (g)
1H3R	1:3	350: 1050
1H4R	1:4	280: 1120
1H5R	1:5	233.3: 1166.7
1H6R	1:6	200: 1200

Notes: H: HDPE; R: RAP

Fabrication of SIPB

The SIPB was fabricated in dimensions of 100 mm length x 100 mm width x 60 mm thickness to fit the compression machine base. The fabrication of SIPB was divided into three phases, namely heating, mixing, and curing for 7 and 14 days. Initially, the HDPE was heated in a metal mould at a temperature up to 140^{o}C and maintained until it was completely melted. RAP was added to the tray containing of HDPE and stirred for 5 minutes under heat to make SIPB. The melted plastic and RAP should be mixed completely to prevent the structure of IPB from cracking and to increase the bonding of RAP and HDPE blends to develop full strength. Then, the mixture was poured into a pre-prepared mould with 100 x 100 x 60 mm internal dimensions in three equal layers. Each layer was manually tamped 25 times using a tamping steel rod at 5 cm height before placing each new layer to regulate the same compaction pressure. Tamping rod compaction was conducted vertically for the sample and must be handled very carefully so that there were no voids, and the samples were denser. Subsequently, the surface was trimmed using a trowel. The samples were kept in the mould for 24 hours to ensure the sample was thoroughly dried. Finally, the samples were removed from the mould and cured for 7 and 14 days to harden. Figure 2 shows a SIPB sample fabricated at HDPE and RAP blending proportion of 1:3 (1H3R).

Figure 2. A SIPB Sample

Testing Method

Three series of laboratory tests were carried out on SIPB to determine its physical and mechanical properties. Density and water absorption tests represented physical properties, while compression test referred to the mechanical properties of the sample. The tests were conducted on each HDPE:RAP blend (1:3, 1:4, 1:5 and 1:6). Three samples were tested for each blend to obtain the average value.

The density test was performed to observe how the HDPE:RAP blend affected the SIPB weight. It is important to ensure the uniformity of the samples prepared to obtain reliable data. The density was estimated using the following equation.

$$\text{Density}, \rho_{SIPB} = \frac{Mass(M)}{Volume(V)} \tag{1}$$

The water absorption test was performed to investigate the effects of SIPB when exposed to water or humid conditions. To begin with, the samples were dried for at least 48 hours at temperature of 110°C before the test was carried out to ensure the water content in the specimen completely dried as suggested by Namarak, Bumrungsri, Tangchirapat, and Jaturapitakkul (2018). This sample was measured as dry SIPB sample. Then, three samples of each blend were immersed in a water tank containing distilled water and kept at room temperature for 24 hrs. After that, the sample was removed from the water, wiped with a dry towel, and it was weighted as wet SIPB sample. The difference between the wet and dry weights of the samples was measured as water absorption (WA) or the amount of water absorbed, as expressed in Equation 2. The percentage increase in the weight of the dry sample can be computed to nearest percentage, according to Clause 40, Water Absorption Test in Malaysian Standards (MS76: 1972).

$$WA, \% = \frac{M2-M1}{M1} \times 100 \quad (2)$$

The compression test was conducted on each HDPE:RAP blend to obtain the optimum blends to produce a SIPB. The test was performed on four different HDPE and RAP blending proportions of 1:3, 1:4, 1:5 and 1:6. This test was conducted in accordance with the MS 1933: Part 1: 2007 Compression Test Standard. All samples were tested with Semi-Auto Compression Machine with a maximum capacity of 3000kN as shown in Figure 3. The load was applied to the smooth surface of the sample steadily and uniformly at a speed rate of 1.5 mm until the sample failed. The compressive strength was determined by dividing the failure load with the sample loading area (100 x 100 mm). About 24 samples were evaluated for a thickness of 60 mm using compression test equipment. The samples were tested under 7 and 14 days of curing time.

Figure 3. Compression Test Machine

RESULTS AND DISCUSSIONS

Density of SIPB

Figure 4 shows the average densities of various SIPB blends (1:3, 1:4, 1:5 and 1:6); each value was the average of three samples. The results showed that the density of SIPB increased from 1.843 g/cm^3 to 1.958 g/cm^3 about 5.88 % increase, with the increasing of RAP content from 3 to 6 in the blends. The 1H3R sample with the highest HDPE content (25% HDPE of total content) showed the lowest density value (1.843g/cm^3). The addition of HDPE could reduce the mass of the sample while maintaining the same sample volume. This could be due to the light weight of the plastic itself with a very low density which is 0.950 g/cm^3 (McKeen, 2016).

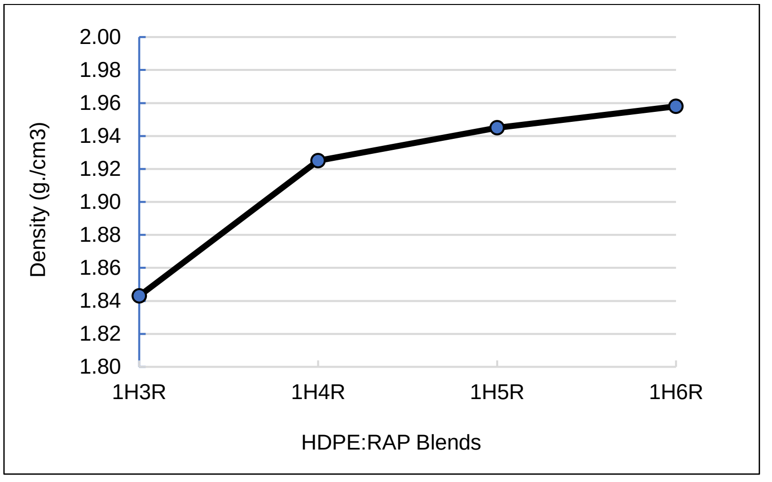

Figure 4. Density of SIPB at Various HDPE:RAP Blends

Water Absorption of SIPB

Water absorption is an important factor in evaluating the durability and resistance of SIPB to brittleness. This is because of the manufacture of interlocking blocks in Malaysia must be resistant to variations in weather factors, particularly in areas that suffer periodic monsoon shifts. The high porosity in the sample will result in high water absorption ability and make it easily cracked and not weather resistant. The water absorption test was performed by immersing the sample in water for 7 and 14 days. Figure 5 shows the percentages of water absorption of different HDPE:RAP blends (1:3, 1:4, 1:5 and 1:6). The results showed that the water absorption values at 7 days were 0.180%, 0.233%, 0.316% and 0.398% for 1H3R, 1H4R, 1H5R and 1H6R, respectively. Meanwhile, the water absorption values at 14 days for 1H3R, 1H4R, 1H5R and 1H6R samples were 0.210%, 0.291%, 0.373% and 0.398%, respectively. In this study, the curing time was set not exceed 14 days as the difference in water absorption of the samples at 7 and 14 days was too small (less than 25%). The RAP absorbed the most water since HDPE absorbed too little water. According to Yasmin et al. (2021), Ismail (2017), and Strong (2006), the water absorption of HDPE is less than 0.002 %.

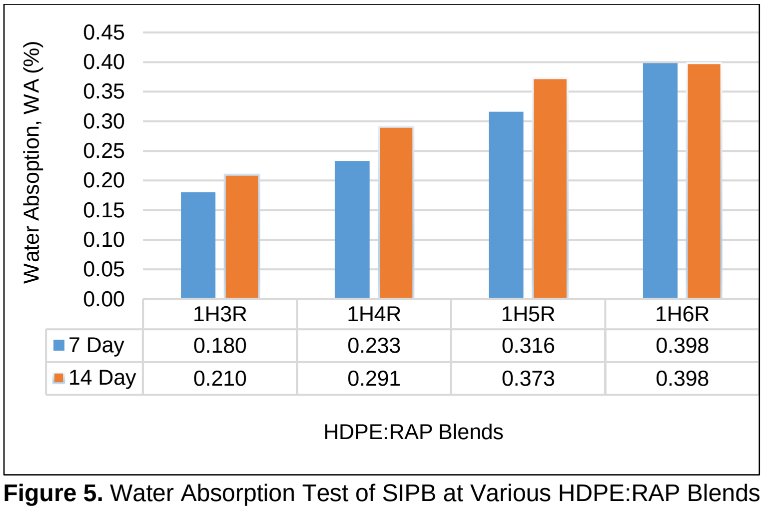

Figure 5. Water Absorption Test of SIPB at Various HDPE:RAP Blends

The findings indicated that 1H3R achieved a minimum water absorption of 0.180 % and 1H6R reached a maximum of 0.398 % water absorption. It is clearly demonstrated that the amount of RAP affected the water absorption of the sample. The absorption of RAP was also reported to be lower than that of RAP aggregates and fresh aggregates (Silviyati, 2020). This is due to the partially aged bitumen layers or complete aggregate surfaces. This old bitumen prevents RAP pores from absorbing water (Silviyati, 2020). However, the water absorption percentage for the entire pavement block sample prepared with a blend of HDPE and RAP was significantly lower than the permissible value of 6.5 % (Namarak et al., 2018). This proved that RAP is suitable for practical application and durability of pavement block and is therefore the desired value for the water absorption test.

Compressive Strength

Compressive strength is one of the important properties to evaluate the performance of SIPB under load. Figure 6 shows the effect of HDPE:RAP blends of SIPB on compressive strength. It showed that the compressive strength values of 1H3R, 1H4R, 1H5R and 1H6R SIPB samples at 7 days of curing time were 7.623 MPa, 5.577 MPa, 3.513 MPa, and 2.027 MPa, respectively. Meanwhile, the compressive strength of 1H3R, 1H4R, 1H5R and 1H6R at 14 days of curing time were 7.650 MPa, 5.653 MPa, 3.563 MPa, and 2.100 MPa, respectively. The findings showed that the compressive strength for 7- and 14-day curing time did not differ significantly. It is due to the use of HDPE in the mixture which makes it easy to harden when exposed to oxygen (Silviyati et al., 2020; Jusoh et al.,2016). Thus, the use of HDPE in SIPB substituting natural aggregates had a significant effect in shortening the curing time compared to conventional IPB (14 - 28 days), as reported by (Gencel et al., 2012; Namarak et al., 2018; Ghuge, Surale, Patil, & Bhutekar, 2019).

Moreover, Figure 6 shows that the lower HDPE content (IH6R SIPB sample) resulted in minimum compressive strength for 7 days (2.027 MPa) and 14 days (2.100MPa) curing times. Maximum compressive strength values of 7.623 MPa and 7.650 MPa were achieved by 1H3R samples for both 7- and 14-days curing times. This indicated that the compressive strength decreased with increasing RAP and decreasing HDPE contents in SIPB fabrication. This was also attributed to lack of HDPE content that did not completely bind RAP. In this case, it was demonstrated that using insufficient amount of HDPE in the mixture resulted in lower compressive strength of the sample.

Nevertheless, the compressive strength achieved did not exceed the specified compressive strength of 30 MPa for a thickness of 60 mm (Bachok, 2020). The fabricated SIPB may not be compacted adequately, resulting in unequal porosity, and the mixture was not sufficiently compressed. According to Namarak et al. (2018), after placing three layers into the mould the mixture should be further compressed using universal testing machine (UTM) at a pressure of 6 or 8 MPa. Therefore, the current SIPB strength can still be used for non-traffic pavement, such as landscaping and gardens as recommended by Kasim and Rohim (2017).

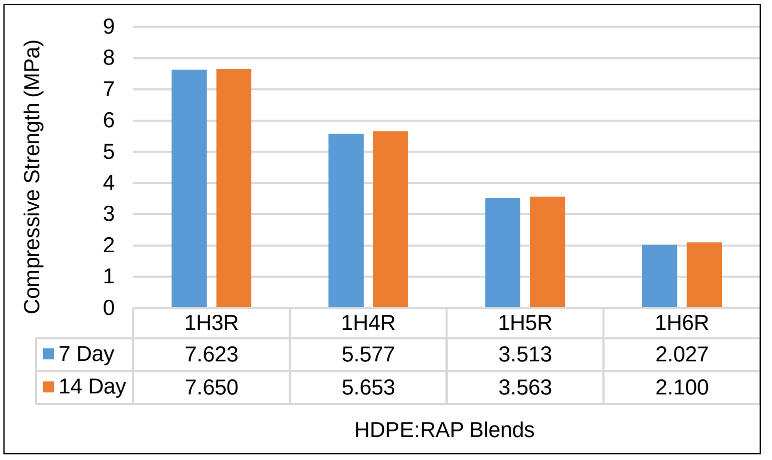

Figure 6. Compressive Strength of SIPB at Various HDPE:RAP Blends

The performance of an alternative IPB fabricated using HDPE and RAP was then compared with the conventional IPB. Table 2 compares the compressive strength and water absorption value obtained in this research and those obtained in other studies. It was shown that the compressive strength of 7.65 MPa is within the range and water absorption value of 0.21% are low when compared to the IPB developed from cement, sand and quarry dust.

Table 2. Comparison of the Usage of The Type of Material, Ratio and Compressive Strength of IPB According to Previous Research

Author	Type of Material	Ratio	Compressive Strength (N/mm^2)	Water Absorption (%)
(Agyeman et al., 2019)	Cement : Sand : Quarry Dust	1 : 1 : 2	5.56	4.6
(Kosnan et al., 2019)	Cement : Sand : Quarry Dust	1 : 3 : 3	28	8.7

CONCLUSION

The purpose of this study was to examine the suitability of HDPE waste and RAP in the development of SIPB to reduce dependence on natural resources and reduce waste burden in our environment. The preliminary study was carried out to evaluate the effect of various HDPE:RAP blends (1:3, 1:4, 1:5 and 1:6) on the density, water absorption, and compressive strength SIPB. The findings showed that the density and water absorption increased as the RAP content increased and HDPE content decreased. The maximum compressive strength of 7.65 MPa was achieved by 1H3R (1:3 HDPE and RAP blend), and it is suitable for landscaping purposes. Nevertheless, their strength can be improved through sufficient sample preparation and fabrication process. Overall, RAP has the potential to replace aggregate contents to produce sustainable, and economical construction products for Malaysian market. The future research will be conducted by utilization of HDPE with other binder materials in order to strengthen the product's properties.

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

(FULL NAME) Ahmad Abd Rahman[1], Maria Diyana Musa[2] and Sumiana Yusoff[2]
[1]Department of Quantity Surveying, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Sarawak, Malaysia
[2]Institute of Ocean and Earth Sciences (IOES), University of Malaya, Malaysia

Abstract (Arial Bold, 9pt)
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Figures: Figures should be in box with line width 0.5pt. All illustrations and photographs must be numbered consecutively as it appears in the text and accompanied with appropriate captions below them.

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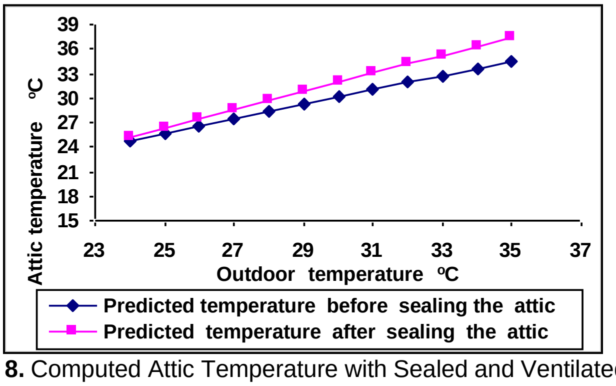

Figure 8. Computed Attic Temperature with Sealed and Ventilated Attic

Tables: Arial, 8pt. Table should be incorporated in the text.

Table caption: Arial Bold + Arial, 9pt. + Capitalize Each Word. Captions should be written above the table.

Table Line: 0.5pt.

Table 1. Recommended/Acceptable Physical Water Quality Criteria

Parameter	Raw Water Quality	Drinking Water Quality
Total coliform (MPN/100ml)	500	0
Turbidity (NTU)	1000	5
Color (Hazen)	300	15
pH	5.5-9.0	6.5-9.0

(Source: Twort et al., 1985; MWA,1994)

Units: All units and abbreviations of dimensions should conform to **SI standards.**

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Five authors	Walker, Allen, Bradley, Ramirez, and Soo (2008)	Walker et al. (2008)	(Walker, Allen, Bradley, Ramirez, & Soo, 2008)	(Walker et al., 2008)
Six or more authors	Wasserstein et al (2005)	Wasserstein et al. (2005)	(Wasserstein et al., 2005)	(Wasserstein et al., 2005)
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