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CONTENTS

PREFACE

This special issue of IJIRM is dedicated to the efforts and hard work of the Department of Civil Engineering and Construction (CECD) at the Infrastructure University Kuala Lumpur (IUKL). The papers in this issue are selected from presentations made in a seminar that involved participants from various Civil Engineering and Construction specialisations such as Structure, Geotechnical, Hydraulic, Water and Wastewater, and Traffic and Geomatic.

The topics in this issue cover various aspects relevant to Malaysia's National Policy for the Fourth Industrial Revolution focusing on issues of sustainability, the Internet of Things (IoT) and emerging technologies. The research findings would hopefully contribute to move forward the construction industry towards digital transformation and smart construction. Another important theme covered in this issue is the advancement of technology for structure design and solutions to the existing problems in the construction industry. Sustainability is a very important consideration both technically and economically. The Construction industry utilises large amounts of raw and natural resources. It is important that research on alternative materials and additives is given its due priority to ensure the success of efforts towards the sustainable use of natural resources.

Finally, we would like to express our sincere thanks to the IJIRM and all those who helped make this special issue possible. It is hoped that the contributions in this issue will help stimulate further research in these and related areas as well as serve as a useful resource for both Civil Engineering professionals and general readers.

Nurazim Ibrahim, PhD
Norul Wahida Kamaruzaman, PhD
Guest Editors,
Infrastructure University Kuala Lumpur (IUKL)
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TARGETED APPROACHES OF ONLINE DISTANCE LEARNING FOR ENGINEERING STUDENTS DURING COVID19

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ABSTRACT

Most educational institutions around the world, notably engineering departments, were obliged to alter their face-to-face teaching processes and convert them to new online learning strategies as a result of the worldwide health emergency caused by the COVID-19 pandemic in early 2020. The objectives of this study are to determine the advantages and disadvantages of online distance learning, to measure the efficiency of output and input information provided by the lecturers and students, and to identify the type of online platform preferred most by both parties. Background research for the study area, data collection, data analysis, result evaluation, conclusion, and recommendations are all part of the scope of work for this study. The methodology section describes the method and procedure for completing this study. Finally, university teachers and engineering department students acknowledged satisfaction with ODL's entire application. Key features include the professors' encouraging endeavours in class delivery as well as the ODL platforms used. Despite the challenges that ODL implementation has presented in the past, lecturers now have the opportunity to try out novel teaching strategies. On the plus side, ODL has proved that learning knows no bounds as the post-COVID-19 new standard.

Keywords:
Online Distance Learning (ODL), Covid19, pandemic, engineering, students

INTRODUCTION

Due to the worldwide health emergency created by the COVID-19 pandemic in early 2020, most educational institutions, especially for engineering departments, throughout the world were compelled to change their teaching techniques which were based on face-to-face teaching and convert them into new online learning tactics.

The Malaysian education system, particularly the Higher Learning Institutions, has made the use of online teaching and learning methods as an alternate teaching method mandatory throughout the country (Selvanathan et al., 2020). In these conditions, each institution developed its own approach, which often included preferred digital tools and platforms for distance learning, such as video call apps, as well as general rules and instructions for lecturers on how to adjust their lesson plans (Garcia-Alberti et al., 2021).

As a result, the purpose of this study is to look into the viewpoints of engineering lecturers and students on online distance learning implementation during COVID-19. By exploring both sides of viewpoints is definitely fascinating for required adjustments in the following semester, but a larger focus should be made on how the adoption of online engineering course learning has influenced their way of teaching and learning in the previous semester. Besides that, a better understanding of the lecturers and students' viewpoints will surely provide useful thoughts on how to enhance online engineering to course learning implementation.

Therefore, some of the questions will be pointed out in this study: (i) what have been the overall reactions from the lecturers and students of engineering to the online distance learning implementation so far?, (ii) what aspects of online distance learning do lecturers and students from the engineering faculty like the most?, and (iii) which online platform both side preferred most?

LITERATURE REVIEW

Many studies have been performed to examine the influence of the Covid-19 pandemic scenario on the education sector in many parts of the world, including the engineering education sector. Despite the fact that all of these studies span a wide range of online distance learning during the Covid-19 epidemic, the focus of this literature review will be on three major topics that have been discussed consistently throughout the research study. The three major topics consist of the following: lecturers and students feedback on online courses, challenges/obstacles affecting online courses and roles of the online platform.

One of the studies was conducted by Dietrich et al. (2020), which stated that instructors had a significant issue as a result of the COVID-19 outbreak, since they needed to convert all of their classes to distance learning as quickly as possible in order to maintain educational continuity and quality. Even if some instructors and students were prepared for the situation, the great majority of teachers and students were forced to change their teaching and learning in a very short amount of time, with no training. Teachers' techniques for online learning in lecture, group project, and lab work have multiplied as a result of the fast change.

Other than that, Rahiem (2020) also has conducted a study to explore and interpret the lived experience of university students in emergency remote learning (ERL) during Covid-19 pandemic. The research used a qualitative phenomenological method with 80 students as participants. A thorough examination of the students' diaries and reflective writings, as well as an online focus group, were used to gain an understanding of their experience. The results will aid to assure the efficacy of on-going ERL and better incorporate similar programs in the future if this happens again by evaluating how university students learnt during COVID-19. As discussed in this study (Rahiem, 2020), lecturers created and conducted remote learning programs without any prior preparation or training. Students, likewise, were not given the time to prepare for this shift in learning.

A study conducted by Lassoued et al. (2020), which aims to reveal the obstacles for achieving quality in online distance learning during the Covid-19 pandemic. According to the findings, lecturers and students encountered self-imposed as well as educational, technological, budgetary, and organizational barriers (Lassoued et al., 2020). Lassoued et al. (2020), as discussed in this study, said that lecturers and students encountered four categories of obstacles during online distance learning: personal, pedagogical, technical, financial and organizational. Furthermore, many technical issues confront e-learning users, such as time and location flexibility, student and learner differences, e-learning not feeling comfortable, increasing irritation and misunderstanding, and poor technology compatibility, all of which obstruct the teaching and learning system.

Elfirdoussi et al. (2020) has conducted a study to investigate the limitations of e-learning platforms and how these activities occur during remote learning in higher education 3 programs. A total of 3037 students and 231 lecturers took part in a research survey for this study. As shown in the study, the responses are arranged starting with the lecturer's responses, followed by the student's responses. According to Elfirdoussi et al. (2020), the bulk of lecturers (94%) provide materials for students and the rest (54%) deliver courses through video conferences. In addition to that, the study also stated, these platforms are used by 49.7% of respondents to supervise projects while 43.7% of lecturers use quizzes and assignments to assess their pupils remotely. Furthermore, 41.2% of participants established a distant training program and 14.6% ensured distance project defense.

In conclusion, the goal of this literature review was to look at the effectiveness of distant online courses from the perspectives of lecturers and students, as well as the obstacles that both parties encounter during online courses and the function of the online platform that was utilized for the online courses. The study examined shows that there were both good and negative aspects that impact both lecturers and students during online courses sessions.

METHODOLOGY

The research approach chosen for this study was both qualitative and quantitative method involving a questionnaire. Rather than identifying cause and effect, qualitative research gives a narrative knowledge of an event or phenomena, while quantitative research places a greater emphasis on the capacity to do statistical analysis. The participants' age, program, current semester, location during online studying, and internet quality were among the questions asked in section 1.

Other than that, the lecturers' and students' surveys were created with the general verbal input from stakeholders throughout the online training in mind. Both lecturers and students were asked to respond to sixteen multiple-choice and two free-response items in the survey. The poll included a range of questions for multiple-choice and one free response, including lecturers' and students' online learning experiences during the Covid-19 epidemic in section 2. This was required since the advantage and negative will be decided by the response during the online session.

Aside from that, in section 3, several of the questions from the multiple-choice and one free-response will revolve on the time or period during which both participants found online learning pleasurable throughout the online session. This sort of inquiry is also important to the study in order to assess how successfully lecturers and students interact, as well as to establish a stress-free environment during online sessions.

Finally, in section 4, the survey will only include several multiple-choice questions on the sort of platform that was utilized during the online learning course. This can assist in identifying the sort of online platform that has been utilized for online sessions on a regular basis, resulting in the most favored platform for online sessions. In order to define the number of respondents needed to complete the survey, a simple formula was employed to calculate the number of lecturers and students in the population.

Multiply the numbers of responders you want by 100, and then divide by the estimated response rate. As for this study, the total numbers of respondents expected were 60, including both lecturers and students, while the estimated response rate is 50%. The outcome of this easy computation is 60 people who will participate in the survey.

As a result, this survey will require the participation of 60 people. For methods of verifying the results, activities such as assuring methodological coherence, sample sufficiency, creating a dynamic link between sampling, data collecting, and analysis, thinking theoretically, and theory creation are examples of verification techniques that assure data dependability and validity (Morse et al. 2002).

The sample must be suitable, refer to 4 individuals who best represent or have expertise of the study issue, while methodological coherence ensures congruence between the research question and the components of the technique. The convenience sampling method was utilized to choose instructors and students of engineering departments from five universities in Peninsular Malaysia for the online survey. Due to the Covid-19, the Movement Control Order (MCO) was still in effect at the time of data collection, Google Form was chosen as the best instrument.

A final result was reached by examining the efficacy of online distance learning from the viewpoints of lecturers and students from engineering departments, as well as challenges that both parties experience during online courses and the function of the online platform that was employed for the online courses. As a result, the approach presented in this chapter was considered sufficient to address the study's research questions.

RESULTS AND DISCUSSION

A total of 60 participants from engineering departments from five universities in Peninsular Malaysia - Infrastructure University Kuala Lumpur (IUKL) in Selangor, Universiti Malaya (UM) in Kuala Lumpur, Universiti Teknologi Malaysia (UTM) in Johor Bahru, Universiti Sains Malaysia (USM) in Penang, and Universiti Teknologi PETRONAS (UTP) in Perak - took part in this survey. The response rate was satisfactory, thanks to the ease of use provided by the technology utilized in the data collection procedure. The qualitative data on the lecturers' and students' opinions included general feedback, what they liked best about ODL, and ODL implementation ideas. There are a total of 4 sections with 16 questions, of which 2 questions are open-response, while the rest of the questions are multiple-choice.

Section 1: Participants General Information

According to the results gathered, the respondents consist of the age range between 20 to 50 years old, with the majority of 61.7% to be in range of age 20 to 25 years old, while age 36 to 40 years old are the lowest with 1.7% as seen in Figure 1.

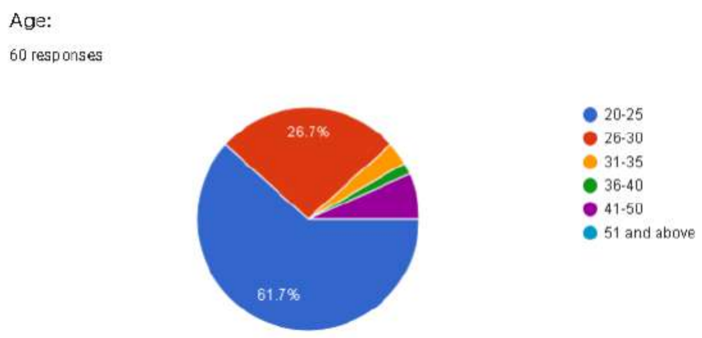

Figure 1: Age of the Responses

According to Figure 2, most respondents are from Bachelor of Civil Engineering (BCE) programmed with 16.7%, while others are from other programmes within engineering departments with 1.7%.

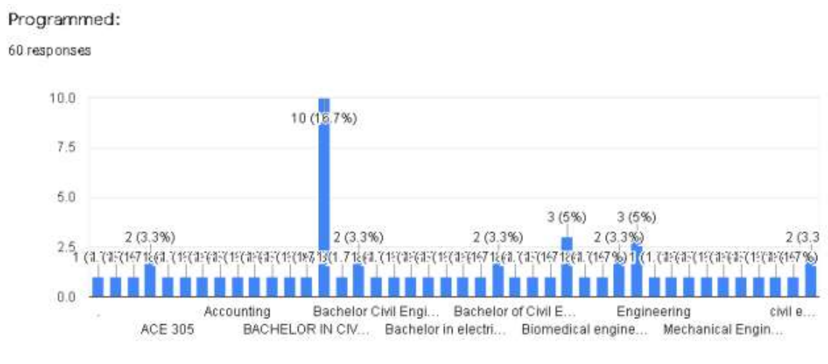

Figure 2: Respondent Programmes

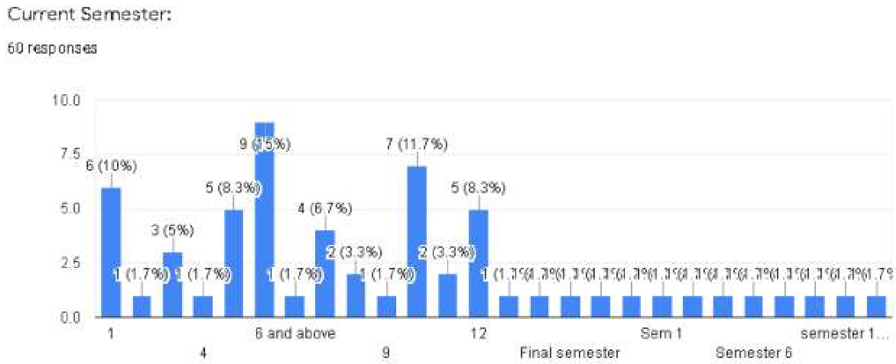

Figure 3: Respondent Current Semester

For Figure 3, the data show the respondents' current semester which the highest falls to semester 6 with 15%, while the lowest goes to final semester, 1st semester, etc. As shown in Figure 4, most respondents located in West Malaysia (Peninsular) with 40%, while the minority located East of Malaysia with 1.7%. Majority of the respondents have a good quality during the ODL with 83.3%, while the other 16.7% of respondents have a bad internet connection as shown in Figure 5.

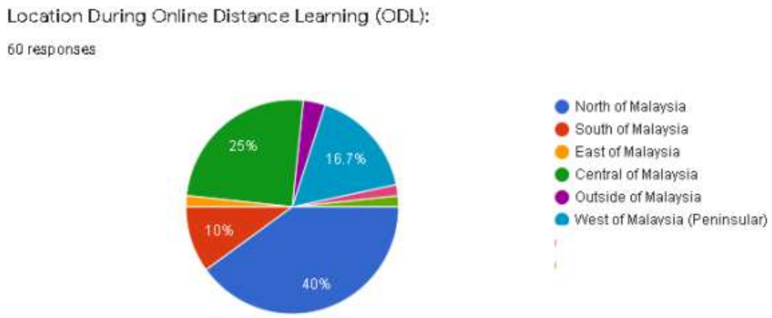

Figure 4: Location of respondents during ODL

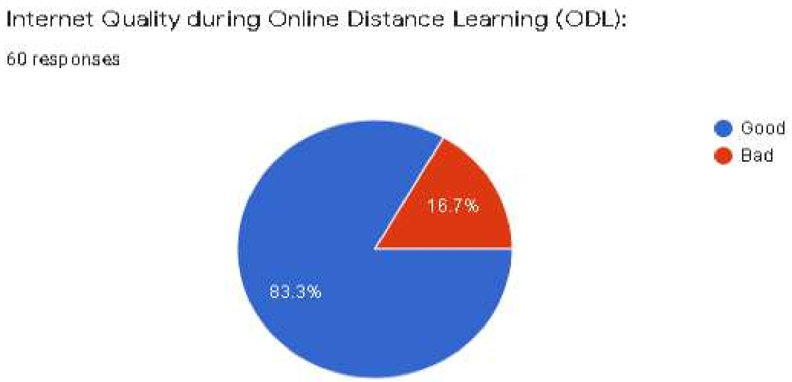

Figure 5: Respondents internet quality during ODL

Section 2: Experiences during Online Distance Learning (ODL)

In this section, the survey asked a series of multiple-choice questions and one free-response question about lecturers' and students' online learning experiences during the Covid-19 epidemic. According to Figure 6, about 55% of the respondents agreed on 'the ability to attend class from any location' as enjoyable, while 33.3% of the respondents agreed on 'easier to understand due to the helps of recording video during online classes and the lowest with only 11.7% of respondents agreed on 'the ability to adjust the class time due to time constraints'.

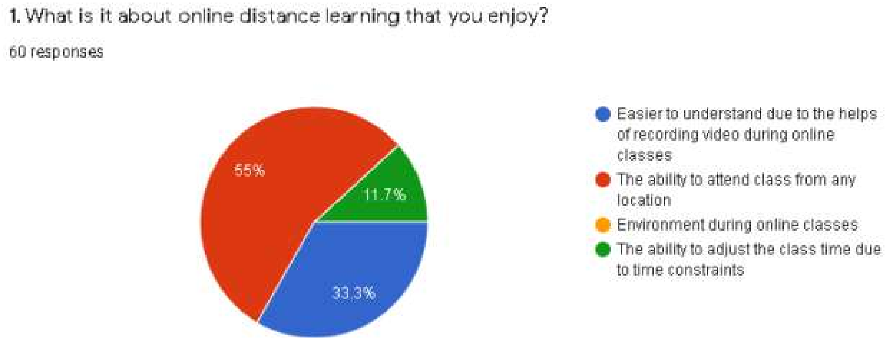

Figure 6: What About the ODL the Respondents Enjoyed

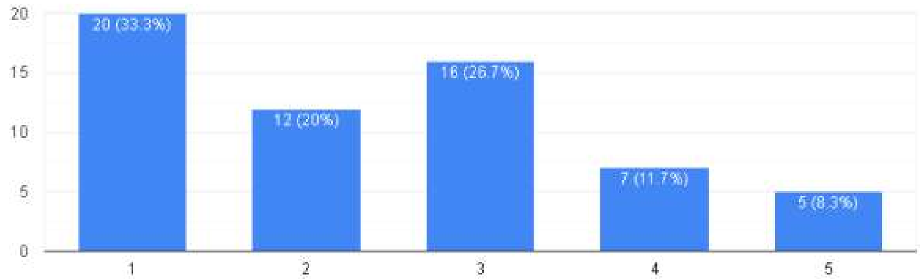

Figure 7: Difficulty in Using Distance Learning Technology by the Scale of 1-5

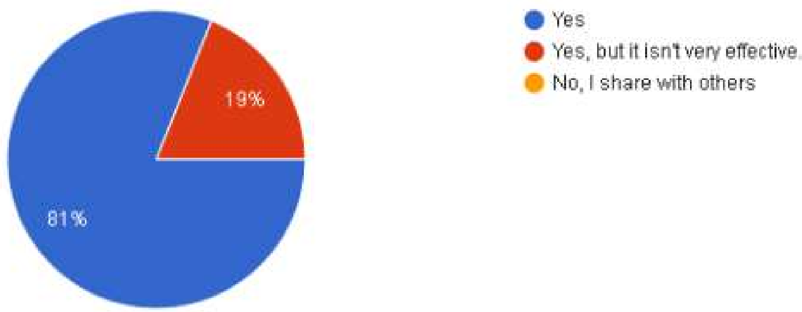

Figure 8: Access to Gadget

Figure 7 shows a question about the difficulty of using distance learning technology such as a computer, laptop, or other device, with a scale ranging from 1 (very simple) to 5 (challenging). According to the data gathered, the majority of the respondents find that it is very simple to use the gadget needed for ODL with 33.3%, while the minority with 8.3% of the respondents find it is challenging.

As shown in Figure 8, most respondents have access to gadgets that allow them to learn online with 81% of the respondents, while 19% of the respondents have access but it isn't very effective. As seen in Figure 9, the majority of 79.3% of respondents use laptop during their ODL, while 5.2% of respondents are using smartphone and tab during their ODL.

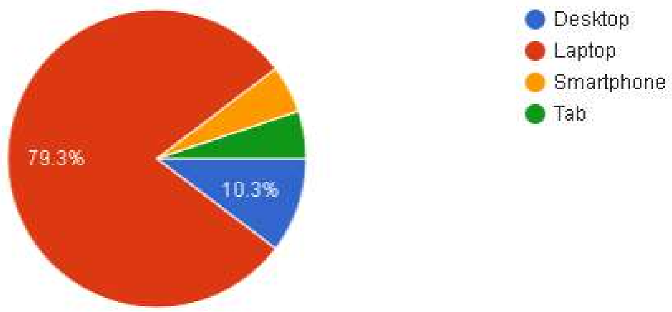

Figure 9: Type of Gadget

Figure 10 displays the data on how supportive the university is in providing resources needed for ODL and the majority with 62.1% of respondents agreed on 'moderately helpful'. While the lowest with 1.7% of the respondents agreed on 'not helpful at all'. 9

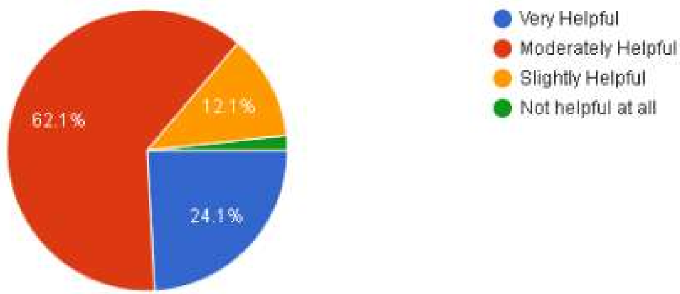

Figure 10: Support from the University in Providing Resources

For the last question in section 2, it is an open-response which asks about how enthusiastic they be during ODL. Majority of the respondents find ODL "very interesting" and "allow access to the information and knowledge anywhere" as the respondents stated. While there are also negative respond regarding ODL, such as stated by one of the respondents, "not really enjoying the ODL" and "lack of concentration, understanding, and other factors, "I was unable to properly grasp the scope of what was being done" as stated by one of the respondents.

Section 3: Interaction between Lecturers and Students during ODL

In section 3, there are a total of 5 multiple-choice questions in which the respondents are able to select more than 1 answer. As shown in Figure 11, majority of the respondents agreed on presentation as the most engaging activities during ODL (60%), while the lowest activities that the respondents find engaging during ODL is projects (28.3%).

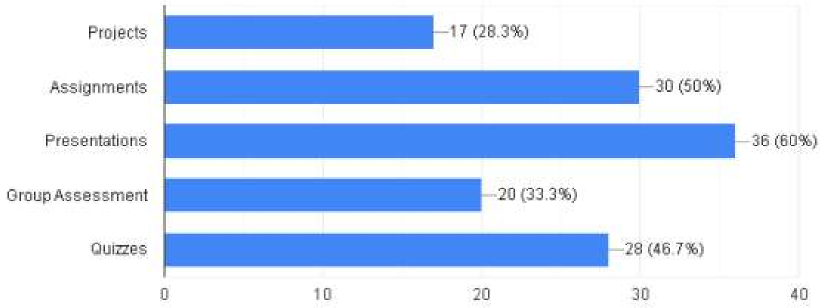

Figure 11: Engaging Activities during ODL

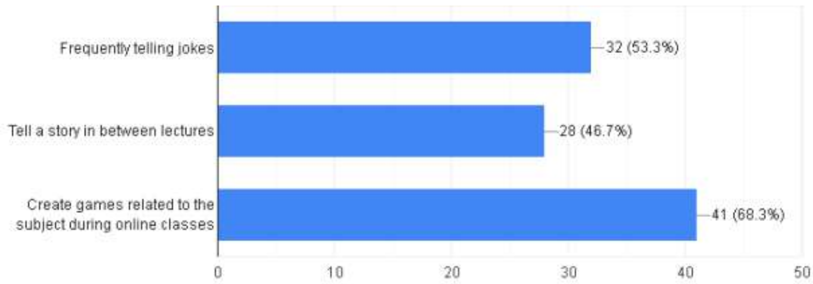

Figure 12: Thing That Make ODL More Enjoyable

Figure 12 displays data for the things that make ODL more enjoyable according to the respondents, which the majority (68.3%) of respondents would like to do is 'create games related to the subject during ODL', while 'tell a story in between lectures' is the lowest (46.7%).

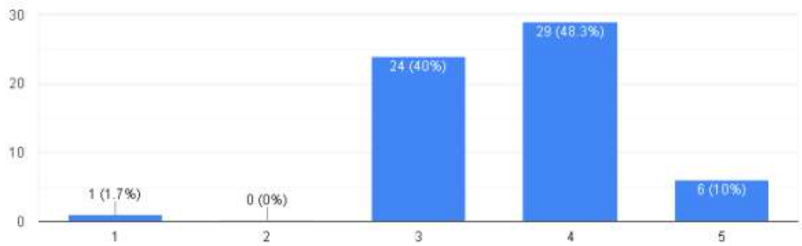

Figure 13: ODL Rating on the Scale of 1-5

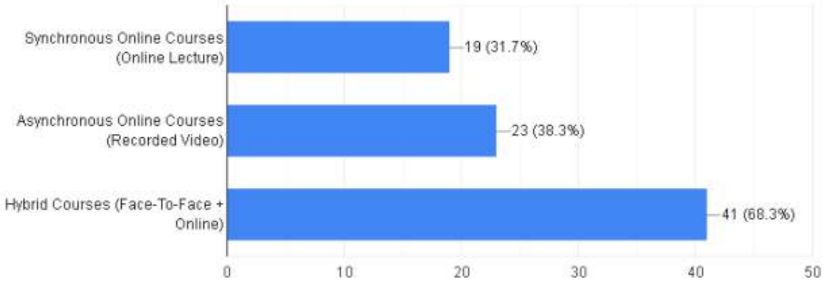

Figure 14: Preferred Learning Environment

From Figure 13, the respondents were asked to rate their ODL during Covid-19 pandemic, from 1(very dissatisfied) to 5(very satisfied). As shown, most respondents were satisfied with their ODL (48.3%), while 1 respondent found it very dissatisfied with their ODL (1.7%). As seen in Figure 14, the majority of the respondents (68.3%) agreed on hybrid courses as their learning environment preferred which combine both face-to-face and online learning at the same period of time. As for asynchronous online courses, about 38.3% of respondents preferred as it is a recorded video provided by the lecturers and lastly the synchronous online courses which have the least preferred (31.7%) by the respondents.

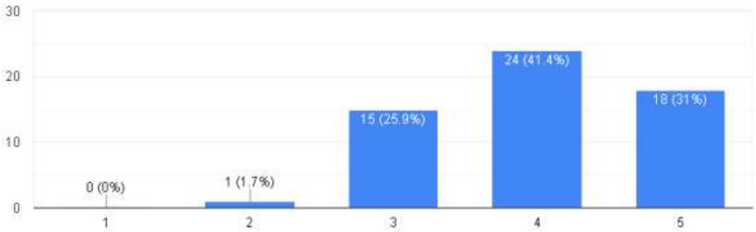

Figure 15: Time and Effort Rate at the Scale of 1-5 by Respondents

Figure 15 displays the data gathered as the respondents rate their effort during ODL, which range from 1 (less effort) to 5 (a lot of effort). About 41.4% of the respondents put effort during their ODL, while 31% of the respondents put a lot of effort during their ODL.

Section 4: Favourable Online Platform

The survey will only have 5 multiple-choice questions in this part about the type of platform that was used throughout the online learning course. This can help determine the type of online platform that has been used on a regular basis for online sessions, culminating in the most preferred platform for online sessions.

As shown in Figure 16, about 58.3% of the respondents preferred Google Meet, while 51.7% of the respondents agreed on Microsoft Team and lastly, around 35% of the respondents agreed on Zoom as their preferred online platform during ODL.

As seen in Figure 17, the results reflect the respondents' reasons for preferring their earlier response. The majority of respondents (76.7 %) believe their preferred online platform is easier to use than the other two online platforms, with 50% citing the high quality of video and audio while using the online platform as a reason, and around 45% citing the platform taking less time to open.

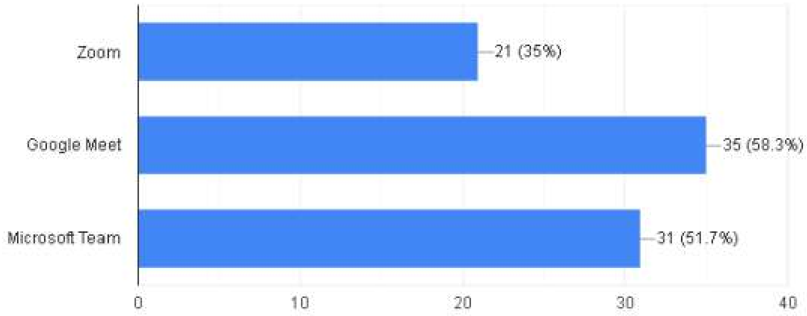

Figure 16: Preferred Online Platform

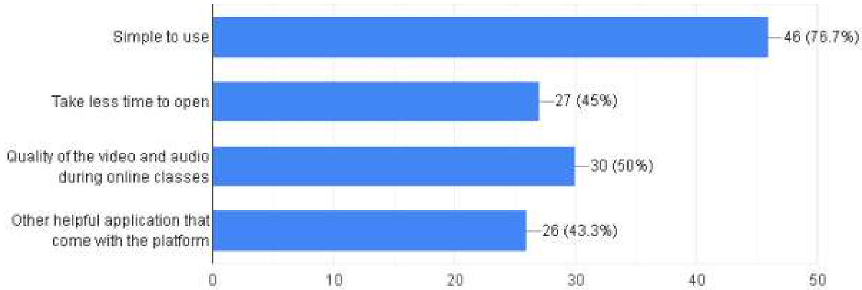

Figure 17: Reasoning on the Preferred Online Platform

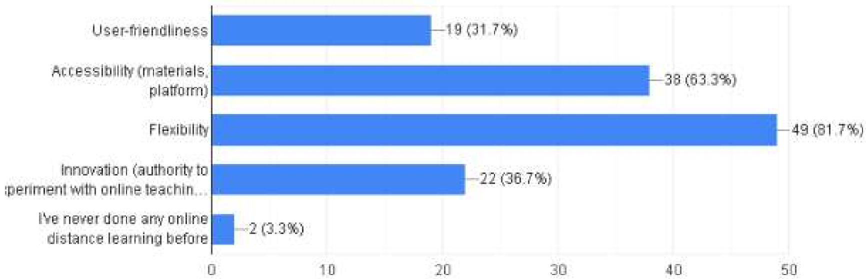

Figure 18: Experience by the Teachers on ODL

Figure 18 shows that the majority of respondents (81.7%) agree on the flexibility since it makes ODL more enjoyable. When it comes to topic material accessibility, roughly 63.3 % of the respondents are satisfied. 14 Figure 19: Challenging task Figure 19 shows that the majority of respondents (73.3%) consider communication between lecturers and students to be the most difficult responsibility during ODL, along with sustaining all students' interest and engagement.

While the least favourable group (6.7%) felt that there are 'no problems have arisen' during their ODL. As shown in Figure 20 below, the data represents the respondents' opinion on ODL being part of practice in university once the universities reopen. Majority of the respondents (61.7%) agreed on 'university will revert to its previous state, with minor modifications', while 33.3% of the respondents agreed on 'university will be different with online learning as part of the university routines' and lastly, the less (23.3%) of respondents agreed on 'university will convert back to its original practice', which 100% face-to-face learning.

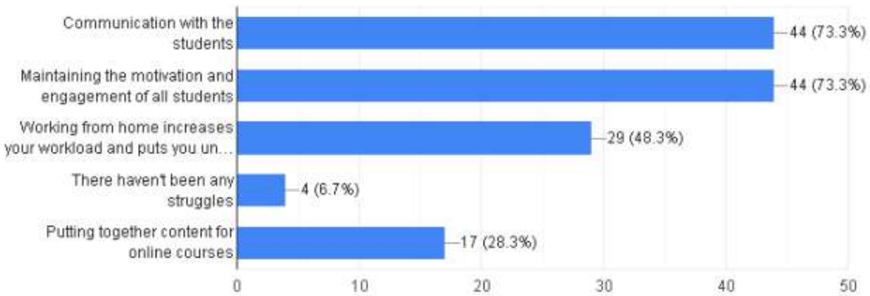

Figure 19: Hurdles for the Teachers during ODL

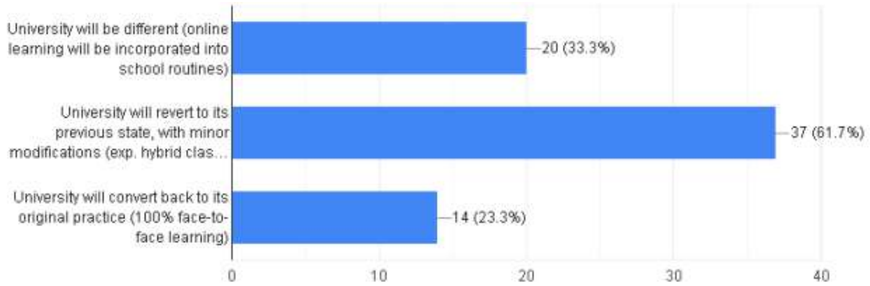

Figure 20: Effects of ODL in Universities after Covid-19

CONCLUSION

In conclusion, university lecturers and students from the engineering department expressed satisfaction with the overall application of ODL. The lecturers' encouraging initiatives in their class delivery, as well as the ODL platforms utilized, are the key elements. The hybrid techniques are the most popular and favoured platforms, in which some of them can attend courses while the rest can join the class via an online platform, where they can record the class and replay the teachings at any time. Due to bad internet connection concerns, some students suggested that ODL not be continued in the following semester.

Despite the difficulties that have been encountered in the past with ODL implementation, lecturers now have the possibility to experiment with new teaching methods. On the plus side, ODL, as the post-COVID-19 new standard, has demonstrated that learning has no bounds. Instead of conducting lessons within the four walls as is customary, the deployment of ODL will elevate teaching and learning to a whole new level, allowing both lecturers and students to express themselves creatively.

There are several recommendations suggested, in order to have an even more quality ODL, such as:

1. Establish guidelines: Online instruction differs from face-to-face instruction. Lecturers can address the norms that encourage good learning with students as they transition to this mode of learning. This might include issues like suitable attire, when to mute/un-mute, when to use chat, when to raise your hand to contribute, how to use backgrounds, how to cheer, and what to do while classes are recorded.

2. Develop good relationships with students: Lecturers understand the value of building meaningful relationships with and among students. This is just as crucial, if not more so, when teaching online. Consider adding tools and tactics that promote communication between you and your pupils.
3. Don't rebuild the wheel: One of the best things about online learning is that there are already a variety of high-quality resources at your fingertips. Lecturers are not curriculum writers; those who are have already completed this task. Find out what resources are available, while having more time to focus on the important aspects of teaching, such as assisting students in learning, developing connections, building relationships, and ensuring that their social emotional needs are addressed.

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CORRELATION ANALYSIS ON THE EFFECT OF CHEMICAL COMPOSITION OF LIMESTONE AGGREGATE UPON MECHANICAL STRENGTH OF CONCRETE

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ABSTRACT

Limestone is a sedimentary rock that is no stranger in construction work due to its chemical composition, calcium carbonate, which has a cement-like characteristic when it is mixed with water, thus resulting in a binding agent to hold concrete together. It is a very popular choice to make cement but not as an aggregate. The main problem encountered is that there is not enough information on the appropriate amount of calcium carbonate within concrete. The purpose of this research paper is to study the effect of the chemical composition of limestone aggregate towards the mechanical strength of concrete. The objective is to study the relationship between the percentage of limestone aggregate and the mechanical strength of concrete. The extraction of data from past research papers about limestone aggregate percentage as its mechanical strength were tabulated where the parameters were analysed using the Pearson correlation analysis to study the strength of the relationship between the two parameters. The result shows the relationship between the two parameters is strong as when there was an increase in the percentage of limestone aggregate, the mechanical strength tended to also increase. The result obtained shows the relationship between parameters is strong which indicated that limestone is suitable to be used as concrete aggregate.

Keywords:
Calcium Carbonate, Limestone Aggregate, Compressive Strength, Flexural Strength.

INTRODUCTION

Concrete is a composite material consisting of cement, water and aggregate. Generally, the bond between aggregate with the binding agent is the result of the hydration process. It involves the chemical reaction between water and cement which produce calcium silicate hydroxide gel (C-S-H gel). The strength of concrete is contributed by the arrangement of fine and coarse aggregate inside the concrete matric. The arrangement contributes to the density and indirectly has a significant impact on the concrete strength and durability. Thus, it is important to determine the physical and chemical properties of aggregate to achieve the targeted strength of concrete. Various aggregates are available in the market supplied to construction projects all over the country, especially in tropical regions. The availability of limestone is very wide in Malaysia. Limestone can be easily found both in Peninsular Malaysia and on the island of Borneo, also known as East Malaysia, as highlighted by Tan Boon Kong (2010). The relationship between the physical and chemical properties of aggregate with the concrete strength and performance would signify the aggregate choice during the concrete mix design stage.

The focus of this paper is to analyse the correlation between the content of calcium carbonate inside the limestone aggregate towards the compressive and flexural strength of concrete. As for the physical properties, the roughness of the limestone aggregate surface is higher as compared to the gravel which will help the bonding effect between all constituents inside the concrete matric. In terms of chemical properties, the content of calcium carbonate is considered the major chemical composition inside the limestone aggregate. The high content of calcium carbonate can be found inside the limestone aggregate. However, for gravel, there is no significant content of calcium carbonate inside the particles. The effect of this chemical composition is significantly important in order to conduct concrete mix design. So far, there is no publication on the correlation between calcium carbonate and concrete properties available.

Limestone is composed of calcium carbonate minerals calcite and dolomite (King, 2016). From the chemistry point of view, calcite is chemically a calcium carbonate ($CaCO_3$). By studying calcium carbonate at the macro and micro levels, the effect of limestone towards the mechanical strength of concrete can be seen. The coarse aggregate influences the mechanical strength of concrete through water absorption, the constitution of limestone aggregate and particle size. The mechanical strength of concrete is affected by several critical factors such as the concrete mix design, the chemical reaction inside the concrete matric and the aggregate properties. Holcim (2015) highlighted that a concrete mix design that uses too much water will reduce the mechanical strength of concrete. The chemical composition of each ingredient affects the chemical reaction when all ingredients are being mixed.

Based on previous research, the incorporation of wet coarse limestone aggregate can produce higher compressive strength compared to dry coarse limestone aggregate (Alhozaimy, 2009). On the other hand, fine aggregate will be broken down during exposition to the heat from the hydration process to create calcium hydroxide. Calcium hydroxide later will start to crystalize along with calcium silicate hydrate which was produced during the hydration process. Outcomes will birth a thick mass of crystals interconnected to each other and all the other substances present (Ernest, 2016). Limestone is composed of calcium, bearing carbonate minerals calcite and dolomite (King, 2016). From the chemistry point of view, calcite is chemically a calcium carbonate ($CaCO_3$). On the other side, dolomite chemically is a calcium magnesium carbonate. For this study, the limestone that will be used is commercial grade limestone which means the limestone consists of 80 percent calcite and dolomite, with less than 20 percent other rock materials (Missouri Department of Natural Resources, 2020).

METHODOLOGY

A lot of research has been conducted on the mechanical strength of concrete with limestone as the aggregate. To find the strength of the relationship between two parameters, a set of data was extracted from the research paper on the percentages, which are limestone aggregate, compressive strength of concrete and flexural strength of concrete. The set of data was then tabulated in a table for the purpose of calculation of correlation analysis. The method of analysis that was used to study the degree of relationship between the parameters is the Pearson Correlation formula.

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

After the value had been obtained from all three parameters, a formation of graph was made to show the degree of magnitude between the relationships of the two parameters**.** The formation of graph was done using Microsoft Excel with additional value of r^2 shown on the graph. Tables 1-2 show the details of the parameters.

Table 1: Parameter percentage of limestone aggregate and compressive strength

No	Author	Year	Title	Percentage of Limestone Aggregate (%)	Compressive Strength (Mpa)
1	H. Beshr , A.A. Almusallam , M. Maslehuddin	2002	Effect of Limestone Fillers the Physic-Mechanical Properties of Limestone Concrete	5	27.8
2	Md. Umar Khan, S.Sridhar	2015	Technology of Flexural Strength, Workability, Compressive Strength and Split Tensile Strength Assessment of Limestone Aggregate Concrete	20	29
3	Md Zeeshan, Prof. Rohan S Gurav, Prof. Brij Bhushan S, Prof. Maneeth P D	2015	Experimental Investigation on Partial Replacement of Natural Fine Aggregate by Steel Slag and Natural Coarse Aggregate by Waste Limestone Aggregate in Cement Concrete	25	31.186
4	S. Kitouni, H. Houari	2013	Lightweight Concrete with Algerian Limestone Dust. Part I: Study on 30% Replacement to Normal Aggregate at Early Age	30	34.99
5	A.Jayaraman , V.Senthilkumar , M.Saravanan	2014	Compressive and Tensile Strength of Concrete Using Lateritic Sand and Limestone Filler as Fine Aggregate	40	36.12
6	Dr.Muyasser M. Jomaa'h	2012	Using of Local Limestone as Aggregate in Concrete Mixture	47	36.33
7	Omar M. Omar, Ghada D. Abd Elhameed, Mohamed A. Sherif , Hassan A. Mohamadien	2012	Influence of limestone waste as partial replacement material for sand and marble powder in concrete properties	50	41.9
8	Naum Sapozhnikov	2007	Concrete with Enriched Quarry Limestone Waste as a Coarse Aggregate	52	42.2
9	Manikanta. D, Sanjith. J and Ranjith. A	2016	Effect of Limestone Aggregate on High Strength Concrete in Both Fresh and Hardened	75	54.81
10	A. M. Kilic, O. Kilic and M. O. Keskin	2010	The Effect of The Rock Type Forming the Aggregate in Lightweight Polymer Concrete on Compressive and Flexural Tensile Strength	100	74.1

Table 2: Parameter percentage of limestone aggregate and flexural strength

No	Author	Year	Title	Percentage of Limestone Aggregate (%)	Flexural Strength (Mpa)
1	Awodiji ChiomaTemitope Gloria, Onwuka Davis Ogbonnaya, Awodiji Olayinka Olujide	2007	Flexural and Split Tensile Strength Properties of Lime Cement Concrete	3	4.16
2	Pathan Maaz Khan L , Farhan A. Vahora	2015	Influence of Limestone and Fly Ash (Class F) as Partial Replacement Materials on the Mechanical Properties of Concrete	12	4.3
3	Md. Umar Khan, S.Sridhar	2015	Technology of Flexural Strength, Workability, Compressive Strength and Split Tensile Strength Assessment of Limestone Aggregate Concrete	20	4.7
4	Khalid M. Shaheen, Ehab E. Aziz	2012	A Sustainable Method for Consuming Waste Concrete and Limestone	25	6.1
5	S. Kitouni, H. Houari	2013	Lightweight concrete with Algerian limestone dust. Part I: Study on 30% replacement to normal aggregate at early age	30	6.39
6	Tahir Kibriya, Leena Tahir	2017	Sustainable Construction—High Performance Concrete Containing Limestone Dust as Filler	55	6.4
7	Jayant Damodar Supe & Dr. M.K.Gupta	2014	Flexural Strength – A Measure to Control Quality of Rigid Concrete Pavements	58	6.587
8	Rozalija Kozul, David Darwin	1997	Effects of Aggregate Type, Size, and Content on Concrete Strength and Fracture Energy	69	8.8
9	A. Kılıc, C.D. Atis, A. Teymen, O. Karahan, F. O¨ zcan, C. Bilim, M. O¨ zdemir	2007	The Influence of Aggregate Type on the Strength and Abrasion Resistance of High Strength Concrete	74	12.8
10	A. M. Kilic, O. Kilic and M. O. Keskin	2010	The Effect of The Rock Type Forming the Aggregate in Lightweight Polymer Concrete on Compressive and Flexural Tensile Strength	100	13.2

RESULT AND DISCUSSION

The analysis of the data was used to determine the relationship between the percentages of limestone aggregate in concrete with compressive and flexural strength and lastly, the relationship between two mechanical strength sets as can be seen in Tables 3 to 6.

Table 3: Calculations based on data percentage of limestone aggregate and compressive strength

No	x	y	$(x - \underline{x})$	$(y - \underline{y})$	$(x - \underline{x}) \text{ x } (y - \underline{y})$	$(x - \underline{x})^2$	$(y - \underline{y})^2$
1	5	27.8	-39.4000	-13.0436	513.9178	1,552.3600	170.1355
2	20	29	-24.4000	-11.8436	288.9838	595.3600	140.2709
3	25	31.186	-19.4000	-9.6576	187.3574	376.3600	93.2692
4	30	34.99	-14.4000	-5.8536	84.2918	207.3600	34.2646
5	40	36.12	-4.4000	-4.7236	20.7838	19.3600	22.3124
6	47	36.33	2.6000	-4.5136	-11.7354	6.7600	20.3726
7	50	41.9	5.6000	1.0564	5.9158	31.3600	1.1160
8	52	42.2	7.6000	1.3564	10.3086	57.7600	1.8398
9	75	54.81	30.6000	13.9664	427.3718	936.3600	195.0603
10	100	74.1	55.6000	33.2564	1,849.0558	3,091.3600	1,105.9881
	$\underline{x}$ = 44.4000	$\underline{y}$ = 40.8436			$\sum$ = 3,376.2516	$\sum$ = 6,874.4000	$\sum$ = 1,784.6295

$$r = \frac{3376.2516}{\sqrt{(6874.4000 \ x \ 1784.6295}} = 0.9639$$

$$r^2 = 0.9639^2 = 0.9292$$

Table 4: Calculations based on data set percentage of limestone aggregate and compressive strength:

No	x	y	$(x - \underline{x})$	$(y - \underline{y})$	$(x - \underline{x}) \text{ x } (y - \underline{y})$	$(x - \underline{x})^2$	$(y - \underline{y})^2$
1	3	4.16	-41.6000	-3.1837	132.4419	1,730.5600	10.1359
2	12	4.3	-32.6000	-3.0437	99.2246	1,062.7600	9.2641
3	20	4.7	-24.6000	-2.6437	65.0350	605.1600	6.9891
4	25	6.1	-19.6000	-1.2437	24.3765	384.1600	1.5468
5	30	6.39	-14.6000	-0.9537	13.9240	213.1600	0.9095
6	55	6.4	10.4000	-0.9437	-9.8145	108.1600	0.8906
7	58	6.587	13.4000	-0.7567	-10.1398	179.5600	0.5726
8	69	8.8	24.4000	1.4563	35.5337	595.3600	2.1208
9	74	12.8	29.4000	5.4563	160.4152	864.3600	29.7712
10	100	13.2	55.4000	5.8563	324.4390	3,069.1600	34.2962
	$\underline{x}$ = 44.6000	$\underline{y}$ = 7.3437			$\sum$ = 835.4358	$\sum$ = 8,812.4000	$\sum$ = 96.4970

$$r = \frac{835.4358}{\sqrt{(8812.4000 \ x \ 96.4970)}} = 0.9060$$

$$r^2 = 0.9060^2 = 0.8208$$

Table 5: Calculations based on data set percentage of limestone aggregate and compressive strength

No	x	y	$(x - \underline{x})$	$(y - \underline{y})$	$(x - \underline{x})$ x $(y - \underline{y})$	$(x - \underline{x})^2$	$(y - \underline{y})^2$
1	3	4.16	-41.6000	-3.1837	132.4419	1,730.5600	10.1359
2	12	4.3	-32.6000	-3.0437	99.2246	1,062.7600	9.2641
3	20	4.7	-24.6000	-2.6437	65.0350	605.1600	6.9891
4	25	6.1	-19.6000	-1.2437	24.3765	384.1600	1.5468
5	30	6.39	-14.6000	-0.9537	13.9240	213.1600	0.9095
6	55	6.4	10.4000	-0.9437	-9.8145	108.1600	0.8906
7	58	6.587	13.4000	-0.7567	-10.1398	179.5600	0.5726
8	69	8.8	24.4000	1.4563	35.5337	595.3600	2.1208
9	74	12.8	29.4000	5.4563	160.4152	864.3600	29.7712
10	100	13.2	55.4000	5.8563	324.4390	3,069.1600	34.2962
	$\underline{x}$ = 44.6000	$\underline{y}$ = 7.3437			$\sum$ = 835.4358	$\sum$ = 8,812.4000	$\sum$ = 96.4970

$$r = \frac{835.4358}{\sqrt{(8812.4000 \; x \; 96.4970)}} = 0.9060$$

$$r^2 = 0.9060^2 = 0.8208$$

Table 6: Calculations based on data set percentage of limestone aggregate and compressive strength

No	x	y	$(x - \underline{x})$	$(y - \underline{y})$	$(x - \underline{x})$ x $(y - \underline{y})$	$(x - \underline{x})^2$	$(y - \underline{y})^2$
1	27.8	4.16	-13.0436	-3.1837	41.5269	170.1355	10.1359
2	29	4.3	-11.8436	-3.0437	36.0484	140.2709	9.2641
3	31.186	4.7	-9.6576	-2.6437	25.5318	93.2692	6.9891
4	34.99	6.1	-5.8536	-1.2437	7.2801	34.2646	1.5468
5	36.12	6.39	-4.7236	-0.9537	4.5049	22.3124	0.9095
6	36.33	6.4	-4.5136	-0.9437	4.2595	20.3726	0.8906
7	41.9	6.587	1.0564	-0.7567	-0.7994	1.1160	0.5726
8	42.2	8.8	1.3564	1.4563	1.9753	1.8398	2.1208
9	54.81	12.8	13.9664	5.4563	76.2049	195.0603	29.7712
10	74.1	13.2	33.2564	5.8563	194.7595	1,105.9881	34.2962
	$\underline{x}$ = 40.8436	$\underline{y}$ = 7.3437			$\sum$ = 391.2918	$\sum$ = 1,784.6295	$\sum$ = 96.4970

$$r = \frac{391.2918}{\sqrt{(1784.6295 \; x \; 96.4970)}} = 0.9429$$

$$r^2 = 0.9429^2 = 0.8891$$

After the value has been obtained from all three parameters, a formation of graph was made to show the degree of magnitude between the relationships of the parameters as can be seen in Figures 1 - 3.

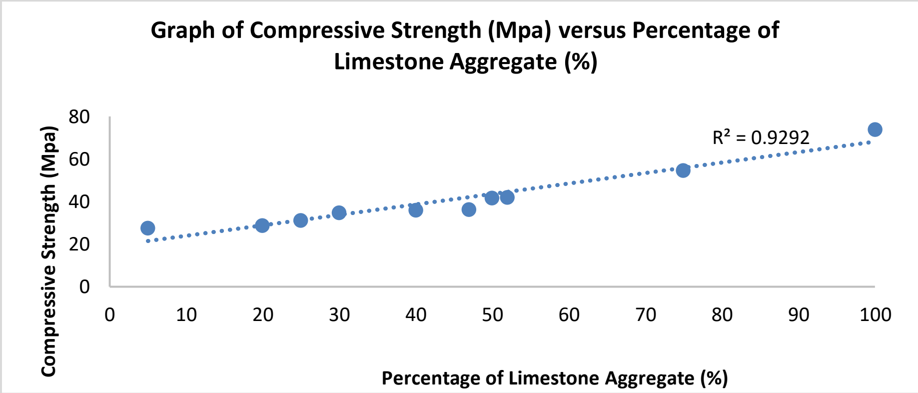

Figure 1: Graph of Compressive Strength versus Percentage of Limestone

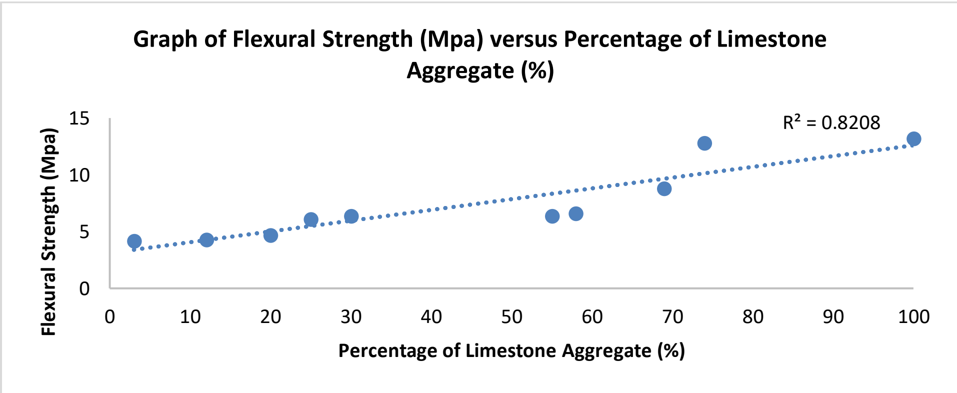

Figure 2: Graph of Flexural Strength versus Percentage of Limestone

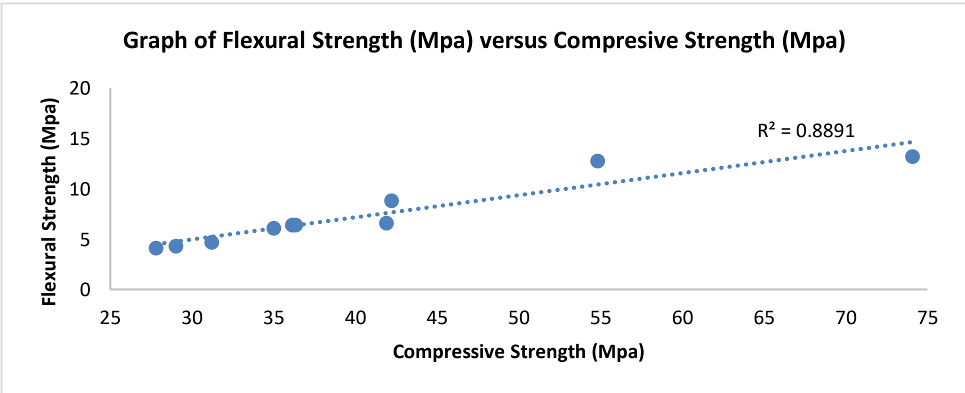

Figure 3: Fraph of Flexural Strength versus Compressive Strength

DISCUSSION

Firstly, the relationship between the percentage of limestone aggregate and compressive strength has been found to have a very strong relationship with the correlation value 0.9292. This is due to the arrangement of material within concrete which gives it a quality of adhesiveness which makes it very strong in compressive strength (Ashish, 2021). Second, the relationship between the percentage of limestone aggregate and flexural strength has been found to also have a strong relationship but not as strong as the first objective with the value only reaching up to 0.8208. This is due to the weakness of the concrete which is very weak in tensile strength (Ashish, 2021). Things could be different if the research is done on reinforced concrete which has reinforcements to help with tensile strength (Bag of Concrete, February 2021). Lastly is the relationship between the two mechanical strengths which is compressive and flexural value at 0.8891. Because the two have a strong relationship with the percentage of limestone aggregate, supposedly the two mechanical strengths have a strong relationship with each other. The graph is formed and the r^2 value falls under a very strong relationship. From each of the tables, it is shown that the value is almost up to 1.0. The increase in the variable will lead to the other variable to also increase (Statistics Solutions, 2022) which is one of the characteristics of the very strong relationship between the parameters.

CONCLUSION

To sum up, everything that has been stated so far in this research paper, it can be concluded that all three objectives have successfully been achieved. It is expected that increasing the percentage of the limestone aggregate will lead to an increase in concrete mechanical strength and the Pearson correlation analysis method has confirmed it. It is recommended to classify the research to only coarse or fine aggregate instead of aggregate as whole to understand the effect of the different sizes of aggregate from the same chemical composition. Research can be done by extracting from past studies which had used the same size of concrete grade to get better correlation values and even on the same concrete mixture for every data of research paper. The research could be done on reinforced concrete in order to get a better reading for flexural strength and other strengths associated with the tensile force.

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APPLICATION OF BUILDING INFORMATION MODELING (BIM) FOR STRUCTURAL ENGINEERING

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ABSTRACT
In the field of civil engineering, i.e. structural engineering, have increasingly used the Building Information Modeling (BIM) approach in both professional practice and as the focus of research. However, the field of structural engineering, which can be seen as a sub-discipline of civil engineering, misses a real state-of-the-art on the use of BIM in this regard. The aim of this research is to review the experiences of early adopters of BIM which give an impact to structural engineering, its barrier and strategy to the construction industry in improving its performance. The quantitative method has been used. Questionnaires on five levels of Likert-Scale as a research instrument were used and floated to employees in Klang Valley, Kuala Lumpur and Seremban. Investigation was done through a survey where 80 questionnaire forms were distributed and 33 completed forms received back were analyzed with Relative Importance Index (RII) method. Results of study revealed the significant usage is that BIM's tools can provide a very effective and clear structural design process to ensure proper structural workflow. The significant barrier of implementation of BIM is social and habitual resistance to change. Training the construction staff and subsiding the price on BIM software are the effective strategies in enhancing the implementation of BIM

Keywords:
BIM, Structural Engineering, Barrier, Strategies, Construction Project, Application

INTRODUCTION

Building Information Modeling (BIM) in general, is the key to emerged technologies in the construction industry (Zezhou Wu et al., 2019). In general, BIM refers to the process and practice of virtual design and construction. BIM is being implemented in the current practices of construction projects, but the understanding of BIM varies among construction players is not well. According to Kerosuo et al. (2015) and Latiffi et al. (2017), this is due to the different capability levels of construction players in adopting and mastering the concept. Over the past decade, the BIM approach has increasingly been used in both professional practice and research relating to the fields of civil and structural engineering (Ciotta et al., 2021). It is more than just software, there are many more functions than basic software, primarily 3D building design that visualises all data of the building and organizes accordingly before the building is even constructed (Memon, 2014). Memon, et al. gives a list of five (5) main features of BIM such as visualization, coordination, simulation, optimization and plotting.

Building Information Modeling (BIM) is a technology that can change the entire design process, therefore the design phase and the related engineers involved will benefit from it (Habte et al.,2021). Despite the advanced technology that has been brought up by BIM, this paper aims to learn the impact and barrier that will be acquired throughout the implementation of BIM in a project and to overcome the matter

LITERATURE REVIEW

BIM-based workflows, innovative tools, combination platforms, and update information can be used throughout the entire life cycle of a facility and building (Grilo et al., 2010; Ciotta et al., 2021; Matameh et al., 2017; Habte et al., 2021). This has been a catalyst for innovation across the architecture, engineering and construction (AEC) industry (Azhar, 2011; Ciotta et al., 2021). According to Bilal et al., (2016) and Vilutiene et al., (2019), BIM models are 3D geometric encoded, in diverse proprietary formats with the potential to add time (4D) and cost data (5D) when attached to them. According to Vilutiene et al., (2019), most vendors offer BIM software that include the three required capabilities needed for structural engineering, which is geometry, material properties, and loading conditions for an analysis. Therefore, it all can be derived directly from a BIM model, stored, edited, and applied by such BIM software. For example, Autodesk Revit can supplement the physical representation of the objects commonly used by structural engineers (Sack et al., 2018; Vilutiene et al., 2019).

BIM is the effective tool collection that has strengthened the construction industry to design, build and manage (Ahmed, 2018). BIM has distinct advantages for the entire life cycle of the project even after its lifecycle but this advantage cannot be gained by the period due to failure to successfully implement BIM technology to the construction industry (Ahmed, 2018).

Ahmad (2018) define that the most important barrier to BIM application is social and habitual resistance to change, traditional method of contracting, training expenses and the training curve are too expensive, high cost of software purchasing and lack of awareness. Based on the report from Memon et al., (2014) research results, the top four (4) strategies to enhance the implementation of BIM are, provision of trial software, training of construction staff, introduction of BIM in university curriculum and subsidize the price of BIM software. According to Habte et al. (2021), structural engineers and the entire design team can use the common database provided by BIM in improving collaboration and communication between them. Changes can be tracked automatically by structural engineers and vice versa if it is made by other members of the design team (Habte et al; 2021).

METHODOLOGY

In this chapter, the research methodology for the study is described to obtain the relevant data. These data are analysed using Relative Important Index and all the results will be present in table form for easy understanding. In statistical analysis, data collection performs a very important aspect.

Primary data is fresh information gathered specifically for your reasons, straight from individuals who are aware of it. Primary data compilation methods differ on the basis of the study objectives as well as the sort and scope of the information being requested. The questionnaire study was therefore spread among the parties who had respected knowledge about this specific topic. Questionnaire survey was used to collect data because it covers a large number of respondents. The choice to use this method because this method is relatively inexpensive compared to others.

The questionnaires were structured in four (4) sections.

Section A: Demographic of the respondents
This section provides the background information of the respondents with their particular details.

Section B: BIM for structural engineering in construction projects.
This section of the questionnaire is to obtain information about how application BIM can improve in structural engineering. Likert scaling method was used to determine the total score obtained by

requirements at this section. A scale of 1 (Strongly Disagree) to 5 (Strongly Agree) is used to determine the degree of implementation towards the statement.

Section C: Barrier in the application of BIM for structural engineering in construction projects.
This section of the questionnaire is to obtain the information about barriers to implement the BIM system in the construction project A scale of 1 (Strongly Disagree) to 5 (Strongly Agree) are used to determine the respondent reaction

Section D: Strategies to overcome the barrier on BIM for structural engineering implementation in construction projects.
Section D question is about the questionnaire which is related to the strategies to overcome the barrier on BIM (Revit) implementation. A scale of 1 (Highly Ineffective) to 5 (Highly effective) are used to determine the respondent reaction.

The analysis from the result from objectives B, C, D is used in the Relative Importance Index (RII). As specified by Odeh and Battaineh (2002), RII is suitable method to determine the ranking of different factors from different group of respondents.

$$Relative\ Importance\ Index = \frac{\varepsilon w}{AN}$$

W is the weighting given to each factor by the respondents, ranging from 1 to 5. From '1' which is 'not effective / strongly disagree' to '5' which is 'strongly agree / very highly effective'.
A is the highest weight for example 5 in this study)
N is the total number of samples.
The Relative Importance Index (RII) ranged from 0 to 1 and from here the CSFs ranking is defined.

ANALYSIS AND DISCUSSION

This section indicates the characteristics of respondents from the survey. Issues covered include type of organization, role and position, years of working experience and working content. Out of 80 sets of questionnaires distributed, 33 sets of questionnaires were returned which were equivalent to 41.25%. The barrier through the minimum on returns of the questionnaire is mainly due to the limited respondent who is applying BIM in the construction project.

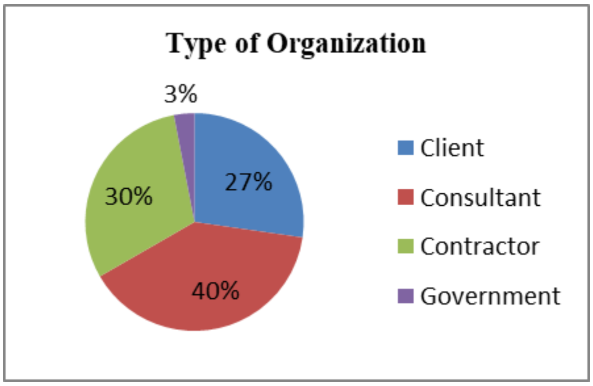

Figure 1 Type of respondent's organization.

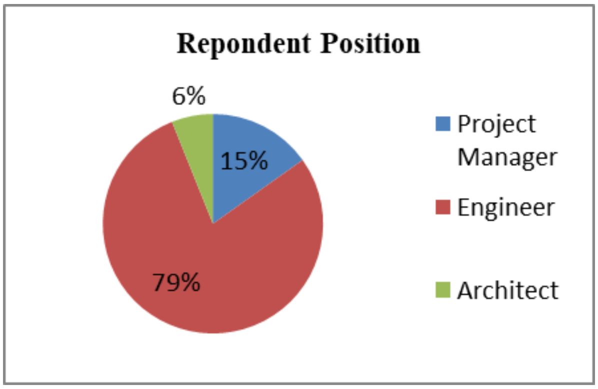

Figure 2: Respondent's position

Figure 1 demonstrates that 27% of respondents were clients, 40% of respondents were consultants, 30% of respondents were contractors and 3% were government servants. Among the responses were received, 15.15% of respondents were project managers, 79% of respondents were engineers and 6% of respondents were architects as presented in Figure 2. There are differences in the total years of working experiences respondents. These results showed that 27% and above of respondents have working experience more than 11-year experience as presented in Figure 3. Others, below18% of respondents have worked less than 10 years.

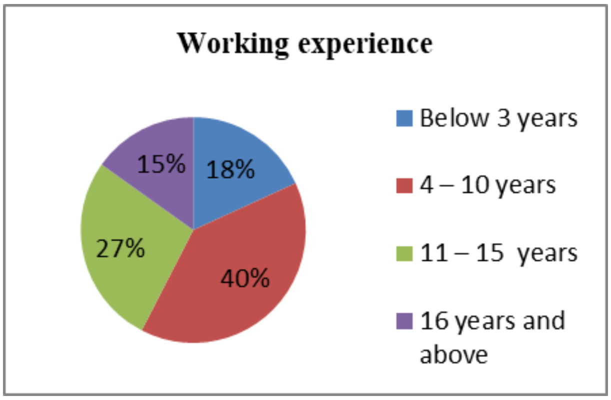

Figure 3: Respondent's working experience

Figure 4 shows that there are 70% of respondents using Revit below one years. 24% of respondents had working experience using Revit around 2 to 4 years. Only 3% of respondents had working experience using Revit for 5 years and above.

According to Table 1, results show most of the respondents agree that "BIM is a very significant element that brings benefits to the construction industry". This statement ranked in number 1 with RII as high as 0.812. Beside this, respondents also agree that "BIM's tools can provide a very effective and clear structural design process to ensure proper structural workflow", this statement is also ranked in number 1 with 0.812 RII as well.

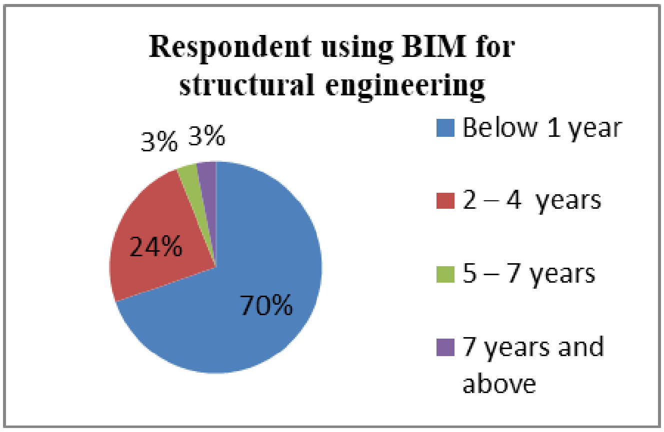

Figure 4: Respondent using Revit

Table 1: Application of BIM for structural engineering

BIM for structural engineering	RII	Rank
BIM can provide a very effective and clear structural design process to ensure proper structural workflow.	0.812	1
BIM is a very significant element that brings benefits to the construction Industry.	0.812	2
BIM can provide a 4D structural information model which includes the accounting of time and enriches all the basic information where it leads to better management of a project.	0.800	3
BIM provides structural analysis which can produce a detailed result required for all parties.	0.752	4
BIM is a structural tool that assists the structural engineer to optimize their structural design, comparing multiple solutions for sustainable design models.	0.745	5

Statement "BIM's can provide 4D structural information model which include the accounting of time and enriches all the basic information where it leads to better management of a project" had RII of 0.800 is 3rd in the ranking followed by BIM's tools provide structural analysis which can produce a detail result require for all parties. With RII of 0.752 and lastly the statement "BIM's structural tools assist the structural engineer to optimize their structural design, comparing multiple solutions for sustainable design models" had the RII of 0.745 and is ranked at number 5.

Table 2: Ranking and RII value on the barrier in the application of BIM for structural engineering

Barrier in the application of BIM for structural engineering	RII	Rank
Social and habitual resistance to change.	0.830	1
Training expenses and training curves are way too expensive if a company wants to implement BIM in a project.	0.806	2
High cost of BIM hardware and tools.	0.800	3
The lack of awareness about BIM.	0.764	4
The involved parties are familiar and adapted with the traditional methods.	0.752	5

In line with the result and findings on the study from Ahmed, (2018) as shows on Table 2, "Social and habitual resistance to change" taking number 1 in the ranking with the RII of 0.830. This indicates that the companies outside refuse to change their working pattern. "Training expenses and training curves are way too expensive if a company wants to implement BIM in a project." taking rank 2 with RII of 0.806 which means most of the respondents agree that the training curves and expenses are way too expensive to use BIM. Statement "High cost for the BIM hardware and tools" ranked at number 3 with RII of 0.800 is ranked at number 4 with RII of 0.764. Lastly with the statement "the involved parties are familiar and adapted with the traditional methods" with RII of 0.752.

Table 3: Strategies to overcome the barrier of a BIM implementation for structural engineering

Strategies to overcome the barrier of a BIM for structural engineering	RII	Rank
Training of construction staff	0.879	1
Subsiding the price of BIM software	0.879	2
Introduction of BIM in university curriculum	0.867	3
Provision of trial software	0.848	4
Mobilizing client on the important of BIM	0.842	5

Findings in Table 3 demonstrates that all of the strategies discussed are quite acceptable by respondents. All the RII value is very close. Strategies "training of construction staff" and "subsiding the price of BIM software" are the most agreed strategies which ranked in number 1 with the highest RII score 0.879. The training of construction staff" is supported by Memon, (2014) study. Besides, introduction of BIM in university curriculum is strategy number 3 with RII value of 0.867. Provision of trial software had an RII value of 0.848 and lastly mobilizing clients on the importance of the BIM is ranked at number.5. All the RII value is 0.8 and above it brings the meaning that these strategies are effective to overcome the barrier of adoption of BIM.

CONCLUSION

This research concluded that the application of BIM for structural engineering did bring advantages to the AEC industry. BIM brings benefits to the construction project about design, management, structural detailing and most significantly in terms of structural workflow. The rate of implementation of BIM in the construction industry is at a slow tempo and this provides a way for the application of Building Information Modeling (BIM) to encourage the faster performance of the construction industry (Ahmed, 2018). In another study by Shin (2017) and Carmo el al, (2022) focused on structural engineering, analysed that related issue inserted in a structural engineering environment aiming to make the best use of BIM collaborations in order to improve work efficiency and efficacy. Mora et al, (2022) state in their study finding that the scientific production proves that the integration of the structural project with the environments of BIM is a reality and both form a symbiotic relationship.

The elements that lead in to this issue are pointed out in this study such as (1) Social and habitual resistance to change, (2) Training expenses and training curves are way too expensive if a company wants to implement BIM in a project, (3) High cost of BIM hardware and tools, (4) Lack of awareness about BIM and (5). The involved parties are familiar and adapted with the traditional methods. So these issues need to be addressed hence if the government wants to see the construction industry to be able to compete globally. The need for continued support from the government will play a good role in increasing the momentum of BIM implementation in the construction sector. On the other hand, the countries are continuously starting to invest in supporting the implementation of BIM in construction projects (Government, 2012; Latiffi et al., 2017).

Construction stakeholders including owners, consultants and contractors should play their very own role by shifting the paradigm from using the traditional method to a more innovative method (Ahmed, 2018) and vice versa. It can be concluded that the construction industry can overcome the barrier to the implementation of BIM through the progressive participation of government agencies and all construction stakeholders (Ahmed, 2018).

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UTILITY DETECTION IN CONCRETE STRUCTURES BY 3D SCANS USING GROUND PENETRATING RADAR

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ABSTRACT
Ground Penetrating Radar (GPR) is a non-invasive geophysical tool to detect utility in concrete structures and below the ground surface. In Malaysia, most contractors are still using traditional ways such as trenching to locate the utility in the structures. The purpose of this study is to determine the applicability of GPR in detecting rebar, utilities, wiring, etc. within the concrete structure. Data acquisition for GPR is carried out by using 1600 MHz antenna to scan 50 cm inside the concrete structure. Results of the 3D scans are enhanced using the RADAN software to interpret accurately the utility in the concrete structure. Based on the results obtained in this study, it can be concluded that GPR is applicable in detecting the utility in concrete structures.

Keywords:
GPR, concrete structure, 3D scan, utility detection, non-invasive.

INTRODUCTION

Ground Penetrating Radar (GPR) is a non-invasive geophysical tool to detect utility underground and in structures. GPR system consists of three basic units which are antenna, control unit, recorder and display unit. The radar generates a brief pulse of electromagnetic energy that is transferred to the object. Radar signal propagation relies on the material's electromagnetic characteristics, primarily dielectric permittivity and electrical conductivity. Differentiation in the dielectric constants (Table 1) and conduciveness of both materials dictate the quality of reflection (Ranjit & Mohamed, 2020; Desai, et al., 2016; Jaw & Hashim, 2013).

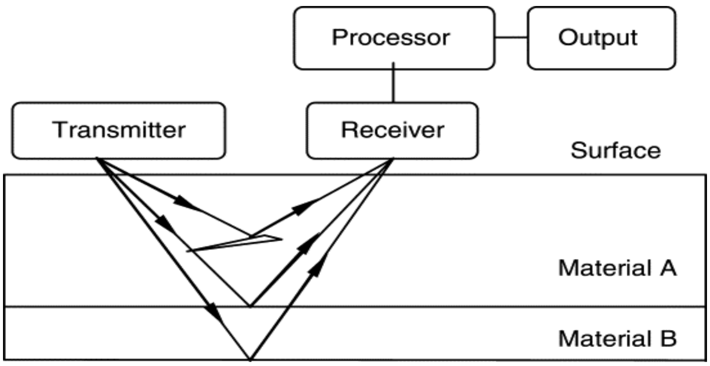

Figure 1: GPR System (Dong & Ansari, 2011)

Table 1: Wave Velocities and Dielectric Constants (Lester & Bernold, 2007)

Medium	Velocity (m/ns)	Dielectric Constant
Air	0.3	1
Water	0.033	81
Rocks	0.15–0.087	4–12
Sand dry	0.15–0.12	3–5
Sand wet	0.055	20–30
Clay dry	0.11–0.09	2–6
Clay wet	0.052	15–40
Concrete	0.10–0.087	9–12

The utility industries still lack exposure to comprehensive guidelines, requirements, procedures and precision of subsurface utility mapping. Cutting into concrete at random without scanning is reckless and potentially dangerous. There is a chance when digging into unscanned concrete that one might encounter an unknown subsurface object or hazard such as pipes, conduits, post tension cables, utilities, live wires, rebar, voids, and more. It can harm and possibly even electrocute workers. Striking subsurface objects can also result in extended delays and injuries. Often, clients will call for GPR scanning after they have already hit an unknown object by accident or surprise. Repairs are needed to fix the damage done by the accident before anything else can be done which further increases delays. GPR provides a clear picture of a proposed cut, core, and trench area, so one might know exactly how it needs to be addressed. This will increase the overall productivity of a project (Barrile & Pucinotti, 2005).

GPR has been successfully used by construction agencies from other countries to locate flaws in a wall (Dérobert, et al., 2008; Lai & Poon, 2012; Orlando & Slob, 2009, Xie, et al., 2013). However, in Malaysia, construction agencies are still using the old traditional ways such as trenching to locate the utility in the structures. This study is to determine the applicability of GPR in detecting rebar, utilities, wiring, etc. within the concrete structure. The objectives of this study are as follows:-

i. To apply GPR to scan inside the structure of a building.
ii. To locate, identify and analyse the subsurface utilities in both vertical and horizontal orientations.

METHODOLOGY

The procedure of application for GPR consists of data collection, downloading of data, processing of data, analysing and identifying the utilities. The flowchart of the methodology of this study is depicted in Figure 2.

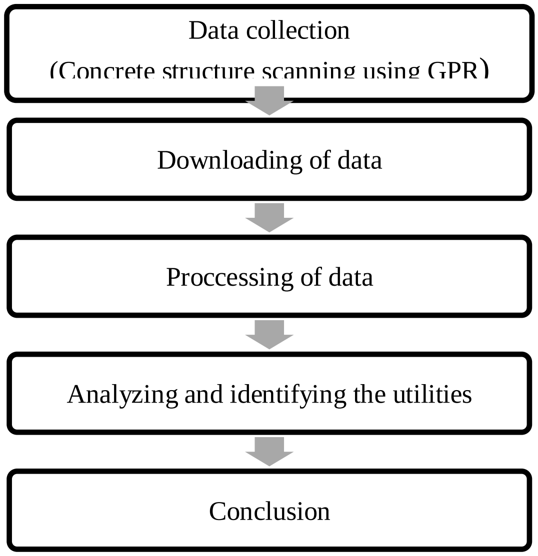

Figure 2: Flow Chart of Methodology

This study uses a battery-operated GSSI handheld GPR unit with 1600 MHz antenna. The maximum penetration depth in concrete structure is 50 cm for the detection of subsurface utilities such as pipes, conduits, cables, wires, rebar, voids, etc.

The 3D scan data is downloaded into a laptop for further processing using the RADAN software. The 3D scan data can then be analyzed to differentiate both metallic and non-metallic utilities such as pipes, cables, rebar, etc. and the depth of utilities.

RESULTS

Six areas have been selected to perform the structural scan using GPR at Block 9, Infrastructure University Kuala Lumpur (refer to Figure 3 to Figure 8). The grid line used in this study has a dimension of 15 cm x 15 cm with a length of 90 cm and a width of 75 cm. The GPR will start the data collection on the x-axis followed by the y-axis. The GPR must be moved slowly in a straight line on the x-axis and y-axis.

Figure 3: GPR Scanning On Area 1 (Wall)

Figure 4: GPR Scanning On Area 2 (Floor)

Figure 5: GPR Scanning On Area 3 (Wall)

Figure 6: GPR Scanning On Area 4 (Column)

Figure 7: GPR Scanning On Area 5 (Column)

Figure 8: GPR Scanning On Area 6 (Column)

The results obtained from the 3D scans are analysed based on the selected Area 1 to Area 6 as below:

i. Area 1 (Wall)

The result of the GPR scan in 3D for Area 1 (wall) is shown in Figure 9. The GPR scan data shows three hyperbolas in the vertical direction. The hyperbolas represent the detected utilities inside the wall which are the rebars. The diameter of the rebars is about 30mm. Further checking reveals that there is a column located behind the wall (Figure 10). The rebars are only detected in the area where the column is located. As can be seen in Figure 9 only vertical rebars are available in the column.

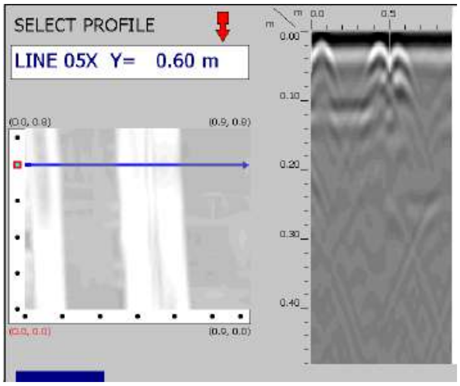

Figure 9: 3D Scan of Area 1

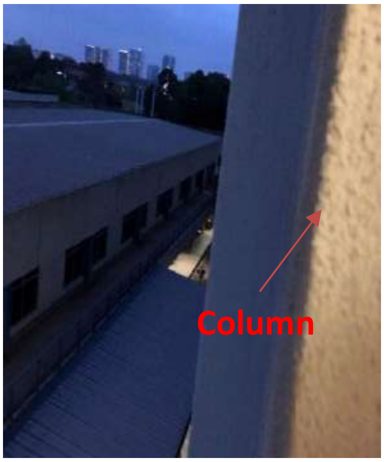

Figure 10: Column Behind the Wall

ii. Area 2 (Floor)

Figure 11 shows the result of GPR scan in 3D for Area 2 (floor). As can be seen from the 3D scan there is no utility detected in Area 2.

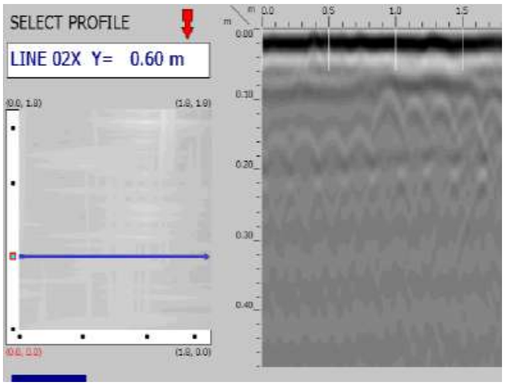

Figure 11: 3D Scan of Area 2

iii. Area 3 (Wall)

Figure 12 shows the result of the GPR scan in 3D for Area 3 (wall). There is no visible hyperbola in the 3D scan therefore there is no utility detected in Area 3.

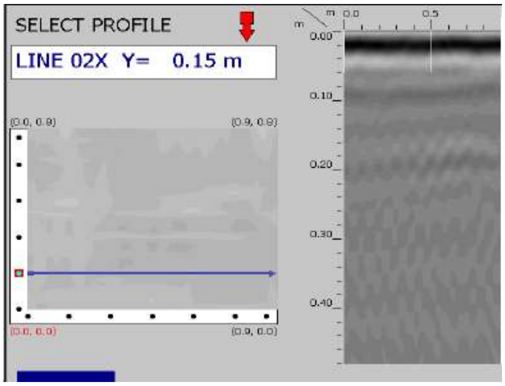

Figure 12: 3D Scan of Area 3

iv. Area 4 (Column)

Figure 13 shows the result of the GPR scan in 3D for Area 4 (column). There is no utility detected in Area 4 as shown in the 3D scan. There is no visible hyperbola in the 3D scan. It can be assumed that this area is near the edge of the column and the rebars in the column should be in the centre of Area 4 which cannot be accessed by the GPR as it is sealed off by a wall.

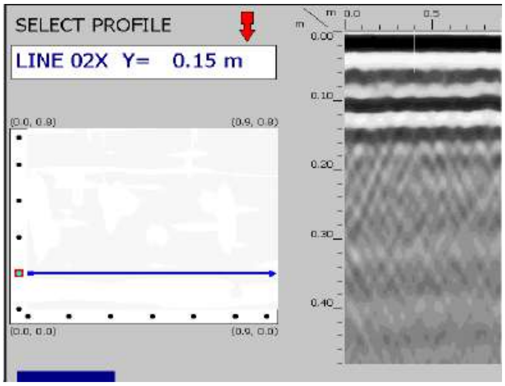

Figure 13: 3D Scan Of Area 4

v. Area 5 (Column)

Figure 14 shows the result of the GPR scan in 3D for Area 5 (column). It can be noticed from the 3D scan that the distance between the vertical rebars is not consistent and the depth of the vertical rebars is not the same. It can be seen that some rebars are placed below the other rebars. Whereas as shown in Figure 15 the distance between the horizontal rebars is consistent and the depth of the horizontal rebars is almost the same. The inconsistent depth of the vertical rebars (Figure 14) may cause failures such as cracking, etc. to the column in the future. It can be presumed that this column is using 30mm rebar size based on the size of the hyperbola in Figure 14.

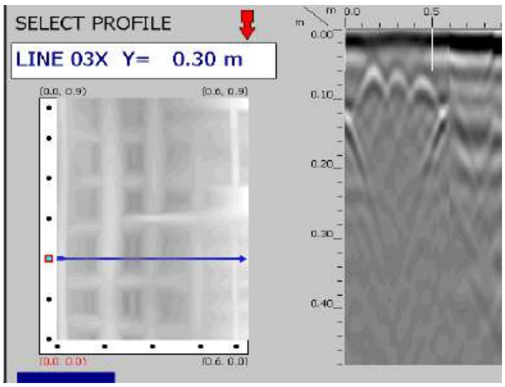

Figure 14: 3D Scan Of Area 5 Showing The Vertical Rebars

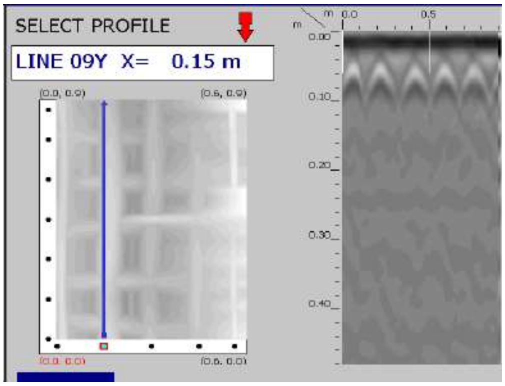

Figure 15: 3D Scan Of Area 5 Showing The Horizontal Rebars

vi. Area 6 (Column)

Figure 16 and Figure 17 show the results of the GPR scan in 3D for Area 6 (column). It can be noticed from the 3D scan that the distance between the vertical rebars is not consistent and the depth of the vertical rebars is not the same. This condition is the same as Area 5 (Figure 14 and Figure 15). It can be presumed that Area 5 and Area 6 have the same structural mechanism since the distance between these two columns is about 20m apart.

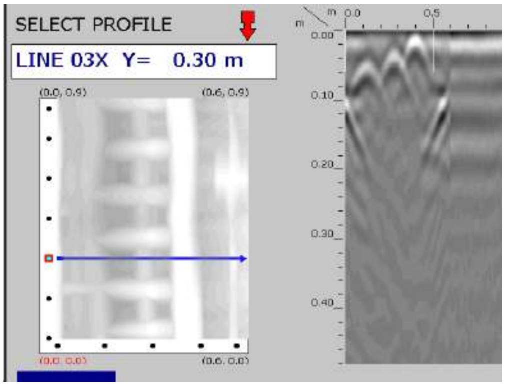

Figure 16: 3D Scan Of Area 6 Showing The Vertical Rebars

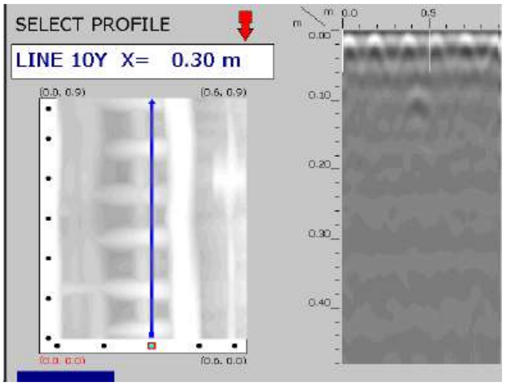

Figure 17: 3D Scan Of Area 6 Showing The Horizontal Rebars

The summary of the GPR scan is depicted in Figure 4.1. It can be summarized that vertical rebars are detected in area 1, no utilities were detected in areas 2, 3 & 4, and vertical & horizontal rebars are detected in areas 5 & 6. The size, depth and distance between the rebars can be obtained from the 3D scan data.

No	Area	Utility
1	Area 1	Vertical Rebars
2	Area 2	No utility
3	Area 3	No utility
4	Area 4	No utility
5	Area 5	Vertical & Horizontal rebars
6	Area 6	Vertical & Horizontal rebars

Table 2: GPR scan Summary

CONCLUSION

Based on the results of the GPR scans in 3D, it can be concluded that GPR is applicable in detecting the utilities in the concrete structure. The distances and the depths of the utilities can also be determined. Any inconsistencies in the location of the utilities can also be determined. The scan data can be used to determine the cause of any failures to a structure and also to avoid any damage to the utilities during the renovation or repairing works. GPR can be a useful tool for the contractors before carrying out any construction works on an existing structure.

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A STUDY ON POLYETHYLENE TEREPHTHALATE (PET) AS PARTIAL REPLACEMENT OF FINE AGGREGATE IN CONCRETE MIXTURE

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ABSTRACT

A major concern in today world is the growth of construction sector which leads the demand of construction material such as cement and aggregate to increase rapidly. As aggregate is non- renewable resource, the continuous of mining and quarrying activities will create more negative effect to the environment and shortage of aggregate in the future. In addition, polyethylene terephthalate (PET) is one of the most widely used plastics in the world, especially in the production of containers for beverages. However, after single use, most PET bottles used as beverage containers are thrown out and activities such as landfill and incineration take place on the management of disposed PET bottles. Therefore, PET as a replacement of aggregate is a mutualism solution that can solve both of the problems. The aim of this research is to determine the effects of polyethylene terephthalate (PET) as partial replacement of fine aggregate in concrete mixture. In all, 15 past studies between 2012 and 2021 were reviewed and discussed based on the findings on workability, density and compressive strength of concrete, and the replacement ratios of vary from 5% up to 60% by volume. It was found that the workability, density and compressive strength on concrete with partial replacement of polyethylene terephthalate (PET) as fine aggregate showed that there was a reduction in term of these three parameters as the replacement of PET as fine aggregate increases. However, two researchers observed that at 5% of replacement level gives a positive effect on the compressive strength of concrete.

Keywords:
Fresh Properties; Mechanical Properties; Recycled Plastic; Polyethylene Terephthalate; Fine Aggregate; Partial Replacement.

INTRODUCTION

Concrete is the most commonly used construction material worldwide which consists of four fundamental ingredients: cement, coarse concrete, fine aggregate and water. Estimated usages of concrete are up to 11 billion metric tons each year (Umasabor & Daniel, 2020). The general ratio of concrete is 1:2:4 which represent cement, fine aggregate and coarse aggregate; hence concrete consists approximately 85% of aggregates. In conjunction with this, aggregate materials are the most extracted natural resources in the world and the multinational construction industry consumed the equivalent of RM1.45 trillion in 2018 alone. Extraction of aggregates has changed the very essence of rivers and other natural ecosystems and may have major adverse social impacts in the area or country. In addition, Polyethylene Terephthalate (PET) is a type of plastic waste which is increasing directly proportional to human waste. According to Waste Atlas (2013), plastic is occupying 9.27 % in average global waste composition.

In Malaysia, the composition of plastic waste is the second highest in the overall generated waste (WWF Malaysia, 2020). Despite that, the plastic waste problem is causing the scarcity of landfill in the coming years. Recycling the PET waste in the form of construction material as a substitute for aggregates in concrete is one of the methods to minimize the effect on the environment and cut the cost of disposal (Adnan & Dawood, 2020). The possibility of replacing aggregates with PET can develop a new market for PET post- consumer and also provide an alternative option of material selection in construction industry. Therefore, the suitability of PET as a substitution of aggregates in concrete has to be studied. This paper will contribute to the community as a whole and towards individual, including us, the researchers. Data produced from this paper will be used to show comparison and to serve as a future reference for researchers on the subject of plastic waste in concrete and how it can improve the environment, industries and mankind.

The objective of this paper is to determine the effects of PET on the workability, density and compressive strength of concrete. Hence, summarization of previous research that has been conducted on using Polyethylene Terephthalate (PET) as a partial substitution of fine aggregate in concrete mixing between 2012 and 2021 were reviewed and discussed in this paper. In all, 15 studies were been studied, and the replacement ratios vary from 5% up to 60% by volume. Besides, this paper also presents the performance of different percentage of PET as fine aggregate replacement in workability, density and compressive strength of concrete based on each researcher's findings as well as the optimum percentage of PET in concrete.

LITERATURE REVIEW

Concrete is essentially a mixture of cement, coarse aggregate, fine aggregate and water. Apart from these basic constituent materials, admixtures are often added to the concrete mix to alter its properties. Fresh concrete, obtained by mixing these materials is workable and can be molded into various forms and shapes. This unique characteristic of concrete gives it the flexibility necessary to construct wide range of structures (Adel et al., 2014). Furthermore, cement undergoes a chemical reaction with water within a few hours of mixing, forming a hardened paste. This reaction is commonly known as the hydration of cement. The characteristics of fresh and hardened concrete are determined by the form and proportion of the constituent materials used in the concrete mix, the handling and positioning of the mix, and the curing of the concrete structure after being cast (Sivakugan et al., 2018).

Polyethylene Terephthalate (PET)

Polyethylene Terephthalate is a thermoplastic polymer for general purposes which belongs to the polymer polyester family. Polyester resins are known for their exceptional combination of mechanical, thermal, chemical resistance and dimensional stability properties. Other properties of PET are shown in Table 1. Islam et al., (2016) stated that in its natural form, PET is a semi- crystalline, highly flexible and colorless resin. It can be semi-rigid or rigid, depending upon how it is processed. It also shows great dimensional stability, impact resistance, chemical and solvent resistance. PET can be processed to fibers, fabrics and food packaging films. PET has been used as a container resin since 1997. Since then, due to its properties and comparatively low cost, the use of PET has continued to expand.

Table 1: Properties of PET material (Askeland & Wright, 2016)

Material	PET
Density (kg/m^3)	1320 – 1340
E (GPa)	2.2 – 2.5
Tensile Strength (MPa)	55
% Elongation	300
Impact Strength (J/m^2)	2

Problem of Plastic Waste

The development of plastic has outpaced that of virtually any other material since the 1950s. Many of the plastic products we make are meant to be thrown out after being used only once. As a result, plastic packaging accounts for nearly half of the globe's plastic waste. Out of 9 billion tons of plastic worldwide, only 9% of the plastic produced has been recycled. Others eventually end in dumps, landfills or in the ecosystem. If current use rates and waste management policies persist, then there will be about 12 billion tons of plastic debris in landfills and the ecosystem by 2050 (Waste Atlas, 2013). Despite that, Recycling and management of plastic waste are amongst the priority activities of environmental protection. A large portion of overall pollution is compensated for by plastic which has contaminated the earth. In natural conditions, plastics takes 400 – 500 years to decompose (Belmokaddem et al., 2020). For recycling, the most commonly used plastic contaminants should be considered, such as PET bottles and PE bags. Besides, there is also a poor recycling rate for plastic waste that greatly adds to environmental pollution. Therefore, in different uses such as acting as aggregate in concrete, plastic waste should be used. (Saikia & Brito, 2012).

METHODOLOGY

Methodology used for this research is review method in which will be carried out to evaluate the performance of PET as fine aggregate replacement in various ratios against controlled concrete. Review method is a collection and summarization of all empirical evidence approach to research in which one or more variables are changed by the researcher and any change in other variables is observed and evaluated.

Data Collection

In this paper, the experimental data were collected from relevant past articles which has been studied by previous researchers. In all, 15 past articles that has been conducted on using Polyethylene Terephthalate (PET) as fine aggregate in concrete mixing between 2012 and 2021 were collected and discussed in this research. Moreover, the collection of experimental data from past articles were in terms of replacement ratio of Polyethylene Terephthalate (PET) as fine aggregate in concrete mixing, workability and density of concrete, and concrete compressive strength.

Data Analysis

All of the data which have been collected from 15 past articles were evaluated in Microsoft Excel. The collected data were combined together and plotted in a line graph based on three types of tests; workability (slump test), density test and compressive strength test which have been conducted by previous researchers. Overall, the plotted line graphs in this paper were the workability against replacement ratio, density against replacement ratio and compressive strength against replacement ratio.

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RESULTS AND DISCUSSION

Workability of Concrete

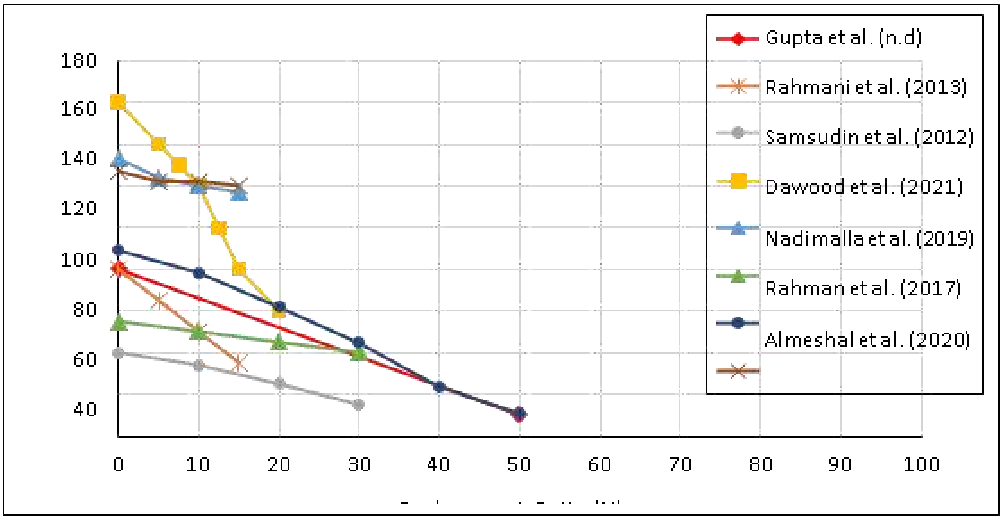

Figure 1: Variation of concrete workability with different replacement ratios of PET as fine aggregate.

Slump test was performed to determine the workability of concrete. From 15 past articles, 8 of them have performed the slump test. In all of the studies as shown in Figure 1, increasing the replacement ratio of PET as fine aggregate leads to a decrease in the slump of fresh concrete. According to Nadimalla et al. (2019) research, they analyzed when replacing 5%, 10% and 15% of fine aggregate with PET particle, the slump of concrete mixtures decreased 6.8%, 9.8% and 12% respectively compared with the slump from the controlled concrete mixture which was similar to Rahman et al. (2017) research. This is because compared to the natural sand, PET particles have a more precise surface area due to their particles shape. Thus, there will be more friction between the particles in the mixtures which leads to less workability.

Dawood et al. (2021) reported that slump values of concrete mixture containing PET as replacement of fine aggregate with 0-20% ratios was occurred in a huge reduction rate when compared with other researchers. At 15% of replacement ratio, the slump reported was reduced by 50% as compared to the slump obtained from controlled concrete mixture. Also, at 20% of replacement ratio, the slump obtained was decreased by 62.5% compared with the slump from the controlled concrete mixture. The authors ascribed this behaviour to the fact the PET particles which have irregular shapes and sizes that were not round as the natural sand. Furthermore, Almeshal et al. (2020) and Gupta et al. (n.d) observed that slump reduced 88% and 87.5% respectively for a concrete mixture containing 50% of PET replaced as fine aggregate when compared with the slump obtained from controlled concrete mixture. Additionally, concrete mixtures with different specific weights of particles may cause segregation problem and poor consistency of mixture, especially light particles such as PET. This problem was raised by authors who discussed the use of PET as fine aggregate in concrete mixing. They also stated that to prevent segregation problem, PET particles should be coated with a hydrophilic chemical type coating. (Almeshal et al., 2020; Gupta et al., n.d). Besides, several researchers advocate the use of superplasticizer to improve the workability for concrete mixture which containing PET particles (Dawood et al., 2021; Saikia & Brito, 2014; Rahmani et al., 2013).

Density of Concrete

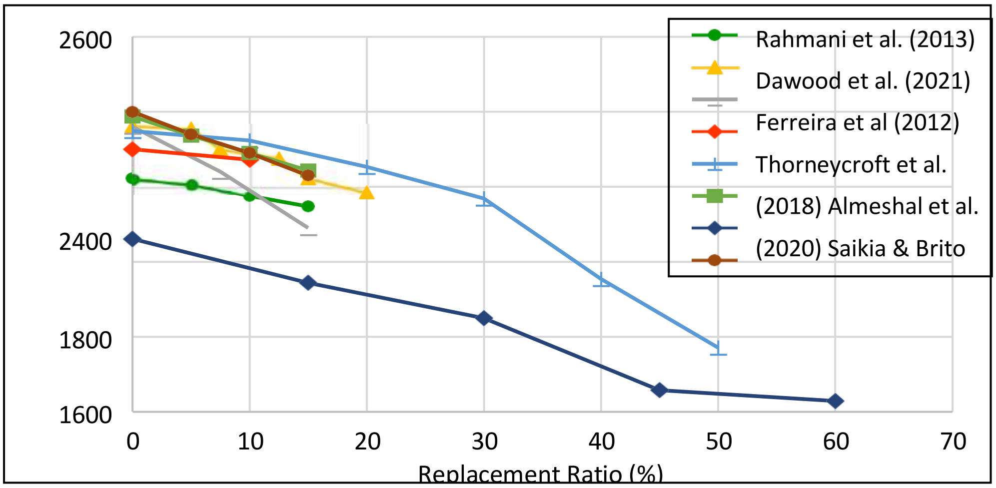

Figure 2: Variation of 28-days concrete density with different replacement ratios of PET as fine aggregate.

The low density of Polyethylene Terephthalate (PET) leads to a reduction in density of concrete. The replacement of PET as a fine aggregate generally decreases the density of concrete regardless of the ratio of the replacement. Figure 2 presents the results obtained from previous studies; 8 out of 15 previous studies have conducted the density test on hardened concrete at 28 days of age. The density of concrete decreases as the replacement ratio of PET as fine aggregate increases. Saikia & Brito (2014) reported the density of concrete with 5% of replacement ratio of PET was 2336 kg/m3 and with 10% of replacement ratio of PET was 2290 kg/m3. Hence, the density of controlled concrete was 2387 kg/m3. It was proved that the 5% and 10% replacement ratios of PET as fine aggregate were affecting the density of concrete to decrease by 2.1% and 4.1% respectively. Similar to Dawood et al. (2021) research, they observed when replacing 10% and 15% of fine aggregate with PET particles, the density of concrete reduced by 3.7% and 5.9% respectively compared to the controlled concrete.

Besides that, Rahmani et al. (2013) observed that the density of concrete not significantly decreased when fine aggregate was replaced with PET particles. At 5%, 10% and 15% of replacement level of PET decreases the density by 0.7%, 2.1% and 3.3% respectively compared to the controlled concrete. Despite the outcomes obtained from the density of concrete containing PET particles as fine aggregate, all of the previous studies stated that the specific gravity of PET particle is more lesser compared to specific gravity of natural fine aggregate. Thus, resulting in the reduction of the weight of produced concrete which concluded that the density of concrete was continuously decreases as the replacement ratio of PET as fine aggregate increases.

Compressive of Concrete

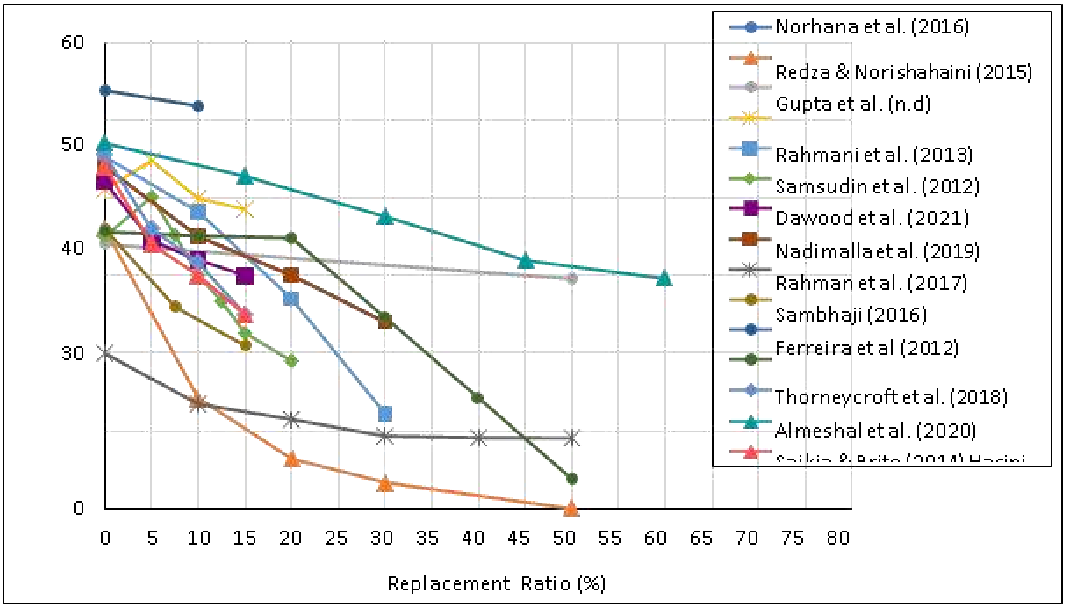

Figure 3: Variation of 28-days concrete compressive strength with different replacement ratios of PET as fine aggregate.

Compressive strength is perhaps the most important of the many parameters that evaluate concrete performance. The quality of concrete is often assessed based on compressive strength. Several parameters such as the Polyethylene Terephthalate (PET) particles shapes and sizes, and water to cement ratio may influence the compressive strength of PET concrete. Figure 3 shows the outcomes collected from all of the 15 previous studies which indicate the effect of PET on the compressive strength of concrete as a fine aggregate at 28 days of age. Also, the figure presents that all studies resulted that the compressive strength of concrete decreases as the replacement ratio of PET increases.

Redza and Norishahaini (2015) observed that the compressive strength of concrete resulting in a major reduction when the replacement ratio of PET as fine aggregate increases. The compressive strength of concrete decreased by 60.4% as compared to the controlled concrete when 10% of fine aggregate replaced with PET. At 20%, 30% and 50% of replacement level, the compressive strength of concrete reduced by 82.1%, 90.6% and 100% respectively compared to compressive strength obtained from the controlled concrete. Their findings have declines more significantly than findings from other researchers. This is due to the PET particles they used were non-uniformly shaped. In addition, large flaky PET particles reduced compressive strength more drastically than small flaky PET particles. Moreover, in Ferreira et al. (2012) studies, the concrete compressive strength was decreased by 27.8% and 41.7% at 7.5% and 15% of replacement level. They stated that this problem which were the PET particles will not interact with cement paste unlike natural aggregates, therefore the interfacial transition zone (ITZ) in concrete containing PET particles is weaker compared to the controlled concrete, which decreases the resulting compressive strength.

However, Rahmani et al. (2013) observed that the compressive strength of concrete containing 5% replacement ratio of PET particles as fine aggregate increased and gradually decreases as the replacement ratios of PET increases. At 5% of replacement level, the compressive strength of concrete increased by 8.9% when compared with the controlled concrete samples. But after increasing the replacement level to 10% and 15%, the compressive strength started to reduce by 11.7% and

15.18% respectively compared to the controlled concrete samples. The authors mentioned that the uniformly shaped and sized PET particles used in the concrete may give a positive effect on the concrete compressive strength in small ratio of replacement. Furthermore, Dawood et al. (2021) also reported that when replacing 5% of PET as fine aggregate in concrete leads to an increase in the concrete compressive strength. The compressive strength of concrete increased by 14.6% which was 40.1 N/mm2 as compared to compressive strength of 35 N/mm2 obtained from the controlled concrete. Besides, at 7.5% of replacement ratio, the compressive strength has no significant change when compared with the controlled concrete. They explained that the structure of the PET particles is affected by the mode of failure when the applied load approaches the ultimate load which means the internal stresses are transferred from shear stresses to tensile stresses, which increasing the concrete strength.

CONCLUSION

The workability of concrete containing PET particles which conducted in slump test was reduced due to the increased surface area of PET particles, and its irregular shape and size results in stiff concrete which is difficult to handle.

The density of concrete values of concrete containing PET particles was lower than the those of conventional concrete due to the light specific gravity of PET particle, which resulting in the reduction of the weight of the produced concrete.

As the replacement ratio of PET particle increases, the compressive strength values of concrete decreases. This trend can be ascribed to the reduce in adhesive strength between the surface of the PET particle and cement paste. However, some researchers found that concrete containing small amount of PET particles helps in increasing its compressive strength. They discussed that the structure of the PET particles is affected by the mode of failure when the applied load approaches the ultimate load (the internal stresses are transferred from shear stresses to tensile stresses, which increasing the concrete strength.

The optimum percentage of PET in concrete as fine aggregate was 5% replacement level. In fact, for 5% of PET content, the average reduced percentages obtained from workability, density and compressive strength of concrete were 9.8%, 1.4% and 8.8% respectively compared to controlled concrete. On the other hand, with further increase of PET contents, the parameters were decreased even more. Besides, in Rahmani et al. (2013) and Dawood et al. (2021) researches, they observed that 5% of PET content attributed to a positive slope of an average increment of 11.5% in the compressive strength.

Eventually, it can be justified that waste PET bottles in the form of particles can be reused as a partial replacement of fine aggregate in concrete technology. There would be an improvement in physical and mechanical properties of concrete d it also can be an environmentally friendly solution for waste PET bottles.

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ENHANCEMENT OF ATTACHED GROWTH PROCESS USING BANANA PEELS AND ORANGE PEEL IN TREATING SECONDARY POME

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ABSTRACT
Secondary palm oil mill effluent (POME) is a type of high organic strength wastewater that are produced from palm oil mill processing. It has been identified as a major contributor to water pollution issue due to its high COD, BOD, TSS and colour concentration. This study aims at enhancement of attached growth process using low-cost adsorbents in treating secondary POME. Attached growth system consists of immobile packing media so that microorganisms can grow as biofilm on the media and oxidize the pollutants in secondary POME. Meanwhile, carbonized orange peel powder and carbonized banana peel powder can be added into the attached growth system and be used as a bio-adsorbent to remove remaining pollutants from secondary POME. In this study, the highest COD, BOD, TSS and colour removal efficiency achieved by modified attached growth system with the addition of carbonized orange peel powder was 65.4%, 67.8%, 40% and 65.9% respectively. Whereas, the highest COD, BOD, TSS and colour removal efficiency achieved by modified attached growth system with the addition of carbonized banana peel powder was 88.5%, 71.0%, 40% and 88.6% respectively. This finding is probably beneficial to low cost and environmentally friendly adsorbents which can be used in wastewater treatment

Keywords:
Adsorbents, Secondary POME, Attached Growth System, Banana Peels, Orange Peels

INTRODUCTION

Palm oil industry has continuously played an important role towards Malaysian economic growth. The product produce from palm oils is used in food application and also in non-food application (Som and Yahya, 2021). In 2020, there was 5.87 million hectares of land area in Malaysia covered by oil palm (*Elaeis guineensis)*. Currently, Malaysia is one of the world's biggest palm oil exporters, contribute to 28% of global palm oil production. At the same time, Malaysia contributes about 33% in global palm oil products exports (Yi et.al., 2021). A huge amount of water is needed in the palm oil mill plant operation and therefore discharge an extent amount of wastewater, which is known as palm oil mill effluent (POME).

Palm oil mill effluent (POME) is a type of high organic strength wastewater. Although the palm oil industry is a major income earner for Malaysia, as it is also identified as a major contributor to the issue of water pollution. Massive treatment processes need to be done to POME before discharging to the environment due to its extremely high colour concentration, high chemical oxygen demand (COD) value, high biological oxygen demand (BOD), and high amount of total suspended solids (TSS). It is highlighted by the fact that there is no chemical added throughout the entire palm oil mill processing process (Zhang et., 2008 Zhen et al., 2021).

The palm oil industry is an indisputable source of water pollution in Malaysia. The concentration of chemical oxygen demand and soluble organics matter contains in the POME wastewater are in the range of 44-103 g/L (Emmanuel et al., 2022). Undoubtedly, the remaining of COD, BOD, TSS and colour concentration in treated POME is the main problem that causes the water pollution. Most of the millers in Malaysia are still adopting the traditional way to treat POME which is the conventional ponding system. However, the conventional ponding system is unable to treat the POME efficiently, especially to fully decolourise the effluent which is aesthetically important even before discharging to natural water bodies (Zahrim et al., 2014). Most of the pollutants are remained remarkably high and not meeting the required discharge standard even the conventional ponding system.

There is no doubt that banana and orange are the most popular fruits in the world. The main residue for both the fruits are their fruit peels. For instances, the banana peel accounts for 30-40% and orange peel accounts for 50-60% respectively of their total fruit weight (Rafie and Chong, 2014). Tones of orange peels and banana peels were discarded as useless daily wastes and it is essential to find applications and uses for these peels because waste management is becoming a concerning environmental issue nowadays. These waste peels are low cost, non-hazardous and environment friendly bio-materials which can be used as adsorbents in industrial wastewater (Thuraiya et al., 2015).

In this study, it is primary aimed to develop a system that is useful for further removal of the remaining COD, BOD, TSS and colour in the secondary POME. Thus, by adding in carbonized orange peel powder and carbonized banana peel powder into attached growth system, it is expected that the removal efficiency of COD, BOD, TSS and colour of secondary POME can be significantly enhanced.

METHODOLOGY

Preparation of Carbonized Banana Peel Powder and Carbonized Orange Peel Powder as Adsorbent

The mature fruit peels were collected as solid waste from fruit juice stalls. The collected fruit peels were processed by scrapping impurities that stay on the inner surface of the peels using a small knife and left the outer surface of the peels for the experiment. Then, the peels were washed three times with tap water and one time with distilled water to remove any external dirts and suspended impurities. The processed fruit peels were dried at 100ºC for 48 hours in Memmert oven to remove the moisture content from the peels. After the drying process, the peels were taken out from the oven and kept in the desiccators for 30 minutes for the purpose of cooling down to room temperature. Next, the banana peels were kept in Carbolite muffle furnace for 30 minutes at 200ºC whereas the orange peels were kept in Carbolite muffle furnace for 1 hour at 200ºC to convert them into carbon form. The peels were ready to be grounded into fine powder and sieved through 300 µm for particle size of equal or less than 300 µm (Yusoff & Nazri, 2022) Finally, the fine carbonized fruit peel powder was washed three times by using distilled water to remove the colour of the carbonized powder itself.

Figure 1: Carbonized Banana Peel Powder and Carbonized Orange Peel Powder

Lab Scale of System Set-up and Cultivation of Microorganisms Process

Cultivation of microorganisms is necessary as a part of preliminary preparation so that the useful microorganisms can be attached on the media. The cultivation of microorganisms is done for a period of one month so that a complete cultivation process can be assured. The cultivation of microorganisms is done by introducing 7 litre of secondary POME that collected from the final discharging aerobic pond influent, which is the same pond as the testing sample to the experimental setup. During the one-month cultivation period, 10% of the 7 litre of secondary POME, which is 700 ml should be discharged out of the system every 5 days so that 10% of 7 litre of fresh secondary POME can be introduced into the system. The reason for this step is to ensure there is sufficient food and nutrients for microorganisms and thus preventing the microorganisms from starving as well as dying. Aeration is also provided with a minimum DO at 3.5 mg/L to ensure sufficient oxygen for the growth microorganisms. For a successful cultivation, the colour of attached growth media should be changed from white colour to brown-yellowish colour.

Figure 2: Colour of Attached Growth Media Changed from White Colour to Brownish Colour

Treatment of Secondary POME

The raw of 7 litre of secondary POME was poured into the experiment set up, namely control system which represented as conventional attached growth system (CS), modified attached growth system with carbonized orange peel powder (OS) and modified attached growth system with carbonized banana peel powder (BS) respectively. The experiment setup as shown in Figure 3. During the experiment, the contact time for the system was fixed at 24 hours, 48 hours, and 72 hours. Aeration was then supplied to the system by using aquarium air blower and diffusers throughout the contact time periods. After the treatment for the required contact time, the treated secondary POME is allowed to settle down for 3 hours. Approximately 500 ml of supernatant after the settlement is taken out by using 1000 ml of beaker and used for analysing.

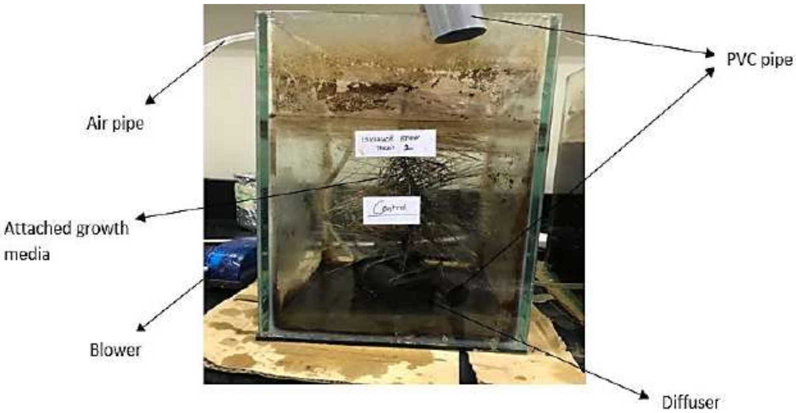

Figure 3: Lab Scale Set-up Represented as Conventional Attached Growth System

The measurement for initial colour concentration before experiment and final colour concentration after the experiment was tested by following platinum-cobalt standard method 8025. Moreover, COD measurement was conducted by using USEPA reactor digestion method 8000. BOD_5 test was carried out using standard procedure of APHA standard method 5210B with YSI 5000 dissolved oxygen (DO) probe. Lastly, TSS concentration was conducted using standard procedure of APHA standard method 2540D.

RESULT AND DISCUSSION

Removal Efficiency of COD, BOD, Colour and TSS of POME

The results obtained for the removal efficiency of selected parameters of secondary POME using CS, OS and BS system are tabulated as shown in Table 1. The finding indicated that BS system has the best treatment efficiency compared to CS and OS system. There are several chemical groups that can be found on the banana peel surface, for example, carboxyl, hydroxyl and amide groups which have been justified to play an essential role in bio-sorption process by increasing the bio-sorption capacity and shortening stable time (Cong et al., 2012). Moreover, banana peel has irregular and porous surface that makes the adsorption process possible. This statement is supported by the image of the banana peel surface that were observed by using electron microscopy (Ibrahim et al, 2012).

Table 1: Removal Efficiency (%) of COD, BOD, Colour and TSS Concentration of Secondary POME

*CT (h) / Parameters	24			48			72		
	CS	OS	BS	CS	OS	BS	CS	OS	BS
COD	26.9	32.7	53.8	32.7	59.6	84.6	38.7	65.4	88.5
BOD	7.1	29.9	41.2	13.7	54.6	64.9	31.5	67.8	71.0
Colour	4.5	40.0	52.3	10.2	59.1	85.2	20.5	65.9	88.6
TSS	20	20	20	60	20	40	80	40	40

*CT (h) – Contact time (hour)
Note: The unit removal efficiency of all the parameter are in the percentage (%).

Effect of Contact Time on Removal Efficiency

Based on the trend of graph that shown in Figure 4 and 5, COD and BOD concentration in CS, OS and BS systems decreased with the increased of contact time. All three systems achieved the highest COD and BOD removal efficiency after 72 hours of contact time. The highest COD removal efficiency that achieved by CS, OS and BS system are 38.7%, 65.4% and 88.5% respectively.

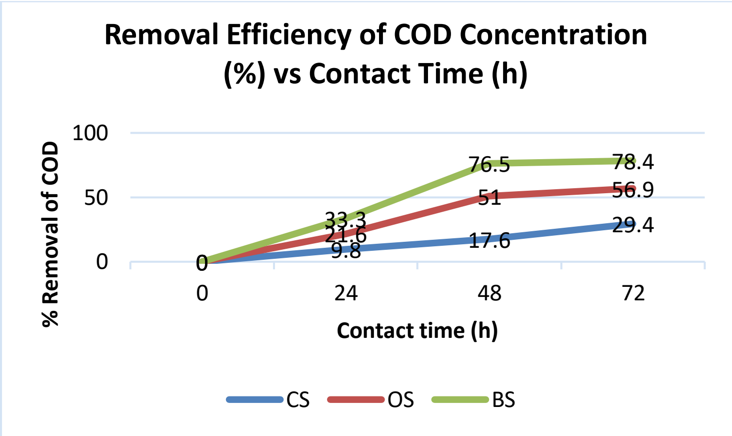

Figure 4: Removal Efficiency of COD Concentration (%) vs Contact Time (h)

Whereas, the highest BOD removal efficiency that achieved by CS, OS and BS system are 31.5%, 67.8% and 71.0% respectively. The highest COD and BOD removal efficiency achieved in BS system can be explained by the addition of carbonized banana peel powder as adsorbents. Besides the attached growth process, the adsorbent enabled the organic substances in secondary POME to stick with the adsorbent surface and thus resulting in a higher COD and BOD removal efficiency. Moreover, the packing media is in brush-like structure can ensure the high surface area to volume ratio for the microorganisms to grow (Ronser, 2017).

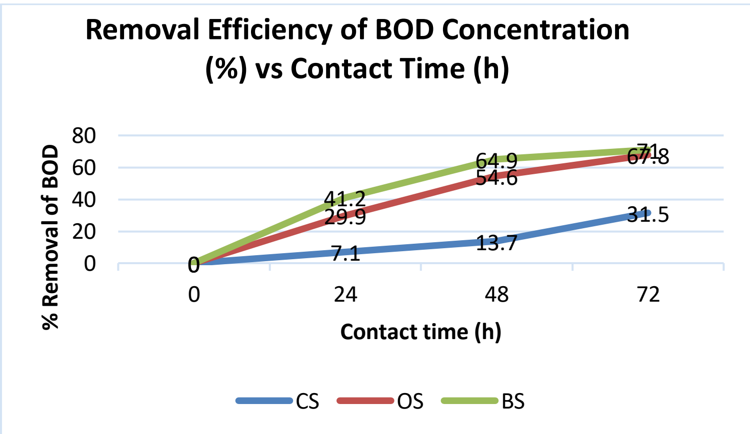

Figure 5: Removal Efficiency of BOD Concentration (%) vs Contact Time (h)

Based on the trend of graph in Figure 6, colour removal efficiency for all the three CS, OS and BS system increased with the increased of time. The highest colour removal efficiency which was 20.5%, 65.9% and 88.6% was occurred at contact time of 72 hours for CS, OS and BS system respectively. The highest colour removal efficiency in BS system can be explained by the adsorption process that carried out by the carbonized banana peel powder (Rafie and Chong, 2014;Yusof & Nazri, 2022).

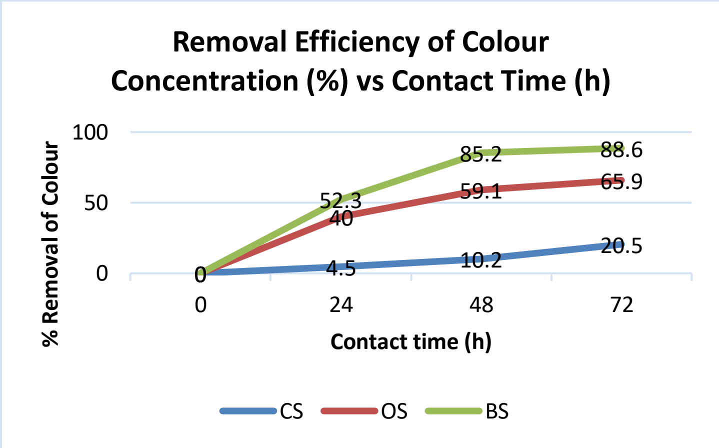

Figure 6: Removal Efficiency of Colour Concentration (%) vs Contact Time (h)

Based on the trend of graph in Figure 7, TSS removal efficiency for all the three CS, OS and BS system increased with the increased of time generally. The highest colour removal efficiency which was 80%, 40% and 40% achieved for CS, OS and BS system respectively throughout the contact time periods. It can be concluded that with the CS system itself, which represented the conventional attached growth system is capable for the TSS removal of secondary POME and with a higher removal efficiency compared to OS system and BS system. TSS removal in OS and BS systems were lower than CS system because the foreign substances, which were the adsorbents that added into the system in powder form did contribute as TSS concentration itself.

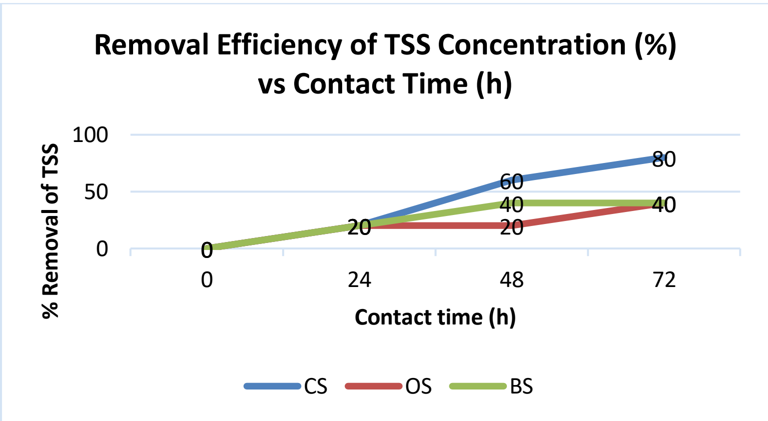

Figure 7: Removal Efficiency of TSS Concentration (%) vs Contact Time (h)

CONCLUSION

Based on the results of the highest COD, BOD, TSS and colour removal efficiency achieved by modified attached growth system, and it can be concluded that carbonized orange peel powder and carbonized banana peel powder can be used as additional adsorbent with longer contact time in improving attached growth process.

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FINITE ELEMENT MODELLING FOR COLD FORM STEEL COLUMN WITH THE WEB AND FLANGE STIFFENER

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ABSTRACT

Cold-formed steel sections are a cost-effective alternative to traditional wood sections, which are mostly utilized in residential structures, and employed in industrial applications. Several unique items have been produced from it. While experimental testing is presently the most reliable approach for studying the behaviour of CFS sections, its effectiveness is limited by the expense of research. There aren't enough studies that use laboratory testing or numerical analysis to investigate the behaviour of CFS sections. As a result, it is more important than ever to utilize Finite Element Modelling (FEM) to simulate the realistic behaviour of CFS sections, especially when longer spans are necessary. While conducted under concentrically applied load and pin-ended boundary conditions, 36 axial compression tests were performed on CFS channels of three different lengths (1 m, 1.5 m, and 2 m) and four different cross-sections to investigate the interaction of local and overall flexural buckling in plain and lipped cold-formed steel (CFS) channels under axial compression. One sample was chosen from the real experiment to confirm the validity of FEM based on a physical experiment for the columns with lipped stiffener using FEM software based on real conducted experimental and nonlinear FE models about the CFS columns with lipped stiffener under the effect of axial load. The obtained FEM results for the ultimate capacity was 120.337 kN, and the percentage error for the FEM 5.8%. Furthermore, a parametric study was conducted for 3 samples of cold-formed steel with intermediate stiffener in the web and lipped in the flange with different angles for the intermediate stiffener and the ultimate capacity was recorded for the three samples was between 200-211kN. Moreover, that present load vs. displacement for samples A, B, and C combined which had an ultimate strength of (1.09621, 211.069), (1.08838, 206.481), and (1.07742, 199.975) respectively.

Keywords:
Cold Formed Steel, Finite Element Model, Parametric study

INTRODUCTION

Cold-Formed Steel (CFS) sections have become well-established in building construction due to its excellent structural performance, corrosion resistance, ease of manufacture, maintenance, and attractive appearance and lightweight. CFS trusses are commonly used as roof structures in industrial and residential buildings. Researchers discovered in the early 21st century that by combining the CFS with other materials, such as concrete, the structural performance of the CFS could be considerably enhanced (Amsyar et al., 2018). Commonly, CFSalso known as Light Gauge Steel or LGS, is used for structural framing in structures of all sizes and purposes all over the world. Multi-story constructions, engineering conformity with local design and building standards, and the ability to survive if any structure constructed with traditional materials are among them. CFS sections are a cost-effective alternative to traditional wood sections, which are mostly utilized in residential structures, and employed in industrial applications. Several unique items have been produced, including C, Z, hat, and more specific chord and web parts, as shown in Figure 1. Furthermore, welding, adhesives, mechanical connectors such as bolts or screws, or even new mechanical connecting techniques such as press joining or rosette joining can all be used to make the connections (Hancock, 2016).

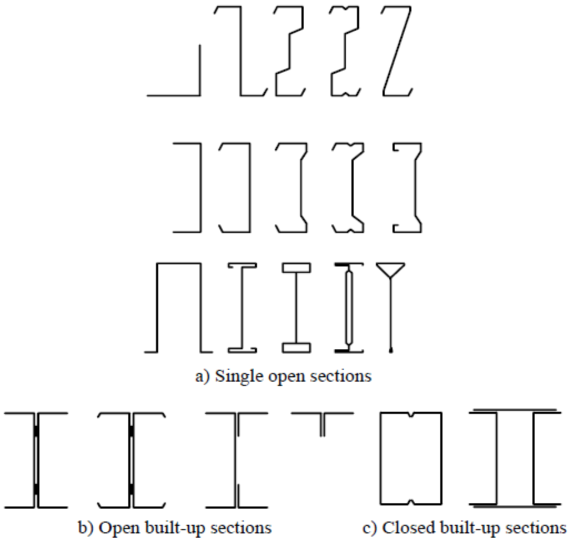


Figure 1: Typical Forms of Cold-Formed Sections

While experimental testing is presently the most reliable approach for studying the behaviour of CFS sections, its effectiveness is limited by the expense of research. There aren't enough studies that use laboratory testing or numerical analysis to investigate the behaviour of CFS sections. As a result, it is more important than ever to utilize Finite Element Modelling (FEM) to simulate the realistic behaviour of CFS sections, especially when longer spans are necessary. In this paper, FEM will be utilized to perform tests on CFS channels with stiffeners and show their behaviour under compressive load.

LITERATURE REVIEW

Material Properties

The study by Ma et al. (2015) discusses the material characteristics and residual stress distributions of cold-formed high-strength steel hollow sections. On high-strength steel hollow sections in rectangular, square, and circular shapes cold-forming effects have been investigated. Cold-formed structural hollow sections were evaluated using 66 standard tensile coupon tests, which evaluated the material characteristics of the high-strength steel structural hollow sections. Flat and corner coupons were machined out of the SHS and RHS, while curved coupons were machined out of the CHS, depending on the cross-sectional shape as illustrated in Figure 2. For the flat tensile coupon testing, the test pieces were 6 mm broad and 25 mm in gauge length. For the corner and curved tensile coupon tests, the corner and curved tensile coupons were 4 mm wide throughout the gauge length of 25mm.

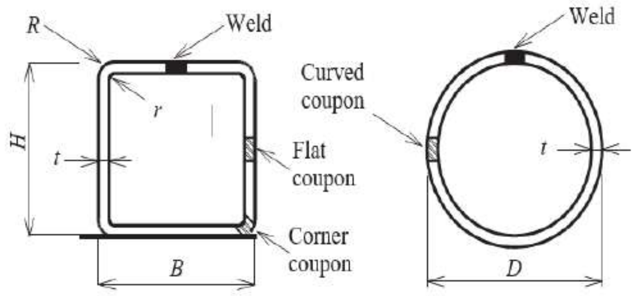


Figure 2: Tensile Coupons Locations

Buckling of CFS

Using an experimental study and finite element analysis on evenly lipped angles squeezed between fixed ends for different column lengths, (Young & Ellobody, 2005) investigated the buckling behaviour of CFS. The lipped angle test specimens were produced from brake-pressed zinc-coated structural steel sheets. The specimens were cut into lengths ranging from 250 to 3,500 mm. Three distinct lipped angles were investigated, each having a nominal flange width of 70 mm and a nominal lip width of 15 mm. The nominal plate thicknesses were 1.2, 1.5, and 1.9 mm. The nonlinear finite element model was validated using recent experimental data.

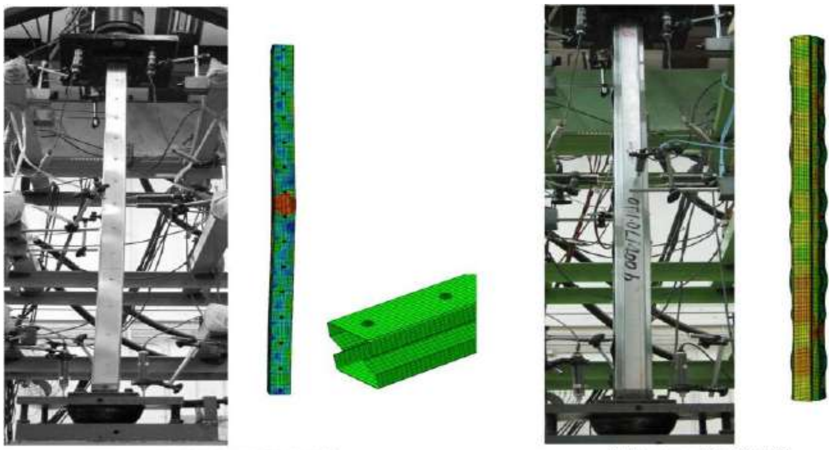
While (Ye, Hajirasouliha, et al., 2018) conducted under a concentrically applied load and pin-ended boundary conditions, 36 axial compression tests were performed on CFS channels of three different lengths (1 m, 1.5 m, and 2 m) and four different cross-sections. The investigation was on the interaction of local and overall flexural buckling in plain and lipped CFS channels under axial compression. The findings were utilized to confirm the validity of Eurocode 3 existing design methods. All the specimens that were examined were made with similar coil width and thickness.

All 36 specimens had local buckling, which was followed by failure owing to the interaction of local and overall flexural buckling around the minor axis. No distortional buckling was evident in any of the investigated cross-sections, even at late stages of post-peak behaviour. The local buckling deformations concentrated towards mid-height in the last phases of the testing, and a yield line mechanism formed. The failed geometries of the 1 m long specimens are shown in Figure 2.

Figure 2: The Failed Specimens with 1 Meter Long

Finite Element Model (FEM)

A numerical study and design of CFS built-up closed section columns with web stiffeners is presented in (Zhang & Young, 2018) research. To predict the structural behaviour of fixed-ended built-up closed section compression members, a finite element model (FEM) was created that considered initial geometric defects and nonlinear material characteristics. In this research, the ABAQUS finite element software was utilised to create a finite element model that was used to examine the structural behaviour of fixed-ended built-up closed section compression members. The FEA was carried out in two stages. First, a linear perturbation analysis was used to conduct an eigenvalue buckling analysis. The ultimate strength and failure mechanism of a built-up closed section column were predicted using a nonlinear approach. The generated FEM was validated against the test findings for cold-formed steel built-up closed sections by comparing the predictions of the FEA column strengths (PFEA) with the experimental results (PEXP). A total of 26 cold-formed steel built-up closed sections with inner and outward web stiffeners were used in this research, as shown in Figure 3.



(a) Specimen VT1.0L1400 (b) Specimen OT1.0L1400

Figure 3: Experimental and Finite Element Analysis Deformation Forms of Built-Up Closed Section

The nonlinear behavior and design of built-up cold-formed steel section battened columns are discussed in (Dabaon et al., 2015) article. The pin-ended built-up columns were made from two cold-formed steel channels that were put back-to-back and connected by batten plates. The behavior of the built-up CFS section battened columns were modeled using the finite element software ABAQUS. Individually, the cold-formed steel channels, batten plates, and end loading plates were defined. The slender cold-formed steel channels (chords) and batten plates were modeled using the S4R shell element from the ABAQUS element collection. The models considered the nonlinear material characteristics of the flat and corner sections of the channels, as well as starting geometric imperfecti8ons, actual geometries, and boundary conditions. The finite element models were compared to tests on the same kind of section that the authors had previously performed and reported on, as shown in Figure 4.

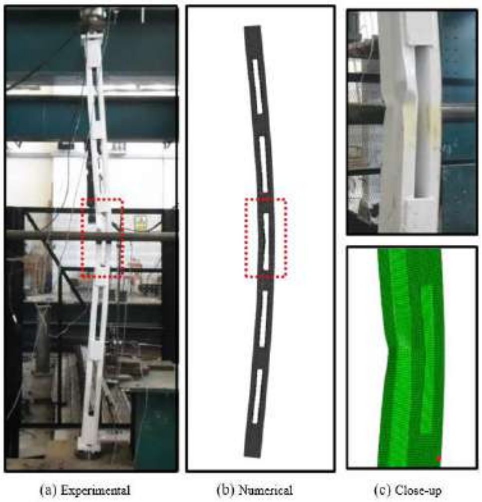


Figure 4: The Built-Up Column Deformed Shape

RESEARCH METHODOLOGY

Verification of the Finite Element Model

Based on the experimental testing results presented by (Ye, Hajirasouliha, et al., 2018) for buckling in CFS lipped channels under axial compression with pin-ended boundary conditions the ultimate capacity for specimen A1000-a is 99.8 kN as demonstrated in section 3.7. Moreover, a follow-up FEM study to the experimental testing results was conducted by researchers (Ye, Mojtabaei, et al., 2018), which followed the same conditions, the ultimate capacity was 113.7 kN. On the other hand, the FEM study conducted under this thesis went through the same conditions of the experimental study. Furthermore, the obtained FEM results for the ultimate capacity that was carried out in section 3.6 for specimen A1000-a produced an ultimate capacity of 120.337 kN. Therefore, the percentage error between the FEM results for the ultimate capacity is 5.8% as shown in Table 1.

Table 1: Differences in ultimate load capacity between Controlled sample and FEM

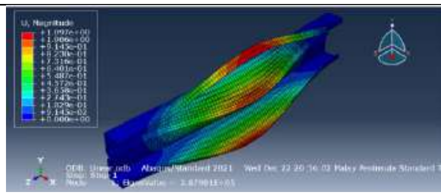
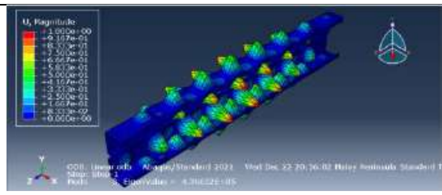
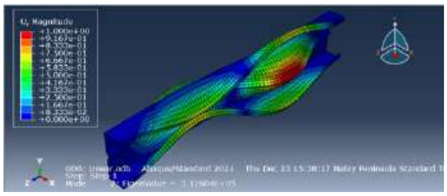
Specimen A1000-a	**Ultimate load capacity**	**Percentage**
Experimental sample conducted by (Ye, Hajirasouliha, et al., 2018)	99.8 kN	
FEM conducted by (Ye, Mojtabaei, et al., 2018)	113.7 kN	$\frac{113.7 - 99.8}{99.8} \times 100 = 14\%$

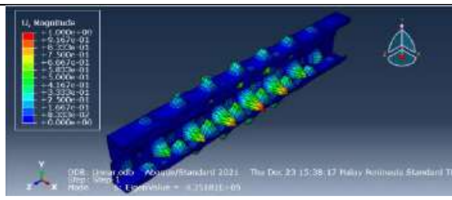
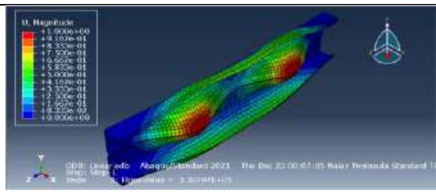
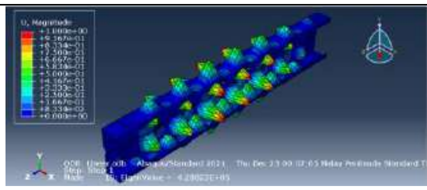
FEM study conducted in this study	120.337 kN	$\frac{120.3-99.8}{99.8}\times 100 = 20.58\%$ $\frac{120.3-113.7}{113.7}\times 100 = 5.8\%$

Parametric Study

The parametric study of the three samples, a linear analysis was conducted with 10 eigenvalues to obtain the buckling type. Furthermore, the first eigenvalues for each sample used a nonlinear analysis to obtain the ultimate capacity and compare it between the three samples to investigate the most suitable intermediate stiffener angle in the web, as shown in Table 2.

Table 2: Result of the parametric study

Sample	Ultimate capacity	Mode	Type of buckling
A Column with the web and flange stiffener. (Intermediate stiffener angle 45^{o})	211.1 kN	1^{st}-2^{nd}	 Global buckling
		3^{rd}-10^{th}	 Local buckling
B Column with the web and flange stiffener.	206.5 kN	1^{st}-5^{th}	 Global buckling

(Intermediate stiffener angle 37^{o})		6th-10th	 Local buckling
C Column with the web and flange stiffener. (Intermediate stiffener angle 30^{o})	200 kN	1st-8th	 Global buckling
		9th-10th	 Local buckling

Vertical Displacement

The typical load-displacement curve for each sample obtained from the tests and the ultimate loads among the three samples and various displacements are shown in Figure 5.

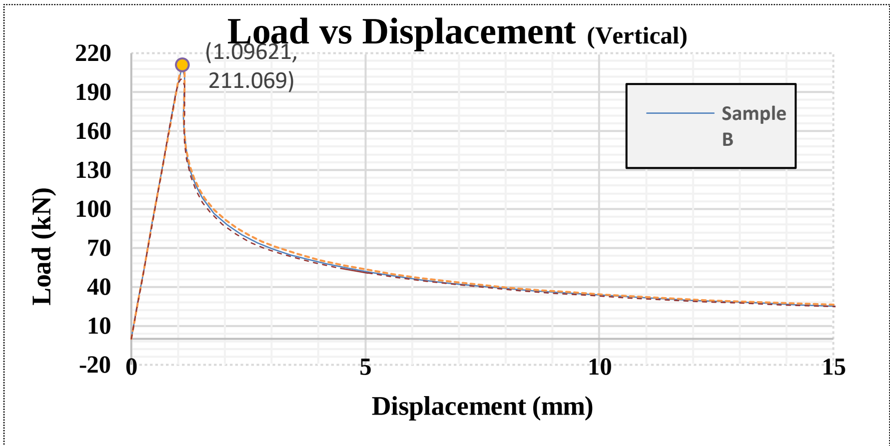


Figure 5: Load vs Displacement for sample A, B and C

DISCUSSION

Verification of the Finite Element Model

Based on the experimental testing results presented by Ye Hajirasouliha et al. (2018), when conducting a study that focuses on the interaction of local and overall flexural buckling in CFS lipped channels under axial compression that concentrically have an applied load and pin-ended boundary conditions, the corresponding obtained results for the ultimate capacity for specimen A1000-a is 99.8 kN as demonstrated in Figure 6. Moreover, a follow-up FEM study to the experimental testing results was conducted by Ye Hajirasouliha et al. (2018), which followed the same conditions of the experimental study to provide a more comprehensive overview on the buckling in CFS lipped channels. Therefore, the obtained FEM results for the ultimate capacity for specimen A1000-a was 113.7 kN, as illustrated in Figure 6. Therefore, the FE simulated load capacity ratio to the experimentally measured load-carrying capacity was 1.139, and the percentage error is 13.9% ≈14%. On the other hand, in the FEM study conducted in this investigation which followed the same conditions of the experimental study, the obtained FEM results for the ultimate capacity that was carried out for specimen A1000-a produced an ultimate capacity of 120.337 kN. Hence, the FEM simulated load capacity ratio in this study to the experimentally measured load-carrying capacity was a 20% percentage difference. Furthermore, the percentage difference between the FEM results from Ye Hajirasouliha et al. (2018)and this study for the ultimate capacity is 5.8%. However, by using a much higher mesh number while performing the simulation analysis can further reduce the percentage difference.

Table 2
Comparison of FE results with tested compressive strength.

Specimen	Length (mm)	P_u (test) (kN)	P_{u1} (FE) (kN)
A1000-a	1000.1	99.8	113.7
A1000-b	1000.0	98.3	117.5
A1000-c	1000.0	98.7	114.9
A1500-a	1499.8	95.1	89.8
A1500-b	1500.0	85.3	81.9
A1500-c	1500.0	91.4	94.06
A2000-a	1999.8	78.4	88.4

Figure 6: Results Obtained by (Ye, Mojtabaei, et al., 2018)

Parametric Study

Table 2 summarised the obtained FEM results for the designed samples. All samples showed improvement in the ultimate capacity after adding the intermediate stiffener in the web which was recorded between 200-211kN for all samples. Sample A with 45^{o} of the intermediate stiffener recorded the highest ultimate capacity of 211kN followed by sample B with 37^{o} that recorded an ultimate load of 206.5kN. Sample C with 30^{o} on the other hand presented the lowest ultimate capacity of 200kN. Hence, the comparison clearly indicates that the 45^{o} intermediate stiffeners present the best ultimate capacity. The observed failure mode presented in Table 2 showed local buckling and global buckling for all three samples.

Vertical Displacement

Researchers (e.g., Aulia & Rinaldi, 2015) presented that a structure's ductility can be considered one of the most essential factors determining its performance and capabilities. Ductility refers to a structure's capacity to produce post-yield deformation before buckling, and it may become the most crucial element in determining damage level. However, as can be seen from Figure 5, that present load vs. displacement for samples A, B, and C combined which had an ultimate strength of (1.09621, 211.069), (1.08838, 206.481), and (1.07742, 199.975) respectively. The behaviour of the designed CFS column with the different intermediate stiffener angles for the load-displacement graph had approximately the same displacement characteristics due to the insignificant intermediate stiffener angles for samples A, B, and C.

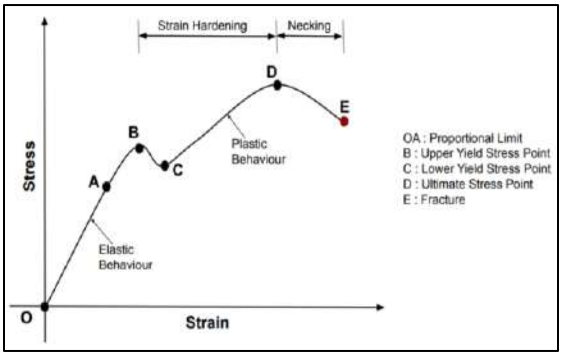


Figure 7: Stress vs Strain Curve

As it can be seen from Figure 7, which demonstrates the Stress-Strain curve for ductile materials, the proportional limit (O-A), according to Hooke's Law, is the point at which stress is directly proportional to strain which makes the stress-strain curve in a straight line within the proportional limit at this region. From point A to B (Yield Point) on the stress-strain curve, the material has elastic characteristics. After the external force is removed, the material will not return to its previous form. If the external load (stress) is increased above the elastic limit. Plastic qualities appear when ductile material is stretched beyond its elastic limit. The higher yield point is the point at which the material's maximum tension is needed to cause plastic deformation. Yield strength is the strength of a material that corresponds to Point B.

Moreover, Plastic properties appear when ductile material is stretched beyond its elastic limit. The higher yield point is the point at which the material's maximum tension is needed to cause plastic deformation. Yield strength is the strength of a material that corresponds to Point B. With a minor increase in tensile force after Point C, the material length will rise (stress). In other words, the Lower Yield Point is the point at which the minimal load is necessary for the material to display plastic behaviour. The ultimate tensile strength of the material is shown by the material strength corresponding to Point D on the stress-strain diagram. A material's ultimate tensile strength is the utmost stress it can bear before breaking. Inside the material, necking begins after point D.

Therefore, since there were no major differences between sample A, B, and C, in load-displacement and stress-strain curves, sample A can be taken as an example to explain the obtained results characteristics across different regions. The point A proportional limit in the Figure 4.6, stress-strain graph for sample A is (0, 195.675) and before this point is the elastic behaviour for the CFS column. The point B, upper yield stress point is (0.00011, 201.01), and before this point is the elastic limit. For the point C, lower yield stress point is (0.00195, 95.902). The ultimate stress in the sample A is (0.0142, 273.673) which represent the point D in the graph.

CONCLUSION

To conclude, the study's objectives were accomplished successfully by simulating a column with the lipped in the flange. The study was on the behaviour of CFS with the lipped stiffener in terms of buckling. The experimental testing results of the buckling in CFS lipped channels under axial compression with pin-ended boundary conditions had an ultimate capacity for specimen A1000-a is estimated by 99.8 KN, followed up by FEM study to the experimental testing results by researchers Ye Hajirasouliha et al. (2018), which followed the same conditions. The ultimate capacity in this case, was 113.7 KN. However, the obtained FEM results for the ultimate capacity carried out under this research in for specimen A1000-a produced an ultimate capacity of 120.337 kN. Therefore, the percentage difference between the FEM results for the ultimate capacity is 5.8%. Which summarizes the first objectives of the study, to produce a nonlinear FEM analysis based on a physical experiment and verifying the validity/ workability of the software simulation.

Furthermore, the second objective was met by making 3 samples of CFS columns with intermediate stiffeners in the web and lipped in the flange by using Abaqus software to show the buckling behaviour under axial load which all were included under the parametric study. The samples maintained the same nominal thickness (t=1.5mm), coil width and height (L=1000mm) as the original specimen A1000-a was included in the study but with additional intermediate stiffeners in the web. Additionally, the 3 samples had different angles of the intermediate stiffeners to validate the study with the best angle consideration. However, the geometric limitation of the sample was based on the study conducted by (Wang & Young, 2014) for the CFS channel sections with web stiffeners.

All samples showed improvement in the ultimate capacity after adding the intermediate stiffener in the web which was recorded between 200-211kN for all samples. Sample A with 45º of the intermediate stiffener recorded the highest ultimate capacity of 211kN followed by sample B with 37º that recorded an ultimate load of 206.5kN. Sample C with 30º on the other hand presented the lowest ultimate capacity of 200kN. Hence, the comparison clearly indicates that the 45º intermediate stiffeners present the best ultimate capacity.

The third objective was accomplished by examining the vertical displacement of the three samples, which revealed that the load-displacement graph behaviour of the proposed CFS column with various intermediate stiffener angles had almost comparable displacement characteristics. Furthermore, for each sample corresponding to the width of the angle, the stress vs strain analysis revealed various upper/lower yield stresses, ultimate stresses, and fracture points.

AUTHOR BIOGRAPHY

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EVALUATION OF THE SHAPE AND SIZE OF THE BED MATERIALS USING SNEED AND FOLKS DIAGRAM

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ABSTRACT
Streams and rivers are critical components of the hydrological cycle. River flow can scour the beds, transport and deposit particles, and thus change the river sinuosity. They will become non-porous or impermeable if the grain is not preserved. Runoff water may immediately enter the river, increasing the water flow rate and causing a flood. The presence of grain particles in the river is critical because they can control the velocity of the water flow, especially during the wet season. This study aimed to examine the particle shapes and sizes of gravel bed materials in the upper, intermediate, and lower stream of the Lepoh River. For analysis, Sneed and Folk diagrams were used. This method has been advocated as the most appropriate method for presenting the shape of particles in an unbiased manner. Around 300-grain particles were collected from the river's upper, intermediate, and lower reaches. The frequency distribution of particles at a, b, and c of the axis was quantified to analyse the shape and size of the bed materials. The study concluded that bed material was classified as very coarse gravel with mostly bladed particles at a higher flow rate and the upper stream. The bed materials were classified as coarse gravel, and the particle shape was platy and bladed at the lower part of the river due to the lower elevation.

Keywords:
Clast Shape, Sneed and Folks, Grain Particles, Bladed, Platy

INTRODUCTION

Rivers flowing to the seas or lake are fed by tributaries and small gullies through which water trickles from rain, snow and ice or subsurface sources. The area of land draining into a river is called a catchment. Most commonly, the catchment is defined as the area that topographically appears to contribute all the water that passes through a given cross-section. River transports many chemical substances and biological species because of domestic, municipal and industrial wastewaters. Rivers flowing through the catchment transport water, sediment, other chemical substances, and biological species.

Deposition and transit of sedimentary materials indicate the transport and deposition methods. For example, if the materials slide down a hill, the resulting deposits are typically chaotic and exhibit a broad diversity of particle sizes. Sediment texture is determined by grain size and interaction between grains. It is possible to deduce transport and deposition modes by studying the microstructure of resultant deposits. When it comes to sorting, it's all about grain size consistency. Because of the energy of the carrying medium, particles are sorted according to cast density. Large clast particles can be carried by high-energy currents (Bui Bui & Rutschmann, 2019).

To sum up, criteria selection is crucial in defining the form and size of gravel bed material when utilising Sneed and Folks diagram as a guideline. It is a triangle (ternary) diagram that plots the ratios of the three orthogonal axes of the particles. Sneed and Folks initially proposed it, and Hickey (1970) and Ballantyne (1982) gave geometrically similar diagrams. This study embarks on the following objectives; (i) determine the factors that influence the shapes and sizes of the gravel-bed river; (ii) evaluate the shapes and size of the gravel-bed river using the Sneed and Folks diagram.

The Sneed and Folks diagram will be used to classify the gravel bed river's shape and size. While the forms and sizes of gravel-bed rivers are the manipulated factors in this study, Sneed and Folks diagram are the fixed variables used to categorise the shapes and sizes of gravel-bed rivers.

LITERATURE REVIEW

Introduction to Clast Classification

Chemical and clastic sedimentary rocks can be distinguished. A substance is carried as solid pieces (clasts), categorised as clastic, while a substance in solution is classified as chemical. Less than 1/16mm clasts are primarily clay minerals, whereas those bigger than 2mm are rock pieces that can be basalt or andesite, granite or gneiss, among other materials (Szilo & Bialik, 2018). As a result, the Udden-Wentworth grain-size scale has been used to study grain size categorisation. This article has six basic kinds of grain size: boulder, cobble, sand, silt and clay.

Clast Shape

There are a few sedimentary rocks that their clast form or roundness may differentiate. Round and angular shapes are associated with lengthy transportation distances and high-energy environments; rounded shapes are associated with long transportation distances and/or high-energy deposition environments such as beaches and rivers (Oakey et al., 2005). When it comes to depositional surroundings, the degree of sorting of clasts might be a significant indication. In water, bigger clasts are less likely to be carried long distances and settle more quickly. According to one theory of river sedimentation, as the energy in the river is lost by sedimentation, the bigger, heavier grains of coarse sand start to accumulate. In contrast, the finer, lighter mud grains are carried far away from shore by currents (Sharma, n.d.).

On the side of form and angularity, particles have angular edges rather than rounded, giving them their characteristic feature. Flow, drag, and lift forces impact the particle form, resulting in particle deposition, entrainment, and transport. Varied conditions with the same weight or b-axis size may react differently to water flow because of their different shapes. As a result, while studying particle shape, it is important to consider the longest, intermediate, and shortest axes, or all of them (Termini, 2021).

A grain's sphericity is determined by its shape, which is measured by its shape. Granules come in numerous forms. A few grains are elongated or flattened, while others are almost spherical (Krumbein, 1941). Diverse processes, weathering, erosion, deposition and transit, will cause the grains to emerge in different shapes. As a result of water or wind erosion, the rocks will seem rounded, whereas crushed rocks will appear angular (Cassel et al., 2021).

Clast Sizes

Particle sphericity refers to how well a particle of a given shape relates to the transport properties of a sphere. In contrast, the expression roundness refers to the degree to which the edges of a particle are rounded. Sphericity can be used as a measure of particle susceptibility and transportability, for instance, the particle's ability to remain in transit after being entrained in a stream. Since abrasion and susceptibility are two separate notions, it's necessary to utilise different spherical definitions in each situation (Afzalimehr et al.,2017).

Deposition and transit of sedimentary materials indicate the transport and deposition methods. For example, if the materials slide down a hill, the resulting deposits are typically chaotic and exhibit a broad diversity of particle sizes. Sediment texture is determined by grain size and interaction between grains. It is possible to deduce transport and deposition modes by studying the microstructure of resultant deposits. When it comes to sorting, it's all about grain size consistency. Because of the energy of the carrying medium, particles are sorted according to cast density. Large pieces can be carried by high-energy currents (Bui et al.,2019).

Larger and heavier particles are deposited as the energy diminishes, while smaller and lighter pieces continue to be carried. There is a sorting process owing to density in this case. As a result of abrasion, grains may be rounded during transit. Because of random abrasion, grains' sharp corners and edges will eventually be smoothed off. Grain rounding indicates how long sediment has been in transit. As a result of the correlation of the three particles' axes (a is the longest particle axis, b is the intermediate particle axis, and c is the shortest particle axis), particles may be grouped into four basic forms. Callipers, rulers, or a pebble box can be used to quantify particle length. In order to identify these forms, the form factor (F) may be used to measure their platy, bladed, and elongated characteristics.

Sneed and Folk Diagram

Particles can be classified as compact, platy, bladed, or elongated according to the Sneed and Folks diagram. Because it uses three orthogonal particle axes, it has been recommended as the best approach for impartially presenting primary particle shape data. Compared to other options, this graphic has some benefits (Graham & Midgley, 2000). Compared to other options, it is easy to grasp, and the plotted numbers are simple to calculate. It used a combination of compactness ratio c/a and form factor F, as shown in Table 1, which defines any point inside the triangle's boundaries. Particles with $F<0.33$ are platy, those with $0.33<F<0.67$ are long and thin-bladed particles and those with $F>0.67$ are elongated particles. The Sneed and Folks diagram shows in Figure 1, C stands for Compatibility, CP for Compact Plates, CB for Compact Blades, CE for Compact Elongated, P for Plates, B for Blades, E for Elongated, VP for Very Plates and VE for Very Elongated (John Wiley, 2000).

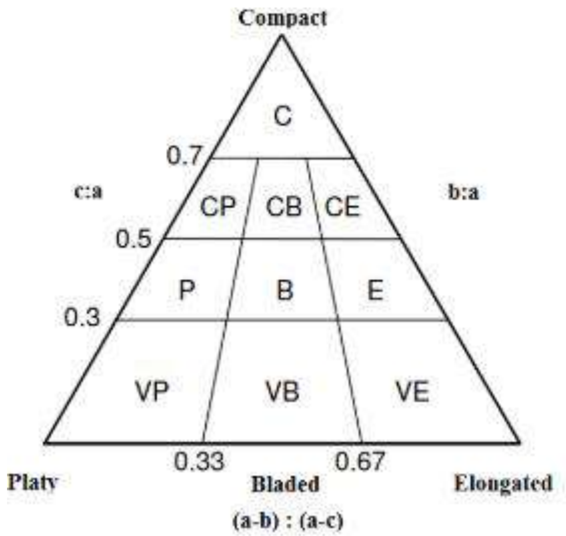
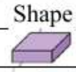
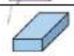


Figure 1: Form factor in Sneed and Folks diagram

Table 1: Form factor for Classification of Clast Shape

Form Factor	Classification	Shape
$F < 0.33$	Platy (P)	
$0.33 < F < 0.67$	Bladed (B)	
$F > 0.67$	Elongated (E)	

The degree of compactness, S, is also used to categorise the particle forms into orders, but differently. For example, when S is more than 0.7, a sphere-like arrangement is produced, and when S is between 0.5 and 0.70, the shape is somewhere between compact platy and bladed or elongated. The particles are extremely platy, bladed, or elongated if S is less than 0.3 or 0.5. If S is less than 0.3, they are classified as very platy

RESEARCH METHODOLOGY

The sample was collected at three locations, the upper, intermediate and lower stream of Lepoh River, with 300 samples. Then, the samples were measured for their dimensions and recorded into the spreadsheet for generating Sneed and Folks diagram. The result obtained was studied to classify the shapes and sizes of gravel-bed rivers using the Sneed and Folks diagram.

To determine the shapes and sizes of a gravel-bed river using a triangular diagram plotting spreadsheet known as Tri-Plot. The sample was collected from the Lepoh River. Therefore, setting up the experiment involved three parts: data entry area, plotting parameters area, isoline values area, Sneed and Folks classes' area and calculation area. First, enter the dimensions of each clast axes (a, b and c) into the data entry table after measuring the clast.

Next, identify the frequency and size of tick marks in plotting parameters, then proceed with isoline values. A minimum of ten data are required to enter the isoline tables for oblate-prolate isoline values and maximum projection sphericity isolines. Then, a specified amount and per cent are entered into the Sneed and Folks classes before Sneed and Folks diagram is fully generated. The data is for shapes of the gravel-bed river and to proceed with the same steps of finding the gravel size.

RESULTS AND DISCUSSION

Figure 2 shows the distribution of form factors in the Sneed and Folks diagram for three locations: the upper, intermediate and lower stream. The shapes and sizes of the particles vary significantly for each location caused by the erosion of water velocity. Hence, the collected data of a, b and c were calculated using Equation 1 to obtain the compactness ratio, elongated and form factor. The highest distribution of form factors at the upper stream is bladed classes (18%), at the intermediate stream is bladed classes (25%), while at the lower stream is compact bladed classes (25%). The deformation of grain shapes indicates the water velocity influence the shape of the grain.

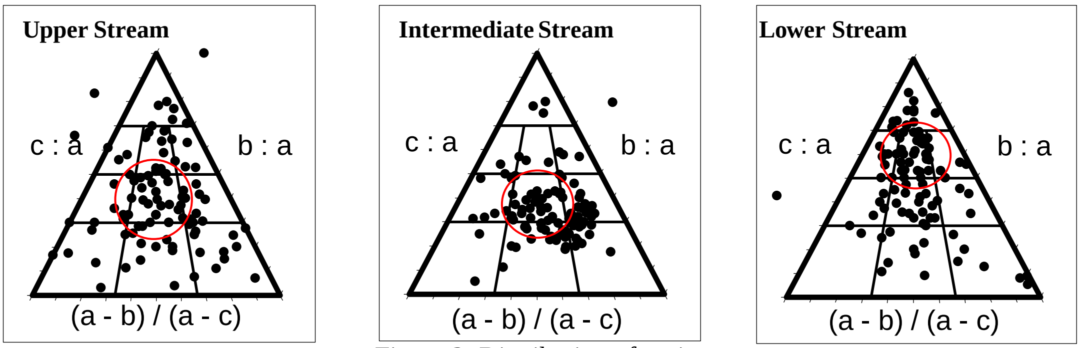


Figure 2: Distribution of grain classification

Next, Figure 3 shows the total amount of grain samples at different locations. The highest samples collected in the upper stream is a medium boulder (MB) with % and followed by the lowest with 0 grains for sand (S), very fine gravel (VFG), fine gravel (FG), medium gravel (MG), coarse gravel (CG) and very large boulder (VLB) and bedrock (B). Next, the highest samples collected for the intermediate stream are small cobble with 25 grains and 0 for sand, very fine gravel, fine gravel, medium gravel, coarse gravel and bedrock. However, it is vice versa for the lower stream, the highest number of samples collected is 20 for sand (S), and the smaller number of samples is 0 for large cobble (LC), small boulder (SB), medium boulder (MB), large boulder (LB), very large boulder (VLB) and bedrock (B).

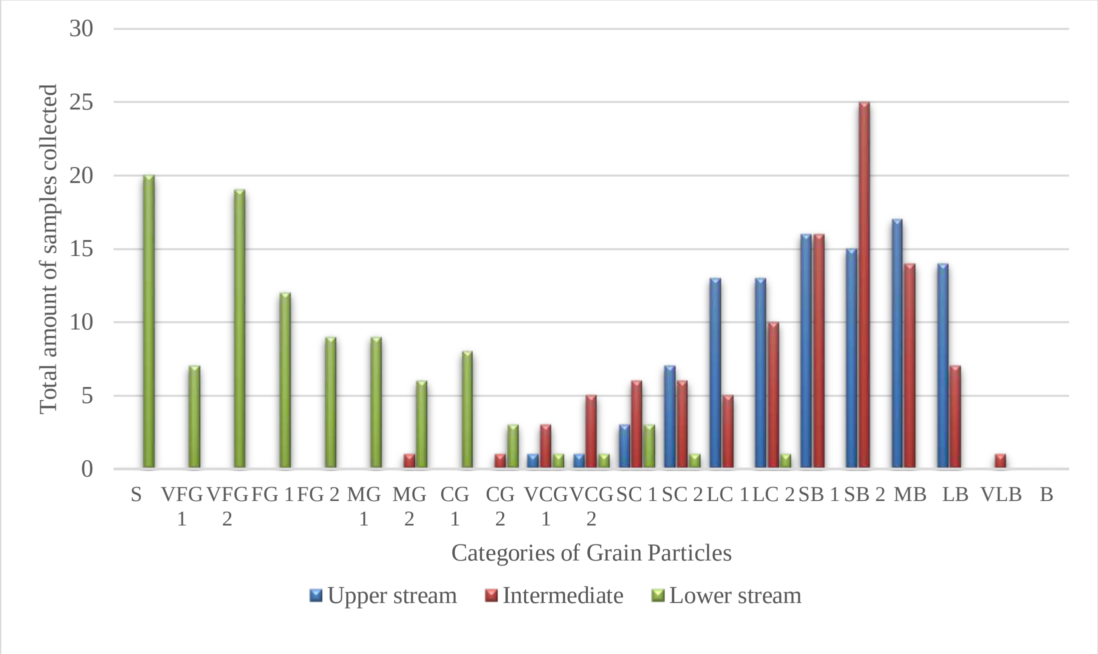


Figure 3: Distribution of grain particles associated with upper, intermediate and lower stream

Hence, the results show that the shape and size of grains vary depending on the location of the stream, which is influenced by the flow of water. The erosion becomes harder and more severe as the velocity of the water increases; however, water flow velocity decreases due to friction along the streambed, where it is slowest at the bottom and edges and fastest near the surface and in the middle. Furthermore, because the grains were transported over a short distance after being broken down from the crushed rock and did not roll very well, the grains became lighter as erosion occurred to the grains. Because of friction between the water and the air, the velocity below the surface is usually slightly higher than at the surface.

The samples collected show that the highest percentage of grains at the lower stream is the cobbles with 55%, followed by the intermediate stream with 50% for the boulders and lastly lower stream with 86% of gravel. It can be seen that the grain particles are significantly affected by the velocity of the stream. The results show that boulders and cobbles predominate upstream compared to downstream. The proportion of cobbles and boulders in the river decreases as it flows downstream, while the proportion of smaller-sized materials increases. Because of the dominance of bed materials and the high elevation, the discharge of upstream flow is greater than downstream. As the particles travel over time, they are worn down by the water or other particles, and their size decreases. The swift water will carry the smaller rocks and sand to the lower elevation. Therefore, the conclusion is in line with the previous research (Franzi, 2013; Haron, 2018; Yang, 2019), where the shapes of grains are larger and bladed at the upper stream while platy and bladed for grains at the lower stream.

Upper stream and intermediate stream obtained the highest percentage of bladed particles with 18% and 25%, respectively followed by very bladed particles with 17% and 23%. Generally, the increased numbers of grains collected were related to the water flow. Since the stream brings the grains, the shape is also affected due to the flow velocity from one place to another. However, it is different for the lower stream as it obtained the highest percentage of compact bladed with 25%, followed by bladed particles with 19%. After being broken down from the crushed rock, the particles were transported over a long distance. As a result of the abrasion, the particles become more compact.

CONCLUSION

From this study, it can be seen that the water flow influences the shapes of grains and the results show that in the upper stream, the grains are larger while the upper stream is smaller. It is concluded that each location has different shapes and sizes of grains affected by the water flow. The maximum percentage for shapes at the intermediate stream is 25% for bladed, followed by 25% at the lower stream for compact-bladed.

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COMPARISON OF SLOPE STABILIZATION ANALYSIS METHOD BY USING CHANGING GEOMETRY AND SOIL NAILING FOR SLOPE FAILURE

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ABSTRACT

Slope stability analysis is the process of analysing the stability and safety of a particular slope, assuring that the pertaining slope is safe for the human surrounding and any related construction activity. SLOPE/W of Geostudio software was utilised in this study to determine the factor of safety (FOS), both before and after slope stabilisation work was applied. Laboratory tests such as the Atterberg Limit, Moisture Content, Sieve Analysis, and Hydrometer tests were carried out to determine the physical characteristics and parameters of the slope. From Ordinary and Spencer methods, the slope's FOS values before stabilisation were 2.965 and 2.985. Then, using Changing Geometry method, both FOS was increased to 4.536 and 4.632, respectively. The same slope was analysed using Soil Nailing, and the FOS value were results 3.972 and 4.205 for Ordinary and Spencer's methods, respectively.

Keywords:
Key words: Slope stabilisation, Factor of Safety (FOS), SLOPE/W, Ordinary Method, Spencer Method, Changing Geometry, Soil Nailing.

INTRODUCTION

Slope failures are common phenomena in a tropical country like Malaysia, characterized by a humid, tropical region and thick weathering profile. The increase in construction industry development has mugged and progressed heavily into hilly areas which has resulted in Malaysia being exposed to frequent landslides and several major slope failures, which have caused damage and inconvenience to the public. Thus, as a mitigation measure, it is crucial to undergo a reliable slope stability analysis so that such an event does not repeat in the future. Besides understanding the importance of slope analysis, we also need to know the causes of slope failures to propose suitable repair work. The FOS from slope stability analysis can classify the slope hazards for the slope area according to Farazi et. al (2018). It is important to do analysis for the slope failure in order to get the finding and give the suggestion of slope stabilisation method. The three main objectives of this study are first to determine the physical properties and parameters of the slope. The second objective is to identify the FOS during failure, and the third objective is to identify the FOS after the proposed slope stabilisation work. The laboratory tests such as the Atterberg Limit test, Moisture Content test, Sieve Analysis and Hydrometer test were conducted to achieve the first objective. Then, the results obtained were used as an input for soil properties, and the software analysis using SLOPE/ W of GeoStudio software was carried out. The slope area chosen for the slope stability analysis was Infrastructure University Kuala Lumpur (IUKL) in Kajang**.**

LITERATURE REVIEW

The resisting force is defined by the cohesion times as the area of the failure surface plus the frictional shear strength were determined using the effective normal stress on the failure plane according to Suman (2014). In addition, the driving force on other hand is defined as the sum of the component of the weight, water forces, and all other external forces acting along the failure surface. All these factors and component as mentioned from the previous researcher was carried out for this study. The slope stability The SLOPE /W of GeoStudio software was used as the method and model for the research analysis and Limit Equilibrium (LE) analysis was used for its simplicity and accuracy in calculating the FOS. These methods use the concept of cutting the slope into fine slices and applying an appropriate equilibrium equation (the equilibrium of forces or moments) in calculating the FOS. Over the years, many improvisations and alternatives have been proposed in these equilibrium equations, such as the Fellenius and Bishop methods. Besides that, SLOPE W is GeoStudio software to determine slope safety in assessing slope stability. SLOPE/W can be used to compute FOS for discrete shear surfaces, such as circular, non-circular and user-de fined surfaces for various shear surfaces. Then, FOS is the ratio of resisting force to driving force, where resisting force is the force preventing the sliding while driving force is the force that causes the sliding of the slope. In this study, SLOPE/W with LE method was used with the Ordinary and Spencer analysis method for the equilibrium equation to calculate the FOS for each analysis.

To use the LE method using SLOPE/W, specific laboratory tests such as the Sieve Analysis test, Hydrometer test, Moisture Content test and Atterberg Limit test were carried out to determine the physical properties and parameters of the slope. The hydrometer test and sieve analysis test were to determine the particle size distribution of the soil and the type of soil on the slope as the Moisture Content test was to determine the unit weight and the Atterberg Limit test to determine the cohesion and angular friction of the soil covering the slope, which the data will then be used as an input for SLOPE/W software. Hence, once the laboratory test was completed, the software analysis using the SLOPE/W was done to determine the FOS of the slope during failure using the Ordinary and Spencer analysis method. With the value of FOS during failure as a benchmark, two types of slope stabilisation work, such as the Changing Geometry method and Soil Nailing, were proposed to increase the stability and safety of the slope. A Changing Geometry method is converting the slope from steeper to gentler by trimming the slope or reducing the extra load applied on the slope, while Soil Nailing is constructed to withstand or resist against downward forces or pushing forces of soil masses. According to Shiferaw (2021), the method of Changing Geometry consider as one of the type chosen for the slope stabilaization work. Then again, the FOS will be computed using SLOPE/W to compare on stability increase of the slope due to the proposed stabilization work.

METHODOLOGY

This study is divided into three (3) parts. Where the first part was the site visit, at the site of the slope, it is being investigated was visited to determine the slope parameters and to obtain the soil samples to conduct laboratory tests. Then, the second part was the laboratory test, where the soil sample obtained from the site visit was used to conduct four (4) laboratory tests: the Sieve Analysis test, Hydrometer test, Atterberg Limit test and Moisture Content test. The laboratory test was conducted to determine the physical properties and parameters of the soil sample taken from the slope, which was then used as an input in computing slope stability analysis through the software SLOPE/W. Lastly, the third part was the software analysis to compute the FOS of the slope during failure and after applying slope stabilization work by using the data obtained from laboratory tests as input parameters. In the software analysis, SLOPE/W of Geo-Studio software was used with Limit Equilibrium (LE) method and Ordinary and Spencer as the analysis method under LE for FOS computation. The two (2) types of slope stabilization work proposed were the changing geometry where the height/elevation of the slope was reduced, and the second type of remedial work was the retaining structure, the application of soil nailing. The software analysis was initially conducted on a trial and error basis, with around 15 trials for each section to determine the most approximate parameter and properties to be used for accurate analysis results.

RESULT

LABORATORY TEST RESULTS

The **Table 1** below shows all the results obtained from the four (4) laboratory test conducted which was to determine the physical properties and parameters of the slope and the required outcome that has been used as an input in the software analysis.

Table 1 Physical Properties Result

Determination	Experiment	Result	Outcome
Type of Soil	Hydrometer & Sieve Analysis test	76% silt	**Silty soil**
Type of Soil	Moisture Content test	W=40%	**Soft Clay**
Unit Weight of Soil	Moisture Content test	Dry Unit Weight, γd= 11.5-14.5kN/m^3	**Unit weight,γ=18.2kN/m^3**
Plasticity	Atterberg limit test	LL=52, PL=33 and PI=19	**MH(Silty soil with high plasticity)**
Angular friction	Atterberg limit test	Medium dense, 36° to 42°	**40°**
Cohesion	Atterberg limit test	5 to 10 kN/m^2	**8kN/m^2**

The **Table 2** below shows the particle size distribution of soil for the slope failure that has been tested.

Table 2 Physical Properties Result

Type of soil	Clay<0.002mm	0.002mm<Silt<0.063mm	0.063mm<Sand<2m	Gravel>2mm
Percentage	4%	76%	20%	0%

As shown in the above **Table 1** and **2**, through the Hydrometer test and Sieve analysis test the type of soil has been ascertained as the silty soil with the detailed description on the soil tested. Where 76% of the soil was tested to be silt hence, the type of soil finalized as silty soil. Then, through Atterberg Limit test, the Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) of the soil has been identified, through which the soil type was further detailed as Silty Soil with High Plasticity (MH). Through Atterberg Limit test also the angular friction, phi (φ) was finalized as 40° with cohesion, c=8 kN/m^2. Besides that, from the Moisture Content test the soil was seen to exhibit the nature of soft clay and the Unit weight of the soil was identified as 18.2kN/m^3.

SOFTWARE ANALYSIS RESULTS

Below are the results obtained from the SLOPE/W software analysis using the Limit Equilibrium method for both the Ordinary and Spencer analysis method in computing the FOS of the slope. **Figure 1** shows the results obtained for all the software analyses, the results of FOS of the slope during failure, FOS value of the slope after the application of slope stabilization work for Changing Geometry where the slope height or elevation was decreased from 2.5m to 2.0m and for soil nailing remedial work for both Ordinary and Spencer method of analysis. From this, the FOS of the slope during failure was determined as 2.965 and 2.985 for the Ordinary and Spencer method. Then, the FOS of the slope after the application of remedial work the Changing Geometry was an increase in FOS to 4.536 and 4.632 and for Soil Nailing also there was an increase in FOS to 3.945 and 4.205 for both Ordinary and Spencer method of analysis from 2.965 and 2.985 during failure indicating an increase in stability of the slope.

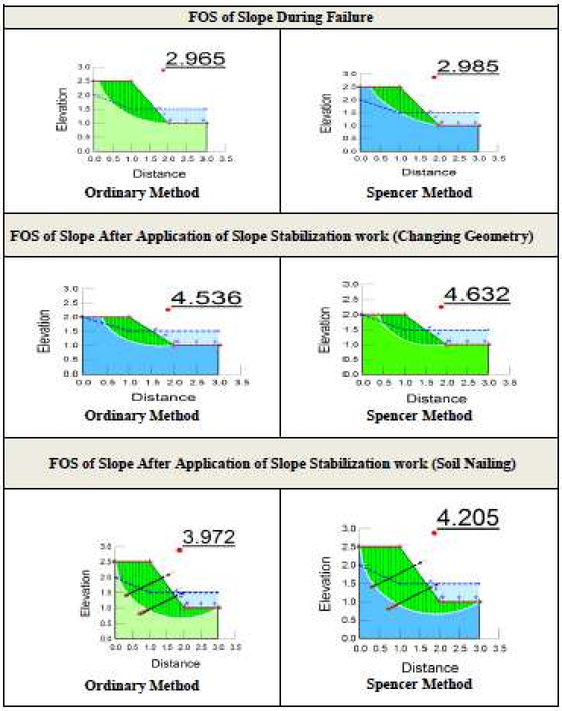

Figure 1 FOS Result based on Slope/ W software analysis

DISCUSSION

The discussion is summarized as shown in **Table 3** below, with an overall summary of all the results obtained from this study. The laboratory test conducted on the soil sample taken from the slope, the soil's physical parameters and properties were ascertained with the soil being classified as silty soil with a little mix of clay and the soil was further classified as silty soil with high plasticity (MH) based on Atterberg limit test by using the plasticity chart. The data obtained from the Atterberg limit test, the frictional angle of the soil was then gauged to be between 36°- 45° from the SPT table for angular friction, with silty soil being classified as soil with medium dense relative density from which phi 40° chosen as an input for software analysis. Besides that, with the soil being tested having a plasticity index of 19%, the soil was classified as cohesive soil with a high degree of plasticity. Hence, the cohesion c of the soil was classified between 5 to 10 kN/m^2 with 8 kN/m^2 chosen for software analysis input. For moisture content test, the moisture content of the soil is identified as 40% from which the unit weight of the soil has been computed as © = 18.2 kN/m^3.

Apart from that, with these physical properties and parameters of the slope soil used as an input, the FOS value is computed using SLOPE/W software. Where the FOS value of slope during failure for both Ordinary and Spencer methods of analysis was identified as 2.965 and 2.985, this FOS value, if compared with the minimum allowable FOS of 1.5 based on the JKR (PWD) guideline, indicates that the slope is safe. Still, in reality, the slope is undergoing what is known as spot failure, the initial stage of failure such as soil erosion, instead of visible massive failure such as translational or rotational failure. Hence it was logical for the value to be more significant than the minimum FOS. Thus, these 2.965 and 2.985 will be used as the failure threshold for this research from here onwards. Any FOS value less than this indicates slope failure, and any value more than this is to be gauged as safe. As for the FOS after the application of slope stabilization work, as a result of reducing the slope height from 2.5m to 2.0m for the geometrical method, the FOS value has increased from 2.965 to 4.536 for the Ordinary method and from 2.985 to 4.632 for Spencer method, improving the slope stability by reducing the steepness of the slope. Apart from that, by using soil nailing reinforcement, the stability of the slope has been increased, which can be ascertained by the increase in FOS value from 2.965 to 3.972 for the Ordinary method and from 2.985 to 4.205 for the Spencer method.

Table 3 Overview of Discussion

Properties	Condition during Analysis	Analysis method	Result FOS	Outcome	Remarks
Unit weight, γ= 18.2 kN/m^3 Angular friction, phi (φ) = 40° Cohesion, ć = 8 kN/m^2	During failure	Ordinary	2.965	-	-
		Spencer	2.985	-	-
	After the application Slope Remedial work				
	Changing Geometry	Ordinary	4.536	4.536>2.965	OK!
		Spencer	4.632	4.632>2.985	OK!
	Soil nailing	Ordinary	3.972	3.972>2.965	OK!
		Spencer	4.205	4.205>2.985	OK!

CONCLUSION

Based on the laboratory experiments conducted, the physical properties and parameters of the soil sample taken from the research slope have been successfully identified. The soil is classified as silty soil (76%) with plenty of clay mixture. Besides that, based on the liquid limit value (LL) and plastic limit value (PL), which were 52% and 33%, respectively, the plasticity index value (PI) was determined to be 19%. Hence, from the plasticity index (PI) and liquid limit (LL) value, the soil sample was further classified as (MH) silty soil with high plasticity; thus, with this parameter, the angular friction value and cohesion property of the soil was further computed, where phi (φ) is finalized as 40° and cohesion, ć as 8 kN/m^2. Apart from that, the moisture content of the soil sample tested was computed to be 40%, hence through which the unit weight, © of the soil sample is calculated as 18.2kN/m^3.

Furthermore, from the software analysis conducted to determine the FOS of the slope during failure using SLOPE/W, the FOS has been identified as 2.965 and 2.985 for both Ordinary and Spencer methods, respectively, which is higher than the minimum allowable FOS by PWD guidelines indicating that even though based on the FOS the slope can be considered safe. Still, it is undergoing spot failure; hence if a structural loading is to be applied to the slope, the slope will undergo massive failure known as sliding. Thus, for the convenient purpose, the FOS value of 2.965 and 2.985 will be used as the threshold value of FOS for this research; any value less than this indicates slope failure, and any value above this indicates that the slope is safe for which the Spencer method of analysis will be more preferable as it is more realistic and accurate as it considers both the force and moment parameter. Then, the FOS after applying slope stabilization work was identified as 4.536 for Ordinary and 4.632 for Spencer for the Changing Geometry work. While, for the Soil Nailing method, the FOS is computed as 3.972 for the Ordinary method and 4.205 for Spencer's method, respectively, using the SLOPE/W software. From both the analysis, the stability of the slope increases, which is vividly visible through the increase in the FOS value from the application of slope stabilization work, making the slope more stable and safer for use and the surrounding activities.

AUTHOR BIOGRAPHY

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INVESTIGATING TIMBER BEAM BEHAVIOR IN TWO-DIMENSIONAL STANDARD FIRE EXPOSURE: A FINITE ELEMENT MODELING APPROACH

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ABSTRACT

This study explores the fire behavior of timber beams subjected to two-dimensional (2-D) standard fire exposure. This paper conducted simulation tests on eight beams of varying sizes and exposure durations to a three-sided fire. The finite element software, ANSYS, was employed to predict and analyse the fire behavior of these beams. It was found that as the size of the beam decreases, its fire behavior also diminishes, with the reduction ratio similarly decreasing. Based on main findings, it was revealed that under a temperature distribution of 945.3oC for a duration of 90 minutes, the fire data from the 60 minutes clearly indicated that the beams with dimension size 75mm×100mm×1000mm could no longer withstand the conditions. The samples were completely charred after 67 minutes and 75 minutes, respectively. The beam with dimensions 100mm×150mm×1000mm, while not entirely burned, was deemed a failure as it was nearly fully consumed by the fire. At this temperature stage, it was also observed that the beam measuring 100mm×200mm×1000mm exhibited less resilience compared to the beam of dimensions 125mm×150mm×1000mm.

Keywords:
ANSYS, Finite Element Modeling, 2-D Standard Fire, Fire Behavior, Timber Density, Mengkulang Timber

INTRODUCTION

Timber structures is one of ancient structures element with human since time immemorial. As a natural and sustainable structure material, timber has a good and great environmental property. The energy required to change over trees into wood and thus into structural timber is altogether less than that required by another structural materials, for example, steel and concrete. Concrete and steel structures are much more expensive than timber structures.

Researchers started to look for the fire behavior of timber structure in the 1960s which have created systemic research methods in 1970s. By the 1990s, a large number of researches in this field have been carried out, and leaded to great achievement. Further in the latest years since 2000s the researchers done more researches in that field (Aseeva et al., 2014).

Timber has more ability for fire than other materials such as concrete or steel. Given this information, researchers are diligently examining the fire behavior of timber (Kathinka Leikanger Friquin, 2010). It is founded that there are no enough tests have been conducted to the fire performance to the timber either for beams or for columns (Bobacz, 2008).The reasons of this lack of tests and experiments is due to many reasons such as the high cost, materials that needed to be used and the equipped place to conduct the tests and experiments needed.

Therefore, researchers have created and found out an alternative method to investigate the behavior of the timber under the fire. One of the methods is by conducting a software analysis programs to predict the performance, endurance or behavior of timber under the fire.
This research used a specimen of solid timber from Mengkulang species (Heritiera spp.) which is considered a hardwood with a normal density of 750kg/m³. It has been selected because that is widely used in Malaysia buildings and structures that made from solid timber.

This research also employed software to examine the fire performance of timber beams under two-dimensional fire exposure. The study also aimed to investigate the fire behavior of timber beams of varying sizes and exposure durations and to examine the residual cross-section of the timber beam post-fire exposure, which is crucial for design purposes.

Software Analysis

This paper utilized ANSYS software to carry out the tests on timber beams subjected to 2-D fire exposure. ANSYS is a computer-based program designed to simulate a wide range of engineering problems. It facilitates the creation of simulated models for various entities, including structures, machine components, and electronics. The primary objective of using ANSYS is to simulate or identify various properties such as strength, thermal heat, elasticity, toughness, and electromagnetism. It also aids in understanding fluid flow, temperature distribution, among other functionalities.

A study from the finite element modeling (FEM) had shown that the performance of the beam is decreasing when the load level increase and the ratio of the reduction will turn smaller. At the point when the load level is higher than 0.5, the performance of the fire is going to be very small (Bilbao et al., 2002). His finding shows that the larger the density of the material, the less the section temperature is at the similar position and more slowly the section temperature increases.

Another study stated due to the negligible differences between 1and 3 mm mesh sizes, as compared to 6 mm, it is recommended that an initial mesh size of 3 mm is used for simple heat transfer analyses in timber, to ensure accuracy while saving on computational time (Lizhong et al., 2007). Furthermore, Babrauskas in 2005 introduced a comprehensive model for analyzing the behavior of solid timber beams exposed to standard fire conditions within the framework of ANSYS software. The outcomes derived from this model exhibit a remarkable level of agreement with experimental data, demonstrating the model's efficacy in simulating the real-world behavior of timber beams under fire exposure. It was shown that not only the predicted temperature profile but the profile of the formation of char has very good agreement with the actual data.

Standard fire curve (ISO – 834)

ISO – 834 is the standard temperature-time curve, it is also called cellulosic curve or standard nominal fire curve (Figure 1). The curve is used to test and check the resistance of material under fire (Friquin et al., 2010). The standard fire curve is typically represented as a graph that shows how temperature within a controlled fire environment changes over time. The curve follows a specific pattern, with temperature rising at a relatively steady rate for a specified duration, usually up to a certain peak temperature. The curve is designed to mimic the thermal conditions that might occur in a real building fire.

The standard temperature-time curve is visually represented as a graph illustrating the evolution of temperature within a controlled fire environment over a specified duration. This curve adheres to a well-defined pattern, with temperature exhibiting a gradual and consistent ascent until it reaches a predetermined peak temperature. The careful orchestration of this curve is essential as it endeavors to replicate the thermal conditions that would be encountered in a real-world building fire scenario (R. , Aseeva et al., 2014; Bobacz, 2008).

The expression that used to define the standard temperature-time curve is:

$$T = T_o + 345 \log10 (8t + 1)$$

(Friquin et al., 2010)
To express about the initial furnace temperature (°C)

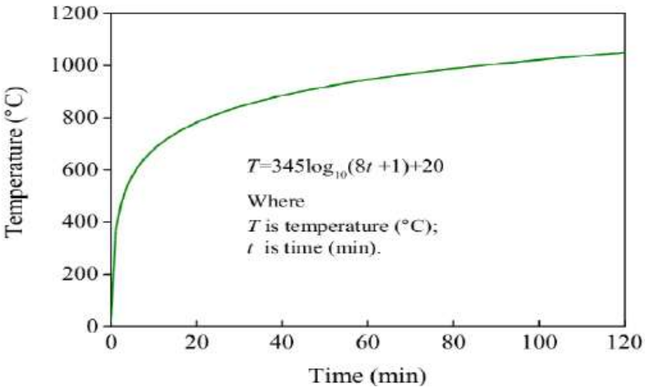

Figure 1: Standard fire temperature-time curve ISO 834 (Kathinka Leikanger Friquin, 2010)

Fire Resistance of Timber

Fire resistance evaluations of timber members are usually established by performing a full-scale test based on standards of specifications such as EC5, ISO 834, ASTM E119 or other test of similar standards (Tsai, 2010). During the fire test, the use of thermocouples helps researchers to observe and study the conditions and behaviors of timber especially during exposure to fire. Usually, thermocouples are inserted at different depths within the specified range to observe the temperature (°C) until the fire test is discontinued.

Since the timber has varied densities, it is essential to investigate its fire response, facilitating a deeper comprehension of its behavior when subjected to fire conditions. This investigation, in turn, will furnish the researcher with valuable insights into the dynamics of timber's interaction with fire. Ultimately, by leveraging the data obtained from this ongoing study, the researcher will gain a comprehensive understanding of how solid timber, specifically varying in densities characteristic of Mengkulang, performs under fire exposure, as explained through advanced software analysis.

METHODOLOGY

This section describes and discusses the methods used in this investigation whereby software analysis was carried out to examine the fire performance under the standard fire exposure of solid timber from Mengkulang. The specimens were exposed on three-sided fire exposure to the standard fire curve according to ISO 834 fire curve.

Eight models of beam from density of Mengkulang Malaysian tropical hardwood have been tested according to ISO 834 fire curve temperature. In conducting the fire performance all of the eight samples were exposed to the fire with a specified exposure period of 30 mins, 60 mins, 90 mins and 120 mins. The durations had been chosen based on the requirements of Uniform Building by Law (UBBL). In general, same experiments were carried out for each of models. The length of the beam model was constant at 1000 mm, while the dimensions of its width and depth vary, as depicted in Figure 2.

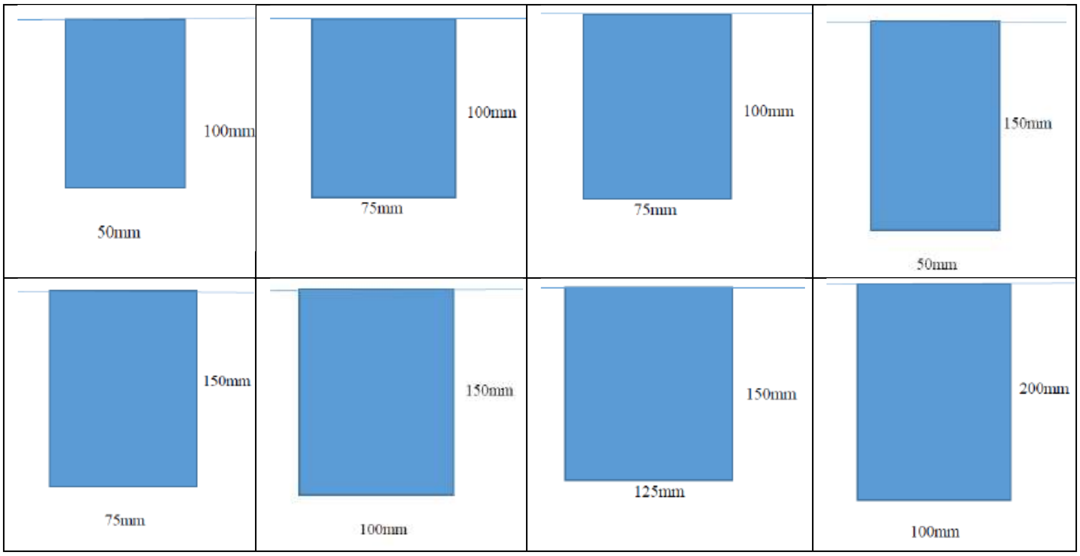

Figure 2: Models of beam size

Steps to Use ANSYS Software Analysis

In order to use ANSYS software analysis for heat transfer it was very important to know how to use the software. The general steps below are going to show how to use the software to determine the heat transfer in a timber beam model:

1. The ANSYS Workbench is downloaded and installed prior running the application.
2. The Engineering data is selected, before choosing the material used for the simulation.
3. After the material is chosen, find the materials needed in the library.
4. Then, the thermal conductivity and density of the selected material is identified.
5. Following that, the element is draw by selecting the geometry icon as shown in the Figure 3.
6. Model icon is selected to start the ANSYS mechanical and key in the required data.
7. After the ANSYS mechanical is started, select solid for the solid design element followed by meshing. The maximum meshing of 20mm was used in this study (maximum allowed meshing for ANSYS student version).
8. The button “solve” is click to run the meshing input on the design element.
9. After that, the steady thermal icon will appear.
10. Heat flux and convection was chosen from the list in the “insert” button followed by inserting the required data. Then, the “solve” button is click to run the input data.
11. Lastly, the “model icon” is clicked to re-open the ANSYS mechanical followed by “right click” on the “transient thermal” icon.
12. Then heat flux, convection, and the temperature parameters are chosen from the list under the “insert” icon. The data is inserted accordingly and press the “solve” icon to get the results as shown in Figure 3.

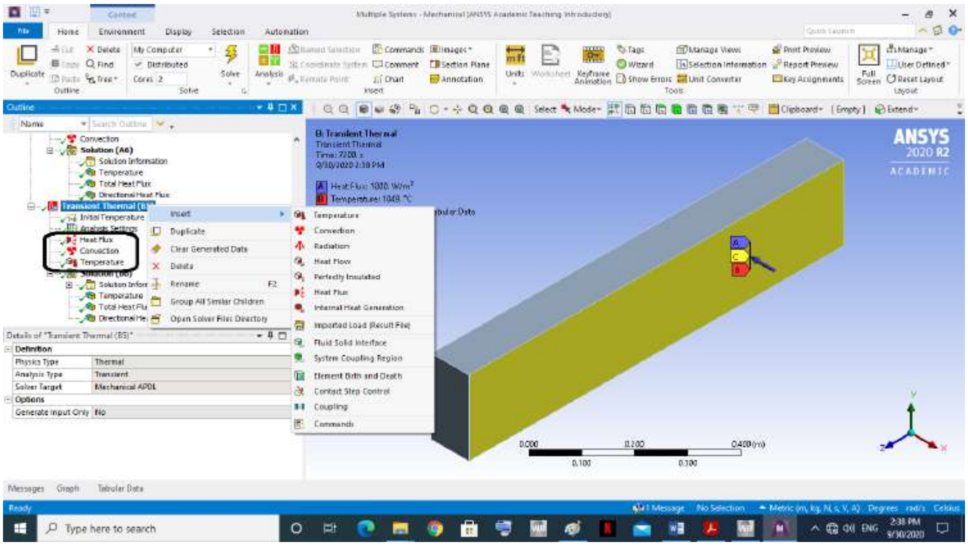

Figure 3: ANSYS mechanical page.

Mesh refinement was applied uniformly across all beams, with a prescribed mesh size of 20 millimeters (mm) due the student version of the software, which prevent the utilization of mesh sizes smaller than 20mm for beam elements. Steady-state thermal applied as well on the beam to express the weather temperature which have been applied with a value of 20℃ with a constant time. Transient thermal has been applied after that to express the increasing on the temperature with time. Standard curve for temperature and time (ISO 834) have been used to express the time and temperature. The temperature has been applied in a three-sides on the beam in order to find the fire performance of the beam under fire from three-sided fire exposure.

The cross section and axonometric view results of each beam is recorded in a different time (30mins, 60mins and 90mins). The simulation results of the tests have been recorded to differentiate between them and to find the most suitable beam that can survive longer under fire to enhance the safety of the buildings in the future.

RESULTS AND DISCUSSION

30 mins fire exposure

The results obtained from the heat transfer simulation, in conjunction with the empirical data gathered during a 30-minute fire exposure, yielded valuable insights into the structural performance of the beams under such conditions. Figure 4- Figure 11 below shows the beams after exposing it to the fire for 30-minute fire exposure.

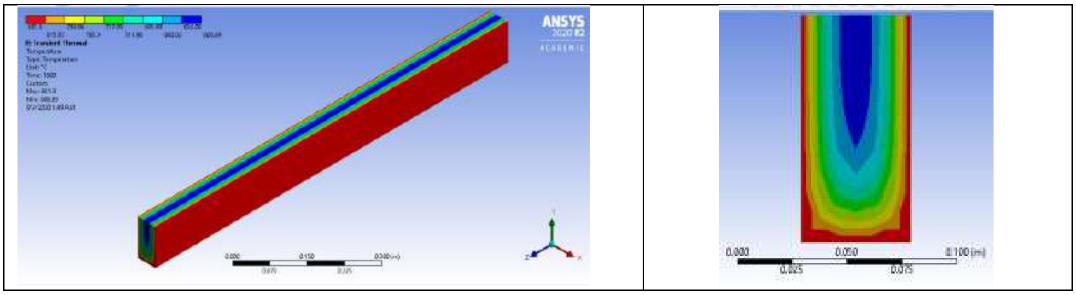

Figure 4: Temperature distribution of the timber beam size 50mm×100mm×1000mm

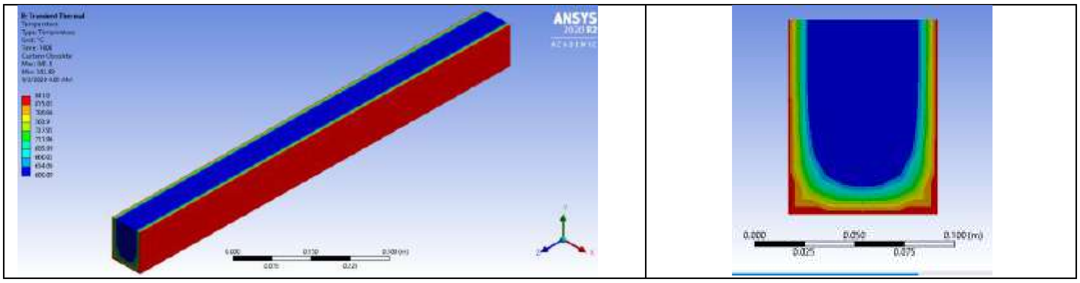

Figure 5: Temperature distribution of the timber beam size 75mm×100mm×1000mm

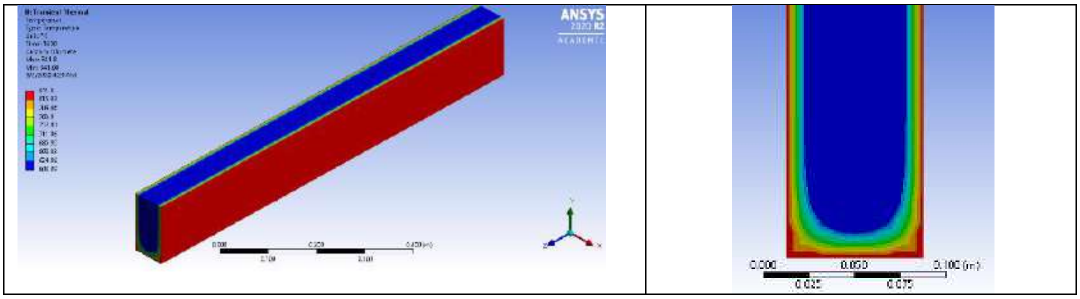

Figure 6: Temperature distribution of the timber beam size 50mm×150mm×1000mm

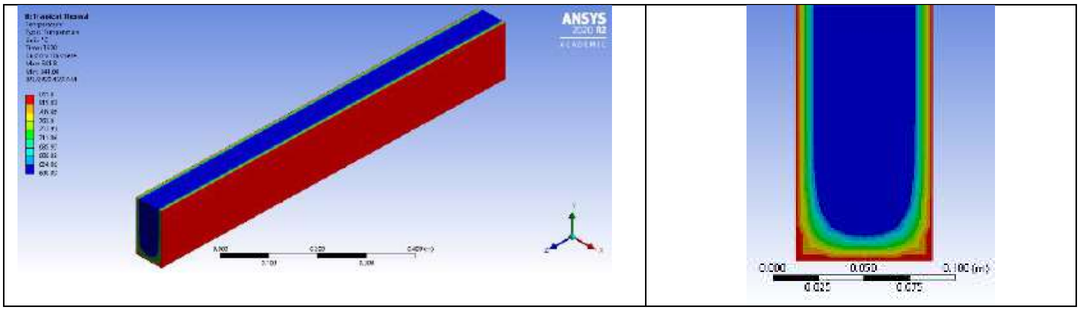

Figure 7: Temperature distribution of the timber beam size 75mm×150mm×1000mm

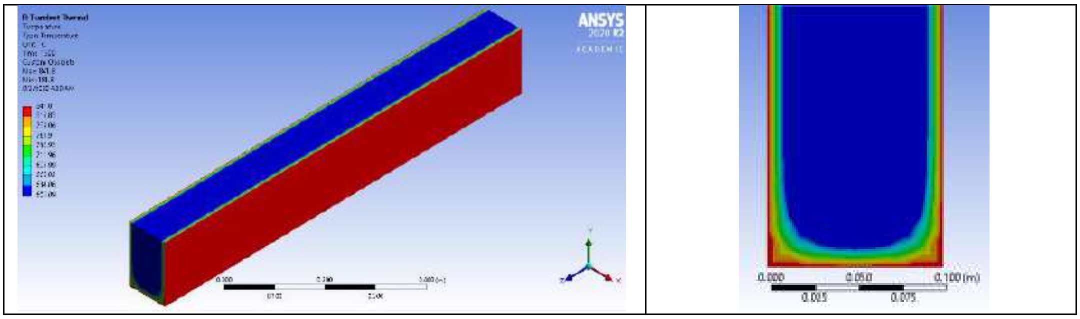

Figure 8: Temperature distribution of the timber beam size 100mm×150mm×1000mm

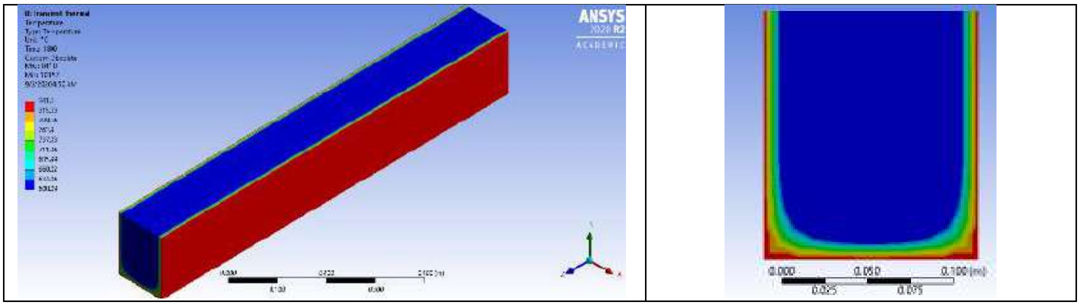

Figure 9: Temperature distribution of the timber beam size 125mm×150mm×1000mm

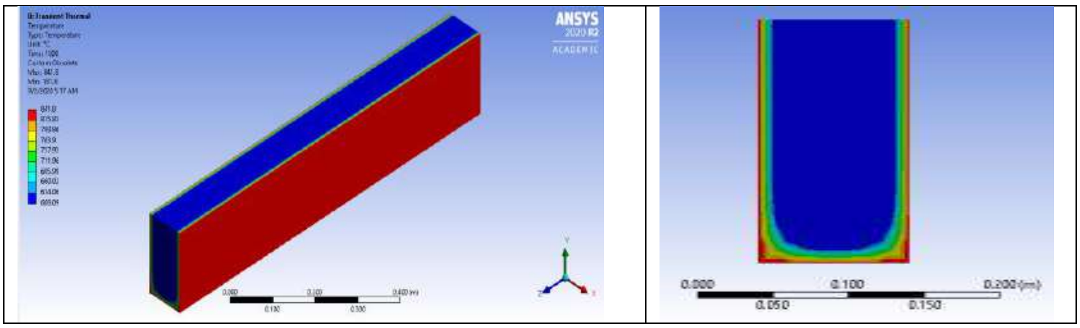

Figure 10: Temperature distribution of the timber beam size 100mm×200mm×1000mm

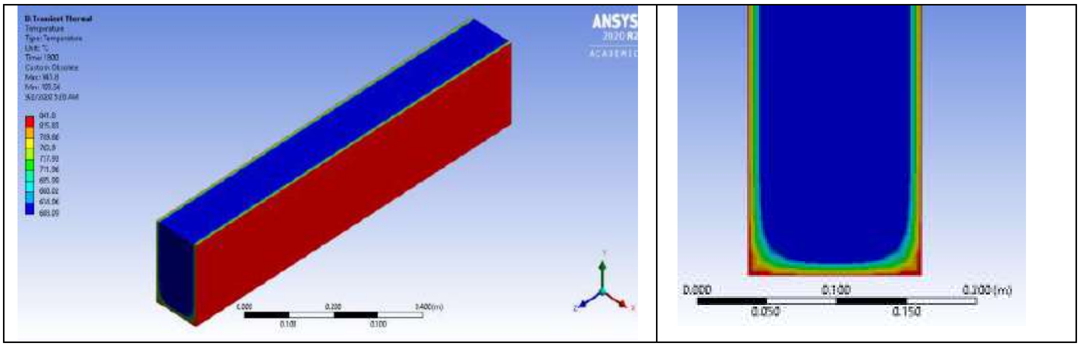

Figure 11: Temperature distribution of the timber beam size 150mm×200mm×1000mm

Notably, it was evident that none of the beams had undergone complete combustion within this timeframe. This outcome can be attributed to the limited duration of heat exposure experienced by the beams during the fire event as supported by Nelson Pine, 2003 & White et al., 2013. The primary reason for the beams' survival and lack of total burnout can be traced back to the thermal dynamics at play. The temperature distribution across the beams remained below critical levels during the 30-minute timeframe. Specifically, the recorded temperature distribution reached a maximum of 841.8^{o}C. This temperature observation was consistent with the established temperature-time curve outlined in the ISO 834 standard (Frangi et al., 2008). These findings underscore the significance of fire resistance measures in structural design and construction. The ability of the beams to withstand a 30-minute fire event without catastrophic failure showcases the effectiveness of timber fire-resistant properties and adherence to regulatory standards.

60 mins fire exposure

The subsequent figures (Figure 12-19) visually document the state of the beams after enduring a 60-minute exposure to fire. These images offer a comprehensive portrayal of the structural changes, damage, or resilience exhibited by the beams under the influence of intense heat and flames.

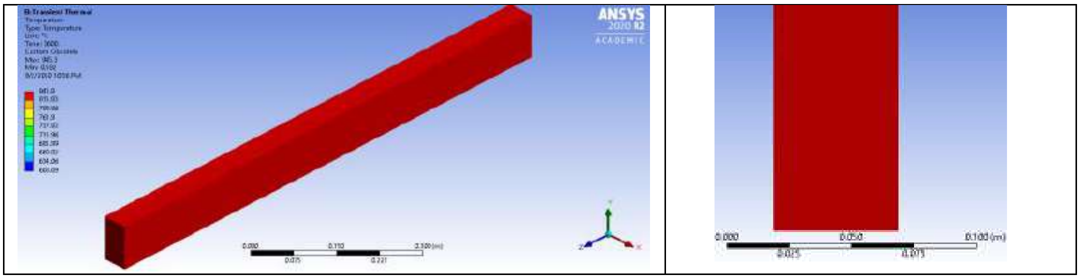

Figure 12: Temperature distribution of the timber beam size 50mm×100mm×1000mm

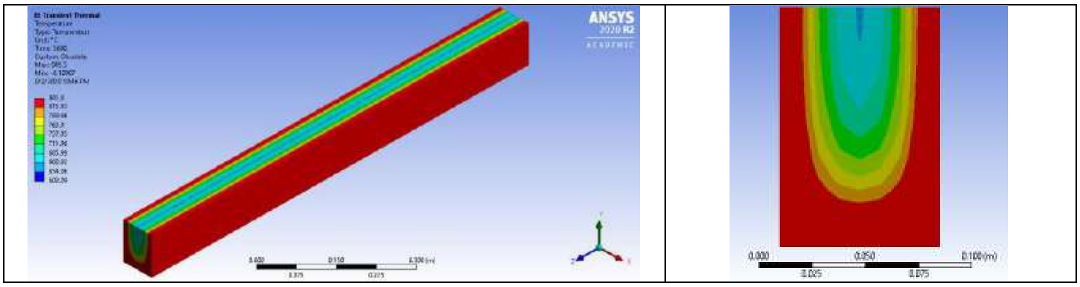

Figure 13: Temperature distribution of the timber beam size 75mm×100mm×1000mm

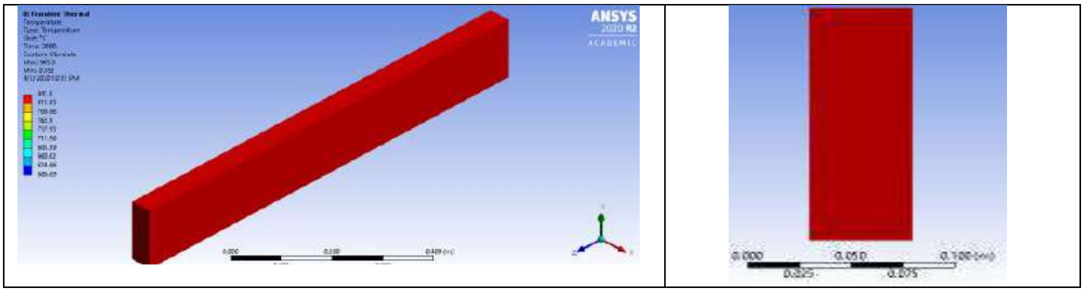

Figure 14: Temperature distribution of the timber beam size 50mm×150mm×1000mm

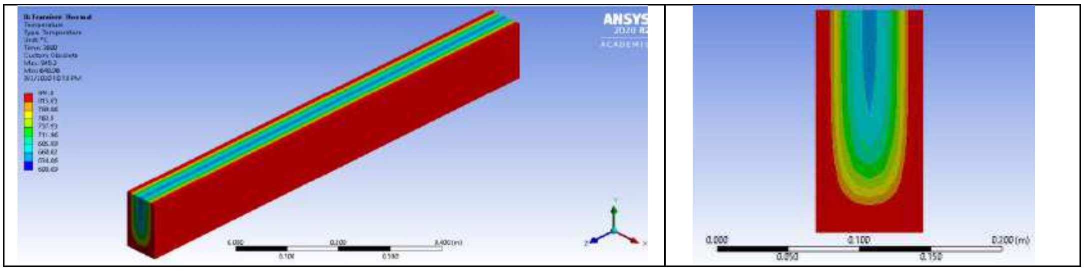

Figure 15: Temperature distribution of the timber beam size 75mm×150mm×1000mm

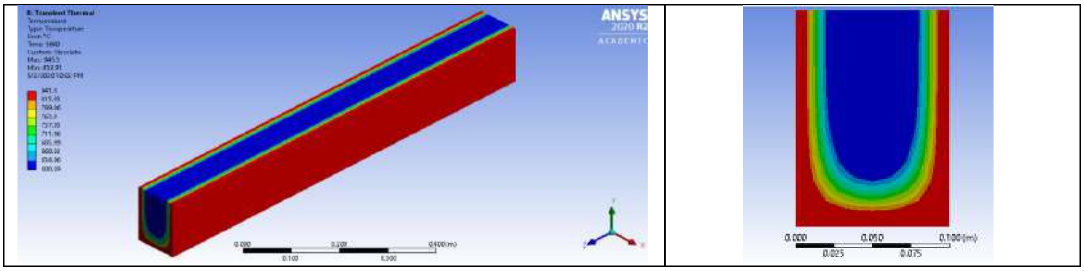

Figure 16: Temperature distribution of the timber beam size 100mm×150mm×1000mm

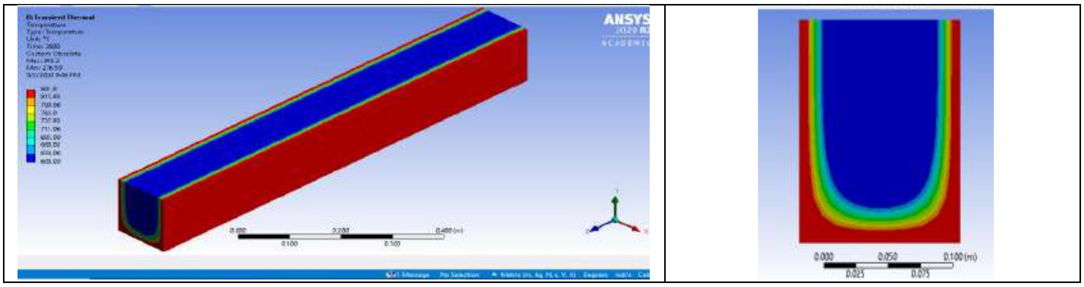

Figure 17: Temperature distribution of the timber beam size 125mm×150mm×1000mm

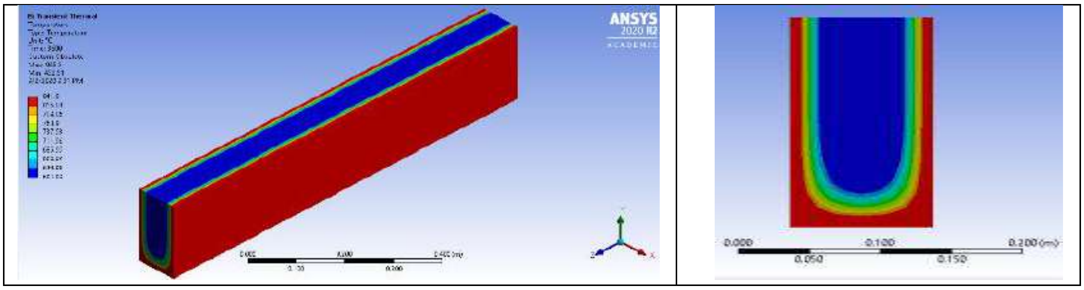

Figure 18: Temperature distribution of the timber beam size 100mm×200mm×1000mm

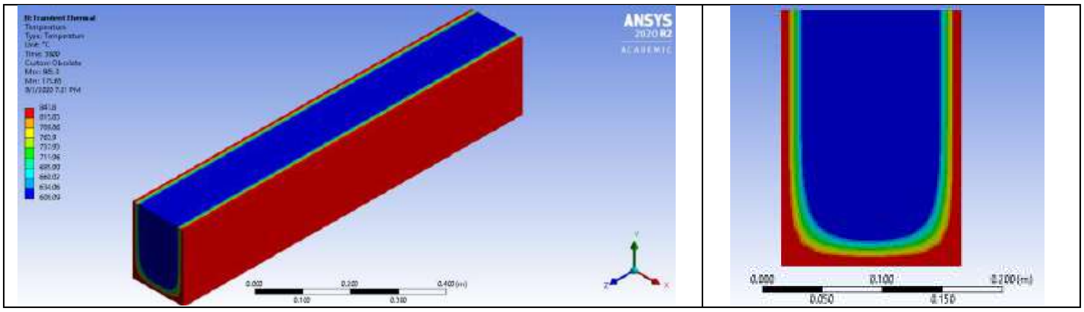

Figure 19: Temperature distribution of the timber beam size 150mm×200mm×1000mm

In the context of a 60-minute fire exposure, where the maximum temperature distribution reached 945.3°C, notable structural responses were observed among the beams under investigation. Several beams exhibited varying degrees of failure, with some succumbing to complete combustion while others displayed partial burnout. Specifically, considering the dimensions of the beam (50mm×100mm×1000mm), it became evident that this beam had completely burned by the 45-minute mark. Conversely, the beam with dimensions (75mm×100mm×1000mm) did not experience total burnout, but it reached a critical stage of degradation that would be classified as failure due to substantial heat-induced damage. Similarly, the beam (50mm×150mm×1000mm) exhibited complete burnout after 50 minutes of fire exposure. This finding is consistent with findings of previous study (R. Aseeva et al., 2014; Babrauskas et al., 2005; Wells et al., 2018).

The beam (75mm×150mm×1000mm) also neared total combustion, although its condition was slightly better compared to the (75mm×100mm×1000mm) counterpart. Notably, the remaining beams remained structurally sound and withstood the fire exposure, exhibiting no signs of significant damage or failure. These observations underscore the varying fire resistance capabilities of beams with different dimensions, shedding light on the critical threshold for structural failure in fire scenarios, which is essential for informing structural design and safety standards (Daud et al., 2015; Fahrni et al., 2017).

CONCLUSION

The findings and subsequent analysis within this research substantiate the acceptability and comparability of utilizing software for experimental testing purposes. Notably, the study explores the structural integrity of beams subjected to three-sided fire exposure and investigates the evolving cross-sectional characteristics of these beams in response to varying durations and temperatures of fire exposure. The software employed for this investigation was the student version of ANSYS, which, while a valuable tool, is associated with certain limitations, particularly in terms of result outputs and input data parameters. It is important to emphasize that this research has diligently adhered to the constraints imposed by the software, utilizing the maximum allowable input data to ensure comprehensive and accurate results within the software's capabilities.

One of the primary objectives of this research was to ascertain the performance and resilience of beams in a fire scenario, specifically the beams' ability to withstand three-sided fire exposure. The utilization of software facilitated the virtual experimentation necessary to investigate this phenomenon. The results obtained from this simulation-based approach provide valuable insights into the behavior of structural elements under fire conditions, contributing to the broader understanding of fire resistance in construction and engineering.

However, it is essential to acknowledge that while software simulations offer numerous advantages, the software inherently possess limitations stemming from their computational constraints and simplifications. Researchers must operate within these confines to ensure the validity and applicability of their findings. Nevertheless, within these boundaries, the study successfully achieved its objectives, offering valuable data and knowledge that can inform future research endeavors and practical applications within the field of structural engineering and fire safety.

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VALIDATION OF OUTER PLATE BOLTED GLULAM TIMBER CONNECTION IN FIRE

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ABSTRACT

A few hundred years ago, people began employing wood to construct buildings with ten stories or more. Today, wood is used extensively in architectural construction around the globe. With a contemporary design, the cost of full-scale testing for bolted glued laminated (glulam) connection experiments is very high and time-consuming. Therefore, using computer software to simulate the behaviour of the glulam connection will save time and money for the research. The results obtained from the computer software shall be within the acceptable margin of error. Finite element modelling (FEM) through Abaqus 6.14 software was used to simulate the behaviour of glulam connections under different conditions by modifying the test methodology and input parameters. Experimental results are used to validate the results from FEM so that the differences are compared. This research uses FEM to validate the results from the work of previous researchers on the tensile test without fire and heat test with constant load. The parameters are used to predict the behaviour of the model subjected to tensile load and heat.

Keywords:
Abaqus, FEM, glulam, tensile, heat

INTRODUCTION

Timber is a fibrous, rigid material of a plant origin. It is a valuable natural resource that can be used as a building material for construction and to make specialised wood goods like more astatic in the building. In modern construction language, the word "timber" is occasionally used to refer to wood that has been processed for use in building construction. Broadly speaking, it is divided into hardwood and softwood. Timber is natural and renewable. Even in situations when only basic techniques and procedures are available, it is extremely helpful because of its high strength-to-weight ratio and ease of usage (Apu, 2003). Timber remained the most common building material up to the second part of the 19th century, according to Douglas (1995).

However, accidents such as short circuits could happen anytime without warning so it is crucial for buildings to retain their structural integrity in order to prevent them from collapsing. Fire plays an important role in our life but a small careless mistake is all it takes to turn its surroundings into an inferno, making it a double-edged sword. When fire is in contact with timber or fibrous materials, they tend to spread very quickly, making it hard to control the situation. Structures constructed with timber should be kept away from inflammable sources as a prevention method of fire.

Due to the tendency of fire to spread quickly, the damage caused can be massive as well. A layer of carbon will form when timber is burnt. The member of the structure will lose its load capacity as the timber has turned into charcoal, which is weak and brittle. While the carbon layer is forming on the timber, it acts as a barrier that protects the remaining timber from fire. The formation of this carbon layer allows us to predict the rate of charring below the surface. Predicting the rate of charring is important in determining the strength of the remaining timber; therefore, the endurance of the structure can be determined.

LITERATURE REVIEW

The use of creativity in the domains of design, engineering, architecture, and construction management has grown significantly and, the Model of Architectural Information is another development in a normal environment (Lu et al., 2017a). In order to predict the tensile capacity of bolted timber connections in fire, the timber connections will be modelled with Abaqus 6.14 with the verification of FEM. The tensile behaviors of the outer plate bolted timber connection in fire is predicted after the FEM results are verified with experimental results.

RESEARCH METHODOLOGY

Finite Element Modelling

The FEM results are verified with the experimental results of bolted glulam connection shown in Figure 1. The material properties of the glulam beam are shown in Tables 1, 2, 3, 4 and 5 whereas the material properties of the steel sections are shown in Tables 6, 7 and 8.

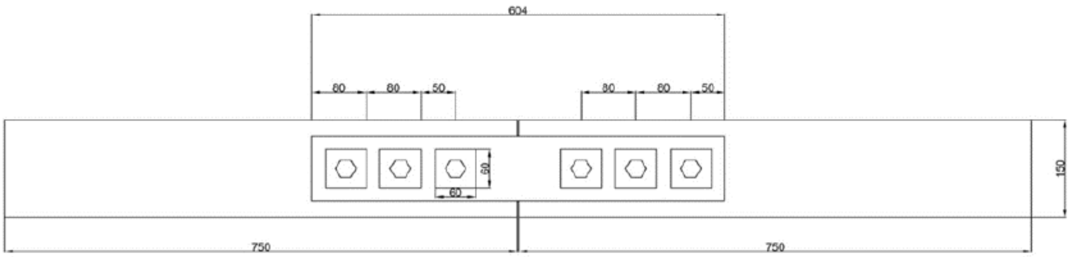

Figure 1: Details of the experimental test setup.

Table 1: Specification of glulam timber used in the research. (ISO Standard No. 834)

Species of Timber	*Heritiera* spp.
Density of Timber, ρ	650 kg/m^3
Modulus of Elasticity, E_1	14,300 N/mm^2
Modulus of Elasticity, E_2	1,144 N/mm^2
Modulus of Elasticity, E_3	715 N/mm^2
Shear Modulus, G_{12}	1,020 N/mm^2
Shear Modulus, G_{13}	960 N/mm^2
Shear Modulus, G_{23}	102 N/mm^2
Poisson's Ratio, ν_{12}	0.3
Poisson's Ratio, ν_{13}	0.2
Poisson's Ratio, ν_{23}	0.2

Table 2: Thermal properties of glulam beam. (ISO Standard No. 834)

Thermal	
Conductivity	Temp
0.12	20
0.12	50
0.12	100
0.12	150
0.12	200
0.15	250
0.15	300
0.15	400
0.07	500
0.07	600
0.09	700
0.09	800
0.35	900
1.5	1,200
Specific Heat	Temp
1.53	20
1.77	50
13.6	100
13.5	150
2.12	200
2	250
1.62	300
0.71	400
0.85	500
1	600
1	700
1.4	800
1.65	900
1.65	1,200

Table 3: Density of glulam beam with regard to temperature. (ISO Standard No. 834)

General, Density	
Density	Temp
650	20
585	50
585	100
585	200
544	250
446	300
307	400
224	500
166	600
154	700
60	800
43	900
34.4	1,200

Table 4: Elastic properties of glulam beam. (ISO Standard No. 834)

Mechanical, Elasticity, Elastic	
E1	14,300,000,000
E2	1,144,000,000
E3	715,000,000
Nu12	0.3
Nu13	0.2
Nu23	0.2
G12	1,020,000,000
G13	960,000,000
G23	102,000,000

Table 5: Plastic properties of glulam beam with regard to temperature. (ISO Standard No. 834)

Mechanical, Plasticity, Plastic		
Yield Stress	Plastic Strain	Temp
1,000	0	20
2,750,000	0.005	20
5,500,000	0.01	20
16,000,000	0.03	20
15,500,000	0.035	20
1,000	0	100
2,750,000	0.005	100
5,500,000	0.01	100
16,000,000	0.03	100
15,500,000	0.035	100
1,000	0	400
2,000,000	0.005	400
2,500,000	0.01	400
3,000,000	0.03	400
2,750,000	0.035	400
1,000	0	600
1,500,000	0.005	600
1,750,000	0.01	600
2,000,000	0.03	600
1,800,000	0.035	600
1,000	0	800
1,200,000	0.005	800
1,300,000	0.01	800
1,400,000	0.03	800
1,300,000	0.035	800
1,000	0	900
1,050,000	0.005	900
1,050,000	0.01	900
1,050,000	0.03	900
1,050,000	0.035	900
1,000	0	1,000
1,050,000	0.005	1,000
1,050,000	0.01	1,000
1,050,000	0.03	1,000
1,050,000	0.035	1,000

Table 6: Specification of S275 steel used in the research. (Andreolli – 2011)

Bolt Grade	Grade 4.6
Bolt Size	M20
S275 Steel Density	7850 kg/m^3
S275 Steel Modulus of Elasticity, E	210,000 N/mm^2
S275 Steel Poisson's Ratio, ν	0.30

Table 7: Thermal properties of S275 steel.

Thermal Conductivity	Temp
53.3	20
50.7	100
47.3	200
47.3	250
44	300
44	350
37.4	400
34	500
30.7	600
27.4	700
27.4	800
Specific Heat	**Temp**
439.8	20
487.6	100
529.8	200
547.3	250
564.7	300
583.7	350
605.9	400
666.5	500
760.2	600
1,008.2	700
803.3	800
650	900

Table 8: Plastic properties of S275 steel. (Andreolli – 2011)

Mechanical, Plasticity, Plastic	
Yield Stress	Plastic Strain
290,000,000	0
290,000,000	0.02
400,000,000	0.05
450,000,000	0.1
470,000,000	0.15
470,000,000	0.2
460,000,000	0.25
450,000,000	0.3

Tie constraint is used as the interaction between the cylindrical face of the bolt and timber hole as well as the steel plate. Incremental displacement load is used to simulate the tensile test. In the analyses with heat, the fire temperature curve is in accordance with ISO 834 as shown in Table 9 and Figure 2. The assembly of the model is shown in Figure 3.

Table 9: Fire temperature curve in accordance with ISO 834.

Time (min)	Temperature (ºC)	Time (min)	Temperature (ºC)	Time (min)	Temperature (ºC)
0	20	21	788.62	41	888.43
1	349.21	22	795.55	42	892.03
2	444.50	23	802.17	43	895.55
3	502.29	24	808.52	44	898.98
4	543.89	25	814.60	45	902.34
5	576.41	26	820.45	46	905.62
6	603.12	27	826.08	47	908.84
7	625.78	28	831.50	48	911.98
8	645.46	29	836.74	49	915.07
9	662.85	30	841.80	50	918.08
10	678.43	31	846.69	51	921.04
11	692.54	32	851.43	52	923.95
12	705.44	33	856.02	53	926.79
13	717.31	34	860.48	54	929.59
14	728.31	35	864.80	55	932.33
15	738.56	36	869.01	56	935.02
16	748.15	37	873.10	57	937.67
17	757.17	38	877.08	58	940.27
18	765.67	39	880.96	59	942.83
19	773.72	40	884.74	60	945.34
20	781.35				

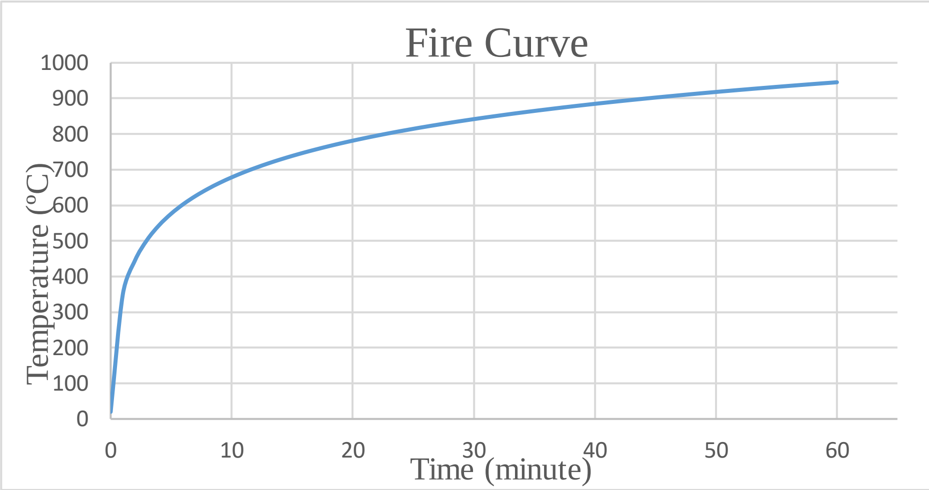

Figure 2 Fire temperature curve in accordance with ISO 834.

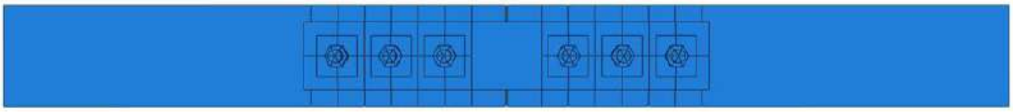

Figure 3 The FEM assembly of the glulam timber beam connection (Gečys- 2013)

DISCUSSION AND RESULTS

Incremental Load Without Heat

Figure 4 shows the comparison of the load-displacement curve of the timber beam connection between the experiment and FEM results. Figure 5 shows the point of failure of both experiment and FEM results. The results from finite element analysis are close to the experiment results. Both finite element analysis and experiment data show that the timber beam connection will fail at around 284 kN with a displacement of about 18.7 mm. The error percentage is less than 10%.

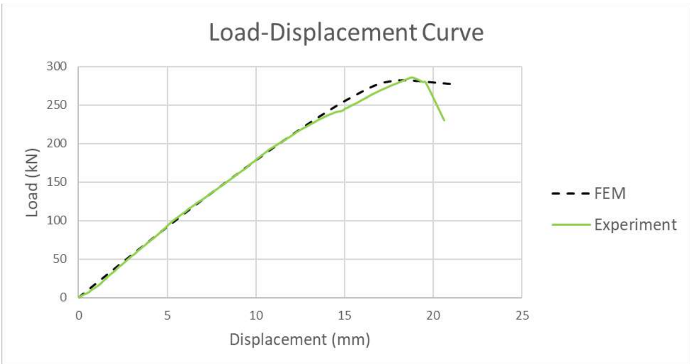

Figure 4 Load-displacement curve of timber beam connection subjected to tensile load.

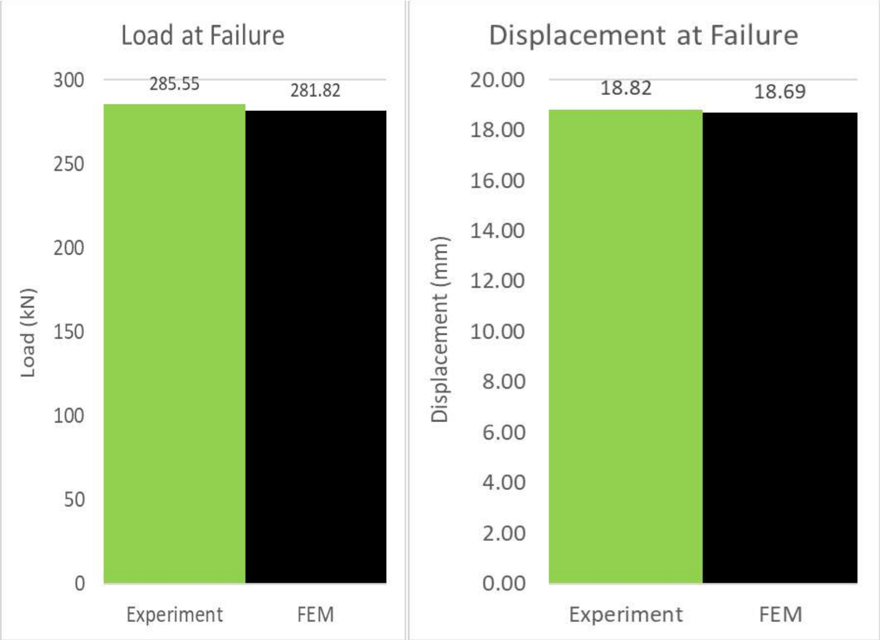

Figure 5: Comparison of load (left) and displacement (right) at failure between FEM and experiment results.

Constant Load With Fire

Table 10 shows the point of failure and differences between the experiment and FEM results. Figure 6 shows the displacement of the glulam beam subjected to 1.9 tons of constant load in fire. Figure 7 shows the FEM load-displacement curve. The difference of temperature at failure between finite element analysis and experimental results is small, indicating the model subjected to 1.9 tons of constant load will fail at around 903ºC. The difference of time to failure between finite element analysis and experimental results is bigger than the temperature difference, within the range of 10%. The difference could be caused by the inconsistent increment of temperature in the experiment.

Table 10: Comparison of temperature, time, and displacement at failure between FEM and experiment results.

	The temperature at Failure (ºC)	Time to Failure (min)	Displacement at Failure (mm)
Experiment	903.0	43.0	-
FEM	907.3	46.5	2.67
Difference (%)	0.5	8.1	-

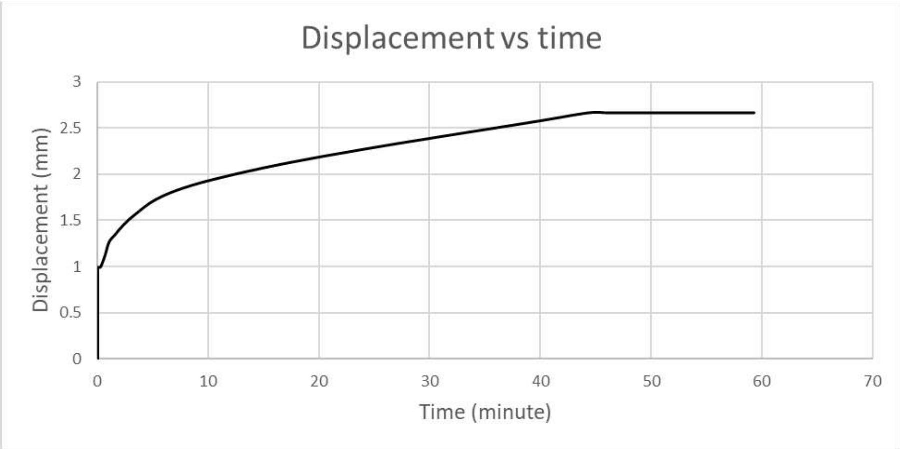

Figure 6: Displacement of glulam beam subjected to 1.9 tons of constant load until failure in the fire.

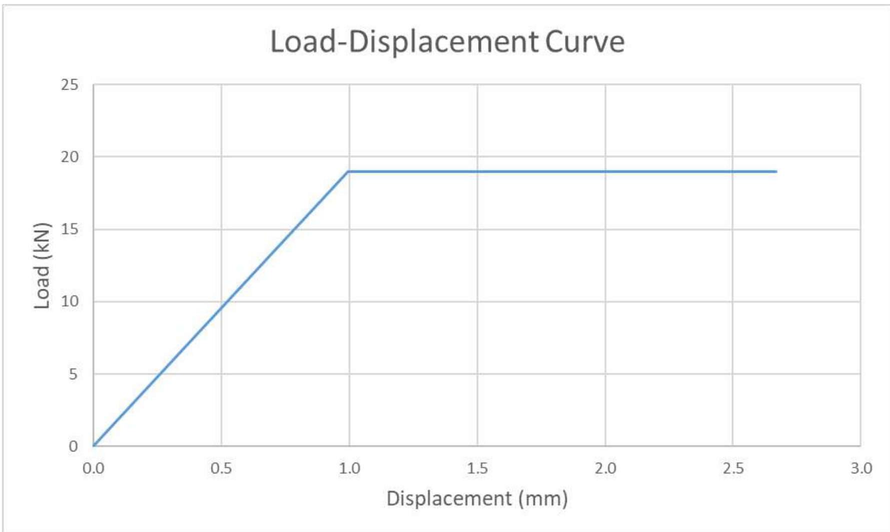

Figure 7: Load-displacement curve of timber beam connection subjected to 1.9 tons constant load and heat

Incremental Load With Heat

Figure 8 shows the load-displacement curve of the timber beam connection subjected to both tensile load and heat. Figure 9 shows the comparison of load-displacement curve between the experiment and FEM results. Table 11 shows the prediction for the point of failure of the model. The results show that the glulam beam connection is expected to fail much earlier when fire is involved. It is predicted to fail at 872℃, with a load of 21.7 kN and 8.2 mm displacement at 36.7 minutes.

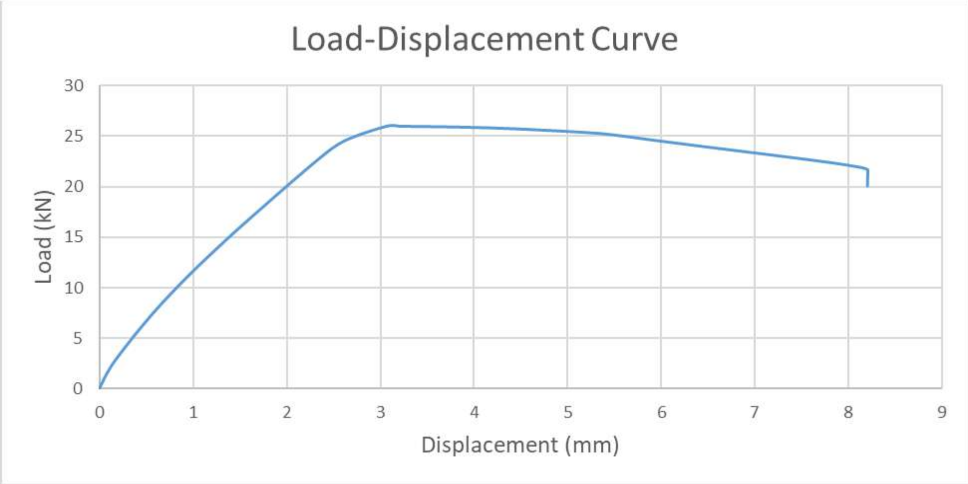

Figure 8: Load-displacement curve of timber beam connection subjected to tensile load and heat.

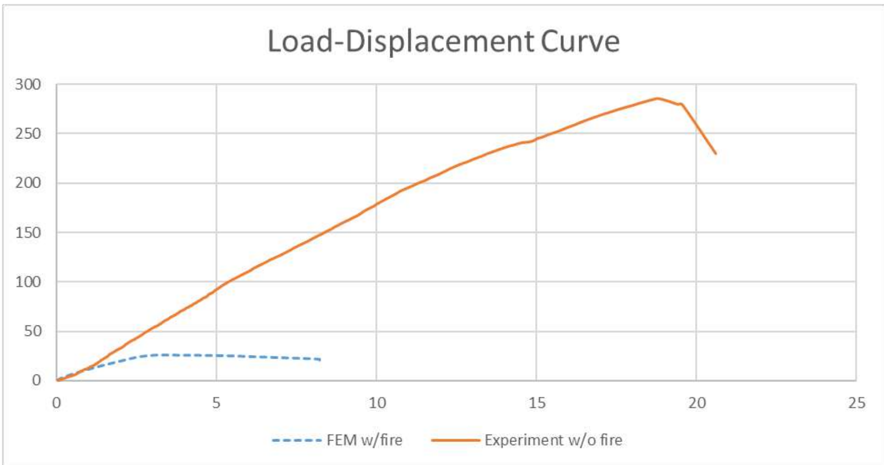

Figure 9: Comparison of load-displacement curve between FEM with fire and experiment without fire.

Table 11: Temperature, load, displacement, and time at failure.

Temperature at Failure (°C)	Load at Failure (kN)	Displacement at Failure (mm)	Time to Failure (minute)
872	21.7	8.2	36.7

CONCLUSION

The finite element analysis of outer plate bolted timber connection is comparable to the experimental works with a small variance of less than 2%. The tensile capacity of Mengkulang glulam timber from this research can be taken at 281 kN. Timber is an anisotropic material, that is, it has different properties in different directions, so the tensile capacity can only be applied if the orientation of the material is the same as in the model. The fibre direction of the glulam timber is along the beam axis. Timber is an anisotropic material, that is, it has different properties in different directions. The tensile capacity of timber is higher along its grain than across it.

From the finite element analysis for the model subjected to constant load and fire, the temperature at failure has a very small difference of 0.5%. However, the time taken for it to fail has a difference of 8.1%. This may be caused by the inconsistent firing of the chamber from the experiment. The data for the actual displacement from the experiment is not available since there is a limitation to the test equipment, making it impossible to install LVDT sensor.

The prediction for heat and tensile load shows that it is significantly weaker when compared to the model without heat. Fire will weaken the cellulose fibre structure found in timber; therefore, it will not be able to withstand the same level of stress and strain as the model without heat. The results obtained from the model with fire can be used to predict the behaviour of bolted timber connections when exposed to heat or fire. In case of fire, the steel plate and bolts are more likely able to withstand the heat as the temperature will be lower than the melting point of steel.

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