UTM
UNIVERSITI TEKNOLOGI MALAYSIA

2nd Proceeding of Civil Engineering

CONSTRUCTION MANAGEMENT, GEOTECHNICS & TRANSPORTATION

VOLUME 2

FACULTY OF CIVIL ENGINEERING
Universiti Teknologi Malaysia,
81310 UTM, Johor, MALAYSIA

Tel : 607-5531581 Fax : 607-5566157

ISBN 978-967-2171-05-8

UTM
2ND PROCEEDING OF CIVIL ENGINEERING VOLUME 2
CONSTRUCTION MANAGEMENT, GEOTECHNICS AND TRANSPORTATION

2nd Proceeding of Civil Engineering

Volume 1- Structure and Materials

Volume 2- Construction Management, Geotechnics and Transportation

Volume 3- Environmental Engineering, Hydraulics and Hydrology

Published by

Faculty of Civil Engineering

Universiti Teknologi Malaysia

81310 Johor Bahru

Johor, MALAYSIA

Perpustakaan Negara Malaysia Catalaguing-in-Publication Data

Printed in Malaysia

ISBN 978-967-2171-05-8

List of Editors

1. Dr. Norhisham Bin Bakhary
2. Dr. Nur Hafizah Abd Khalid
3. Dr. Libriati Zardasti
4. Dr. Kogila Vani Annammala
5. Dr. Eeydzah Aminudin
6. Dr. Nur Syamimi Zaidi
7. Dr. Mohd Ridza Mohd Haniffah
8. Dr. Roslida Abd.Samat
9. Datin Fauziah Kasim
10. Mrs. Normala Hashim
11. Dr. Ain Naadia Mazlan

PREFACE

We proudly present the second proceeding of civil engineering research work by our final year students in the Faculty of Civil Engineering at University Teknologi Malaysia in session 2016/2017. These students had undergone two semesters of final year project where literature reviews were carried out and proposals were prepared during the first semester while the research projects were executed and final year project reports were written up during the second semester. Each of the completed research project was presented by the student before a panel of presentation that consisted of academic staff that are well versed in the particular research area together with a representative from the industry. The final year project presentation that was held on the 4th to 5th June 2017 allowed the dissemination of knowledge and results in theory, methodology and application on the different fields of civil engineering among the audience and served as a platform where any vague knowledge was clarified and any misunderstood theories, procedures and interpretation of the research works were corrected.

All accepted technical papers have been submitted to peer-review by a panel of expert referees, and selected based on originality, significance and clarity for the purpose of the proceeding. The quality of these technical papers ranged from good to excellent, illustrating the experience and training of the young researchers. We sincerely hope that the proceeding provides a broad overview of the latest research results on related fields. The articles of the proceeding are published in three volumes and are organized in broad categories as follows:

Volume 1- Structure and Materials

Volume 2- Construction Management, Geotechnics and Transportation

Volume 3- Environmental Engineering, Hydraulics and Hydrology

The review process was owing to the educational nature of the proceeding. We would like to express our sincere gratitude to all the Technical Proceeding Committee members for their hard work, precious time and endeavor preparing for the proceeding. Last but not least, we would like to thank each and every contributing final year project students for their efforts and academic staff who serve as supervisors for their support for this proceeding.

TABLE OF CONTENT

The Readiness of Project Stakeholders if QLASSIC is Being Made Mandatory in 2020

Amirul Iqram Zulyadin, Abdul Rahim Abdul Hamid

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

rahimhamid@utm.my

Keywords: QLASSIC; Quality Assessment; Project Stakeholders; Construction Industry; CIS7:2014.

ABSTRACT. Construction Industry Development Board (CIDB) Malaysia has introduced Quality Assessment System in Construction (QLASSIC) in 2006 which highlighted the concept of self-assessment to evaluate the quality of building construction work according to the Construction Industry Standard (CIS7: 2014). The current demand for QLASSIC assessment nowadays is more focused on the medium and luxury residential projects. The applicability of this system is not comprehensive and relatively low due to lack of awareness. Therefore, as in CITP 2016 –2020 which one of the strategic thrust is to improve the Quality, Safety and Professionalism in construction industry, CIDB plans to make QLASSIC assessment mandatory for all construction projects in 2020. The aim of this study is to study the current scenario level of implementation QLASSIC assessment, to identify the extent of readiness of project stakeholders if QLASSIC being mandatory in 2020 and to propose strategies to improve implementation of QLASSIC in the construction industry in Malaysia. The research methodology that will be adopted is through questionnaires, and data search from the document issued by CIDB. The data obtained were analysed using frequency distribution, mean and average index, which allows the data presented in the form of charts, graphs and tables. The study found that, 1,246 building were evaluated and the average QLASSIC score in 2015 is the best which 72.50% since QLASSIC have been introduced. Meanwhile, the extent of readiness of project stakeholders is in ready stage if QLASSIC implementation being mandatory by 2020 because they actually have implement the procedure needed in order to practise QLASSIC. Hence, it found that the awareness among construction project stakeholder are important to become the key strategy in increasing the implementation of QLASSIC in Malaysia.

INTRODUCTION

The construction industry plays an important role in the economy, it is clear that construction activities affect nearly every aspect of the economy and that the industry is vital to the continued growth of the economy [1]. Furthermore, demand in the construction industry are driven by the development of other economic sectors, such as public infrastructure and private sectors that include manufacturing and professional services [2]. The quality of the construction industry in Malaysia should be controlled and improved in order to be world class industry. Therefore, in order to achieve this goal, CIDB has introduced a Quality Assessment System in Construction (QLASSIC) which is a system to measure and evaluate the quality of workmanship of a construction work based on the relevant approved standard.

Problem Statement

Nowadays, oftentimes heard that contractors and developers cannot meet user satisfaction and achieve the standards in quality issues. There are four key issues that affect the quality of the construction industry has been listed in 2016-2020 CITP report issued by CIDB which are lack of adequate emphasis on quality assessment and assurance, poor conditions on worksite, including workers' amenities and safety and health standards, complex regulatory framework, processes and procedures, which lead to delays in permits and approvals and room to enhance public perception of the industry and awareness of initiatives to improve the image of the industry [3]. To address the issues of quality in the construction industry, QLASSIC was introduced by CIDB in 2006 guided by CIS 7: 2006.

Nevertheless, there are a large number of contractors and developers who still do not practice QLASSIC because only 3% of the buildings in Malaysia have implemented QLASSIC [3]. For that matter, this study has been conducted with aimed at determining the readiness of construction stakeholders if QLASSIC being made mandatory in 2020.

Objectives

The objectives of this study are:

1. To study the current scenario of QLASSIC assessment implementation.
2. To identify the extent of readiness among construction project stakeholders if QLASSIC being made mandatory in 2020.
3. To propose strategies in increasing the implementation of QLASSIC among project stakeholders in the construction industry in Malaysia.

Scope of Study

The study will be carried out randomly in Malaysia. This study will be focusing on project owners, developers contractors, consultancy company and government agency that engaged with construction project which quality of the building and client's satisfaction as a main priority. In addition, the results of the study are limited to the data that was collected from the literature review and questionnaires.

LITERATURE REVIEW

Quality is one of the basic components that must be controlled in a construction project in order to meet user requirement. After all, the customers ultimately decide if the project quality is acceptable or not [4]. There are several systems that are used for quality control in the construction industry, which each system has its own objectives and concept to ensure the project meet the specified quality.

The example of the quality system are ISO 9001: Quality Management System is a collection of business processes focused on consistently meeting customer requirements and enhancing their satisfaction [5]. It is aligned with an organization's purpose and strategic direction, Total Quality Management (TQM), is a comprehensive and structured approach to organizational management that seeks to improve the quality of products and services through ongoing refinements in response to continuous feedback [6], Construction Quality Assessment System (CONQUAS) is a quantitative measure of the overall quality of a building's workmanship during the various stages of construction [7], Performance Assessment Scoring System (PASS) developed by the Hong Kong Housing Authority is an assessment to measure performance output directly against defined standards and to provide a fair means of comparing the performance of individual contractors [8] and Quality Assessment System in Construction (QLASSIC) is an assessment system that measures and evaluates the workmanship quality of a building construction work based on Construction Industry Standard (CIS 7:2014) [7].

In Malaysia, QLASSIC was introduced by CIDB to be the nation's Construction Industry Standard (CIS). Furthermore, CIS main objective is to provide a benchmark on the standards that can be applied by the construction industry to measure their quality performance [7].

Generally, each construction projects have its own procedure in completing the project with the quality that have been specified but may not implement QLASSIC. Hence, there are few important procedures selected to be the readiness criteria that can determine the extent of readiness of an organisation to implement QLASSIC such as awareness in quality, workers training, construction project team involved, top management commitment and quality control programme. Particular weak points in the construction sector in Malaysia that will affect the quality of workmanship include a lack of skills or efficient training for the construction work being done and insufficient status acknowledgement of construction technologist [9]. Other than that, management that involving various of different parties play important role in improving the productivity of design and quality to construction business to survive and have a competitive edge [10].

Chan (2009) explained that government is responsible in painting a vision of developing the Malaysian construction industry into an innovative, sustainable, professional, profitable and world-class industry [11]. Hence, in order to improve the implementation of QLASSIC, government agency can implement several premium scheme and incentives such as Singapore and Hong Kong to urge contractors to perform better in the construction process to maintain the product quality in Malaysia is up to a satisfaction standard or more [12]. Besides, developer as clients, should be consulted to achieving quality of construction, must adopt a quality management approach towards projects and construction [14].

Quality Assessment System in Construction (QLASSIC)

Quality Assessment System in Construction (QLASSIC) was introduced by CIDB guided by Construction Industry Standard (CIS). Furthermore, CIS main objective is to provide a benchmark on the standards that can be applied by the construction industry to measure their quality performance [7]. The purpose of this scheme is to enable a construction project to be undergone in standard procedure in order to ensure the quality of workmanship in the works. Furthermore the assessments will be conducted by a qualified evaluator of QLASSIC registered, trained and have passed the test conducted by the CIDB [13].

Objectives of QLASSIC. Construction Industry Standard, CIS7:2014 (2014), stated that the user need to achieve any of the following objectives [13]:

1. To benchmark the level of quality of the construction industry in Malaysia
2. To have a standard quality assessment system for quality of workmanship of building projects
3. To assess quality of workmanship of a building project based on CIS 7 standard
4. To evaluate the performance of contractors based on quality of workmanship
5. To compile data for statistical analysis

Scopes of QLASSIC. This assessment is set out for the quality of workmanship for the various aspects of the construction elements for the general building works. It will cover four main components which is, Structural works, Architectural works, Mechanical and Electrical (M&E) works and External works. Assessments on the workmanship

are carried out based on this standard and marks are awarded if the workmanship complies with the standards. These marks are then summed up to give a total quality score (%) for the building project [13].

METHODOLOGY

In this study, the following methodology has been adopted in order to achieve the objective of the study and the methodology of study.

1. In order to achieve the first objective, a review of literature and distribution of questionnaire survey was conducted to study the current scenario of QLASSIC assessment implementation.
2. The second and third objective was achieved through the questionnaire survey in order to identify the extent of preparedness among construction project stakeholders if QLASSIC being made mandatory in 2020 and to propose strategies in increasing the implementation of QLASSIC.

The secondary data have been gathered from several resources such as books, journals, articles, previous researches and electronic resources like e-journal, websites and online material. Meanwhile, the primary data have been collected from the questionnaire surveys which have been distribute using Google Forms to the profession within the construction organisations. The data collected from the questionnaires would be in Likert Scales

After the compilation of data generated from questionnaire, data analysis will be carried out with the help of computer software such as Microsoft Office Excel 2013. The data then will be analysed by using the average index analysis to rate and rank the elements of data according to level of implementation and level of agreement as shown below:

Average Index = Σ ai xi / Σ xi. Whereas, ai = constant which represent the weight for i, xi = variable that represent the frequency of respondents to the I (i = 1, 2, 3, 4, 5).

The classifications for the rating scale are: 1.00≤Average Index<1.50 (least implemented or strongly disagree), 1.50≤Average Index<2.50 (poorly implemented or not disagree), 2.50≤Average Index<3.50 (moderately implemented or neutral) 3.50≤Average Index<4.50 (implemented or agree) and 4.50≤Average Index≤5.0 (well implemented or strongly agree).

Chart diagram were used to visualize the results from the analysis. Then, all the results will be discussed in detail and the conclusion and recommendation will be made accordingly.

RESULTS AND DISCUSSION

The results presented below were based on the objective of the study. The objective 1 has been achieved through a review of the literature and questionnaires survey, meanwhile objective 2 and 3 have been achieved only through questionnaire survey. About more than 60 questionnaires sets were distributed to the targeted respondents randomly but only 30 responses were received within the desired period. The results from the questionnaire obtained were analysed to achieve the objectives that have been set. The questionnaire contained of four sections which include basic respondent information, QLASSIC implementation, activities carried out to determine readiness in implementing QLASSIC and strategies to improve the implementation of QLASSIC in construction project.

Respondents Background. For 1st section of the questionnaire, it identified the basic personal information in order to help interpret the result. The demographic characteristic of respondents are given in Table 1 - 4.

Table 1: Respondent's Company

Type of Company	Frequency	%
Developer	5	17
Contractor (G1:1, G5:1, G6:1, G7:11)	19	63
Consultancy	3	10
Government Agency	1	3
Other	2	7

Table 2: Respondent's Company

Position in Company	Frequency	%
Project Manager	2	7
Quantity Surveyor	2	7
Safety & Health Officer	3	10
Civil Engineer	6	20
Project Engineer	5	17
Supervisor	8	26
Other	4	13

Table 3: Respondent's Experience

Working Experience	Frequency	%
Less than 2 years	8	27
Between 2 to 5 years	11	36
Between 5 to 10 years	9	30
More than 10 years	2	7

Table 4: Projects Involved

Projects Involved	Frequency	%
Residential	13	24
Non-Residential	9	16
Mix-Development	12	22
Social Amenities	5	9
Infrastructures	16	29

Objective 1: Current scenario of QLASSIC assessment implementation

QLASSIC assessment has benefited various parties, whether buyers or developers and contractors, as in buyers will get product that meet the requirements meanwhile developers and contractors have their company marketability increased [7]. Thus, the number of construction projects increased each year however dropped in 2015. Based on latest CIDB Annual Report which in 2015, since QLASSIC were introduced in 2006, a total of 1246 building projects were evaluated. In terms of average QLASSIC score, the 2015 statistics shows it stands at 72.5% [15]. This is an improvement over 2014 when the average score was 69.9% and this average score is the best since 2007. This improvement confirms that the contractors are more skilled and are able to produce quality building works. Figure 1 shows the average QLASSIC Score and the number of QLASSIC evaluation that has been made since 2007.

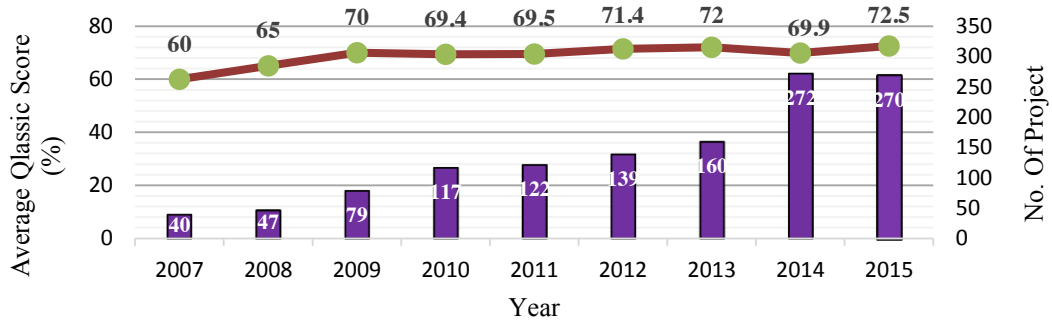


Figure 1: Average QLASSIC Score and the number of QLASSIC evaluation that has been made since 2007

Eventually, the QLASSIC assessment construction projects in Malaysia still very low in numbers. Table 5 provides details of the number of QLASSIC assessment construction projects towards non QLASSIC assessment construction projects in Malaysia [15].

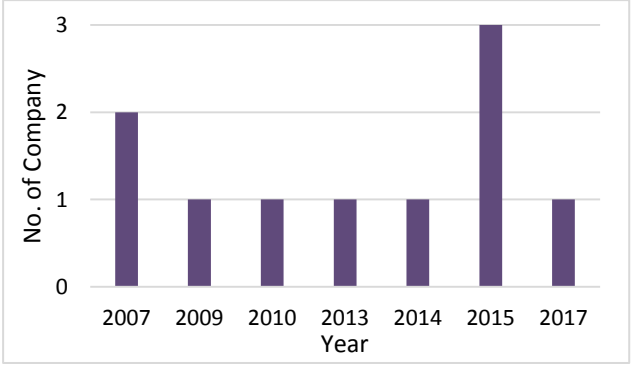
Table 5: Numbers of QLASSIC Projects and Non-QLASSIC Projects

Year	No. of Projects	Non-QLASSIC Projects	QLASSIC Projects	% QLASSIC Projects
2007	7385	7345	40	0.54
2008	6522	6475	47	0.72
2009	7039	6960	79	1.12
2010	7302	7185	117	1.60
2011	7725	7603	122	1.58
2012	7998	7859	139	1.74
2013	8119	7959	160	1.97
2014	7939	7667	272	3.43
2015	6885	6615	270	3.92

Meanwhile, the data obtained from questionnaire survey found that 19 respondent out of 30 have ever heard about QLASSIC, however only 9 respondent out of 19 have implement QLASSIC. Other than that, majority of the respondents agree that QLASSIC can improve the performance of construction project and the company's marketing. Besides, all of them will implement QLASSIC in their future project and the majority of the projects often obtained highest mark in Architectural Works component. The detail result from the questionnaires survey regarding the scenario of QLASSIC implementation are given in Table 6-7 and Figure 2–5.

Table 6: Numbers of QLASSIC Projects and Non-QLASSIC Projects

Heard of QLASSIC	**Yes**	**Percentage**	**Maybe**	**Percentage**	**No**	**Percentage**
	19	63%	2	7%	9	30%
Implementation of QLASSIC	**Yes**	**Percentage**	**In Progress**	**Percentage**	**No**	**Percentage**
	9	30%	1	3%	20	67%



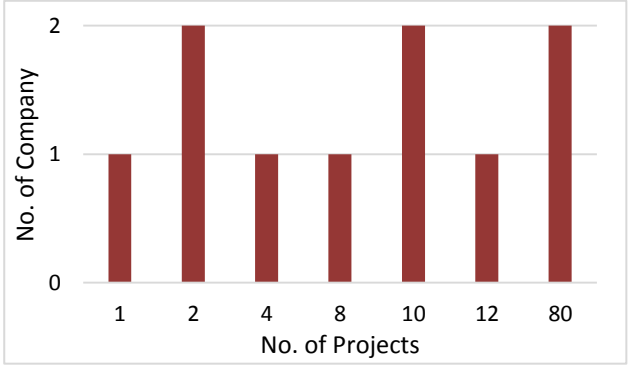


Figure 2: Year of QLASSIC start being practised

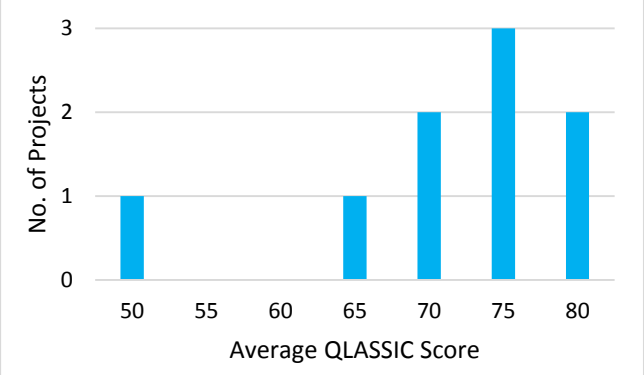


Figure 3: No. of projects have adopted QLASSIC

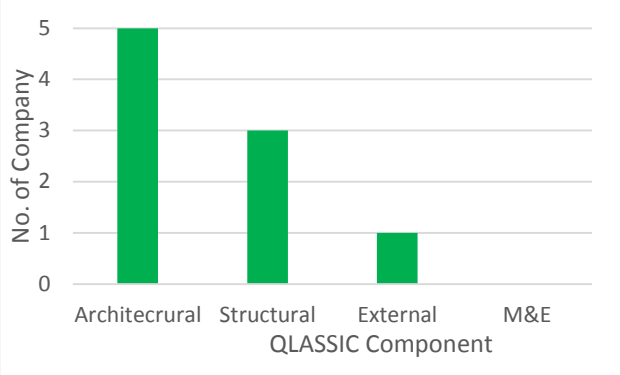


Figure 4: Average QLASSIC score from previous projects

Figure 5: QLASSIC Component often get highest score

Table 7: Respondent's answer based on question asked

Question	Yes	Percentage	Not Sure	Percentage	No	Percentage
Improve project performance	8	89%	1	11%	-	-
Improve company's marketing	9	100%	-	-	-	-
Will continue to implement QLASSIC	9	100%	-	-	-	-

Objective 2: The extent of readiness among company involved in construction if QLASSIC being made mandatory in 2020.

The second objective was conducted to determine the level of readiness among company that involved in construction industry if QLASSIC being made mandatory in 2020. It were determined by investigate the implementation of readiness criteria which are awareness in quality, training programme, quality control programme, various construction project team involved and top management commitment.

From Figure 6-10, it was found that the mean of readiness criteria for various construction project team involved obtained the highest score which 4.10 indicate that there are various parties responsible in ensuring the quality of the construction project. Meanwhile workers training aspect obtain the lowest score which 3.59, however still in the range of implemented showing that the workers involved in the construction project have undergo training to control the quality of the workmanship. On the other hand, the aspect of quality control obtained 3.97, awareness aspects 3.80, and top management 3.87 which indicate that the procedures involving quality control, awareness aspect and top management were implemented. Those numbers shows that they have taken action to control the quality of the workmanship which include procedures like periodic inspection and testing during construction project take place. Also in term of quality awareness which include corrective and prevention action in their work and top management role to plan the project in order to achieve the quality have been specified.

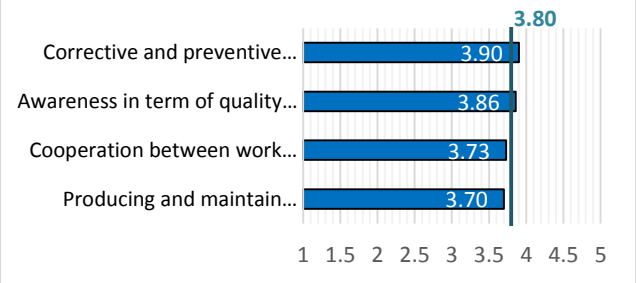


Figure 6: Mean of implementation level (Awareness)

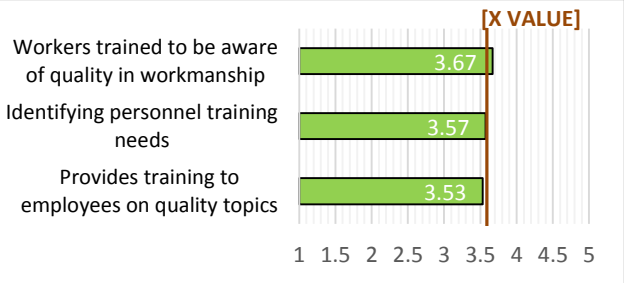


Figure 7: Mean of implementation level (Training)

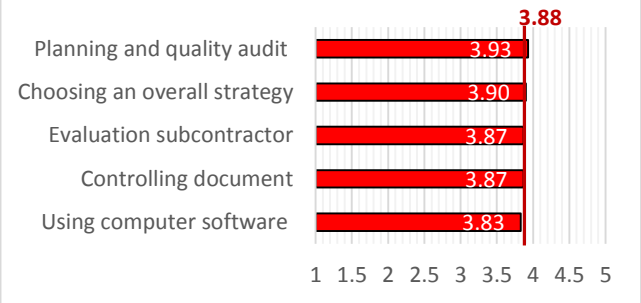


Figure 8: Mean of implementation level (Management)

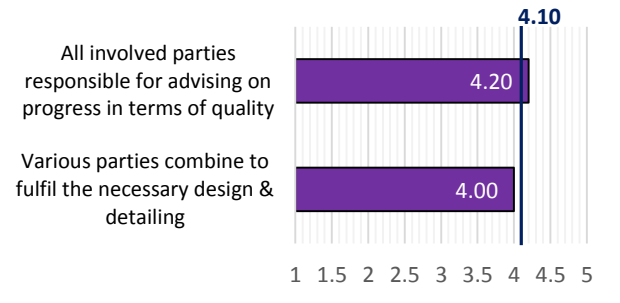


Figure 9: Mean of implementation level (Team)

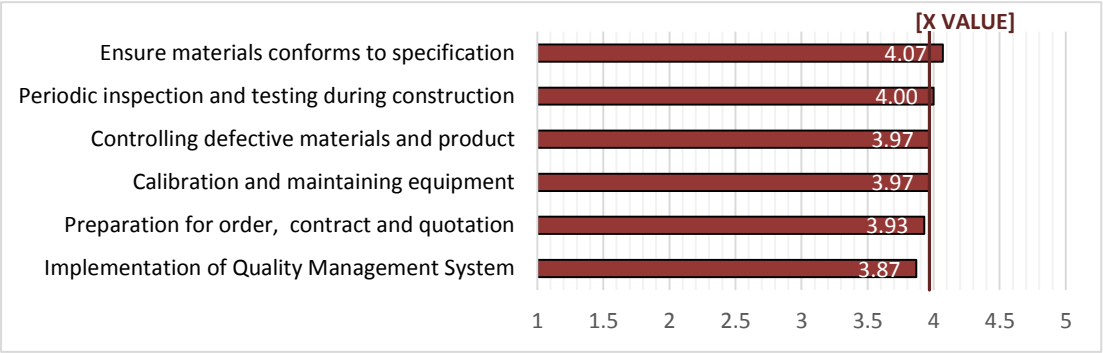


Figure 10: Mean of implementation level (Quality Control)

Objective 3: Strategies in increasing the implementation of QLASSIC among project stakeholders in the construction industry in Malaysia.

From Figure 11-13, it was found that the construction company role (mean score = 4.19) become a key strategy in increasing the implementation of QLASSIC. Without the high commitment from the management of the construction company, the organisation may fail in producing a quality construction product in the end of the construction project, because one of the pillars of the project delivery process is the management of the quality of the product or service a construction company provides. The role play by clients (mean score = 4.05) which include government or developer also one of the important factor in encouraging the implementation of QLASSIC because the project specifications generally spell out the quality standards for the project and by reference become a part of the contract between the project owner and the contractor. Other than that, government role (mean score = 3.95) not only acting as clients but also acting as the regulator body such as CIDB that managing the overall construction activities in Malaysia can contribute by promoting QLASSIC to construction company to increase the awareness in importance of the implementation of QLASSIC assessment.

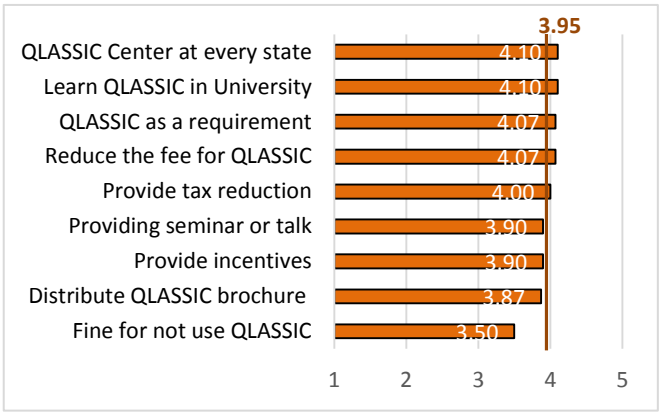


Figure 11: Mean agreement of strategies play by Government

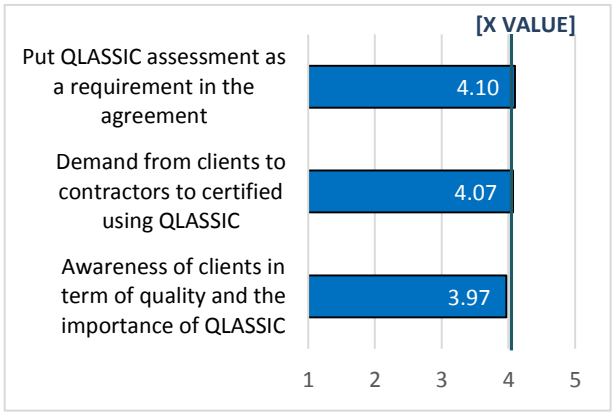


Figure 12: Mean agreement of strategies play by Client

Figure 13: Mean agreement of strategies play by Construction Company

CONCLUSION

The conclusions that can be drawn from this study are as follows.

1. The first objective was to study the scenario of implementation QLASSIC assessment in Malaysia and been achieved by doing the review of literature. The number of building that has been evaluate using QLASSIC since 2007 until 2015 is 1246 building and as the latest in 2015, only 3.92% construction project has been evaluated. It shows that, the implementation of QLASSIC still low and need to be improve. However, the average score of the QLASSIC score increase each year which show that contractors are more skilled and are able to produce quality building works
2. The second objective of the study was to identify the extent of preparedness among construction project stakeholders if QLASSIC being made mandatory in 2020 have been successfully achieved. According to study conducted, as a whole can be said that all the procedures listed based on the readiness criteria are performed by construction companies and it shows that they are in ready stage. However, the level of implementation is still not well implemented but it can be upgraded to increase the readiness to implement QLASSIC assessment.
3. The final objective is to propose strategies in increasing the implementation of QLASSIC among project stakeholders in the construction industry in Malaysia. From the finding, majority of the respondents agree that the strategies play by the construction company is the key strategy in increasing the implementation of QLASSIC which awareness in term of quality among top management and employee. Awareness about QLASSIC also important among clients, so that they will take action in demanding QLASSIC assessment in their agreement with contractor. Other than that, majority of the respondents also agree that government need to provide QLASSIC center at every state to help monitor and promoting QLASSIC to construction project stakeholders.

REFERENCES

[1] Oladinrin, T. O., Ogunsemi, D. R., & Aje, I. O. (2012). Role of Construction Sector in Economic Growth: Empirical Evidence from Nigeria. FUTY Journal of the Environment, 7(1), 50-60.

[2] Sundaraj, G. (2006, September). The Way Forward: Construction Industry Master Plan 2006-2015. The Ingenieur.

[3] CIDB. (2015, September). Construction Industry Transformation Programme 2016-2020. Kuala Lumpur: Construction Industry Development Board (CIDB) Malaysia.

[4] Tam, V. W., & Le, K. N. (2007). Quality improvement in construction by using a Vandermonde interpolation technique. International journal of project management, 25(8), 815-823.

[5] Said, I., Ayub, A. R., Abd Razaki, A., & Tee, K. K. (2009). Factors affecting construction organization quality management system in the Malaysian construction industry.

[6] Arditi, D., & Gunaydin, H. M. (1997). Total quality management in the construction process. International Journal of Project Management, 15(4), 235-243.

[7] Ali, M. C. (2014). Exploring the potential of integration quality assessment system in construction (QLASSIC) with ISO 9001 Quality Management System (QMS). International Journal for Quality Research, 8(1), 73-86.

[8] Tam, C. M., Deng, Z. M., Zeng, S. X., & Ho, C. S. (2000). Performance assessment scoring system of public housing construction for quality improvement in Hong Kong. International Journal of Quality & Reliability Management, 17(4/5), 467-478.

[9] Razak Bin Ibrahim, A., Roy, M. H., Ahmed, Z., & Imtiaz, G. (2010). An investigation of the status of the Malaysian construction industry. Benchmarking: An International Journal, 17(2), 294-308.

[10] Jraisat, L., Jreisat, L., & Hattar, C. (2016). Quality in construction management: an exploratory study. International Journal of Quality & Reliability Management, 33(7), 920-941.

[11] Chan, T. K. (2009). Measuring performance of the Malaysian construction industry. Construction Management and Economics, 27(12), 1231-1244.

[12] Kam, K. J., & Abdul Hamid, A. H. (2012). Malaysia, Singapore and Hong Kong approach towards quality assurance initiative in the building construction industry; the three major countries which have the small land for fast development progress. Elixir Literature, 46, 8525-8529.

[13] Quality Assesment System in Construction. (2006). Master Builders, 3rd Quarter. Retrieved November, 20, 2016, from http://www.mbam.org.my/mbam/images/MBJ3Q06(pdf)/@Qlassic.pdf.

[14] Quality of Construction. (n.d.). Retrieved March 20, 2017, from http://fidic.org/node/751

[15] CIDB. (2016). Annual Report 2015. Kuala Lumpur: CIDB Malaysia.

Safety in Road Construction and Maintenance Site

Jasmin Aida Johari, Aziruddin Ressang

Faculty of Civil Engineering, UniversitiTeknologi Malaysia, Malaysia

aziruddin@utm.my

Keywords: Safety Management; Risk; Hazard; Maintenance.

ABSTRACT. Safety management is very important to eliminate and reduce risk and hazard during construction. In road construction or maintenance site, the safety management is quite different from the normal construction site. In normal construction site, safety issues is involving only the area within the constructed or developed area while in road construction and maintenance sites, the safety issues not only involving the area within the construction site but also taking into account the traffic flow on the existing road. The key objective of this study is to study the issues that contributing to accidents during road construction that are related to safety management of the construction site. From the study, the involvement of management and workers in increasing the awareness about safety in road construction and maintenance site is important. To produce an effective safety management on road construction site, both parties plays very important roles.

INTRODUCTION

Road is an element or route that connecting every part of the country and making travelling through land much easier and comfort. The construction of roads in Malaysia has begun since the days before the Independence's Day where the purpose the British constructs it was to connect the port and the tin and rubber production area. Today, the usage of roads in Malaysia has expanded to wide range such travelling, transporting and it connecting every part of the country.

Problem Statement

Although the construction industry is well-known as the booming industry but it also listed as one of a hazardous industry due to the accident rates. According to the latest statistic (September 2016) of accidents by sectors investigated by the Department of Occupation, Safety and Health (DOSH) Malaysia, the construction industry is the third highest number of victims involved in accidents after the manufacturing and agriculture industry [1].

According to Ganapthy, the flagman's risk of fatal accidents is high because during the maintenance work, he is placed in the highest risk zones [2]. Previous studies also stated that agents of all the hazards occurred usually in the usage of equipment and machineries [3]. A person who tends to work with equipment or machineries is more expose to the risk of physical injury. The study also stated that attitudes of workers also considered as factor that may contribute to risk of accidents.

It is deniable that our country owned a good law on safety policies but the enforcement of the law is questionable. The safety regulation was constructed by the responsible authorities such as the Department of Occupational Safety and Health which required the employer to ensure the safety of workers in the work zone.

Objectives

The objectives of this study are:

1. To study risk and hazards in road construction and maintenance site.
2. To study on factors that contributing to hazards in road construction.
3. To propose ways to produce an effective safety management on road construction.

Scope of Study

The study will be focusing on road construction site in Johor, in maintenance work (on existing road) or construction work (on new road). The targeted respondents are all the participants involved in the road construction projects such as general workers, contractors, site supervisor, project manager and others. The chosen respondents will be interview and answering the questionnaire

LITERATURE REVIEW

Construction is any form of process of constructing either buildings or infrastructure. In this study, it will focus on the construction of one type of infrastructure. Infrastructure is structure, systems and facilities that serve the needs of the country. Example of infrastructure provide by the government to the nation are airports, bridges, tunnels, roads and much more.

The main national road network in Malaysia is the Malaysian Federal Roads System which under the responsibility of Ministry of Work. Malaysian Expressway System is a network of national controlled-access expressway in Malaysia, forming the backbone network of Malaysian national highway.

According to the DOSH data on the road accident case in construction or maintenance site, there are 8 cases recorded between the years of 2011 to 2015[1]. Among the 8 cases recorded, there were 2 cases caused by the driver of the vehicles. The first case was happened in the road construction area in Johor.

There are differences between normal construction site such as buildings and road construction site. In normal construction site, the workers have to consider and deal with close area where all construction process occurs in one area. They have to be alert on activities such as the movement of lorry in and out from site, the movement of tower crane lifting materials etc. In road construction site, the same elements as normal construction site also need to be considered by all workers.

According to the Ministry of Works, a minimum of 10 safety alert sign boards should be place on specific location during road construction. To control the traffic flow during the construction, a flagman is appointed to give orders and signal the road users to smoothen the traffic. Road construction site can be classified into 3 category of zone (Straight Lane road construction, U shape lane road construction and T junction lane road construction) and risk level [2].

Based on the data of accidents analysis by DOSH, there a few cases of road construction accidents that happen due to no safe work procedure was implemented, especially when involves machineries. Unsafe act is a break of a safety procedure which can lead to occurrence of accidents where unsafe condition is hazardous physical condition which can lead to accidents [4].The behavior of irresponsible workers who misuse the safety equipment and disobey the working procedure will create an unsafe work environment thus increase the possibility of accidents. It is very crucial that the management paid attention to this serious matter by having inspection on worker's behavior and attitude, and also to the machineries and tools used.

It is essential for workers to have a safety workplace in order to increase the efficiency and productivity. Safety is when workers are in the condition of protected by any hazard or any non-desirable events, physically, psychologically, emotionally etc. while management system is a process that proactively organized a set of components which allowing the organization to accomplish the goals [5].

The government has launched the Construction Industry Master Plan 2006-2015 (CIMP) to enhance our county's construction industry towards globalisation [6]. The plan was developed to overthrown the weaknesses of the construction industry including quality deficiencies, over dependency on foreign labor and the low productivity of the construction industry. There are seven (7) strategic thrust developed in order to achieved the mission of the plan. Among the listed thrust which is the third, is focusing on striving for highest standard of quality, occupational safety and health, and environmental practices. To achieve the vision it has to start from the lower but most important core which is safety management. There are two (2) key elements which are employer's responsibility toward management on safety and workers contribution to enhance safety environment.

According to Kuang Lee, there are six (6) elements under the management activities on sites, which are safety inspection, safety meeting, safety regulation, enforcement, safety training and education and safety communication [7]. Among all of the elements, there is one important element there is a key to a successful safety management, communication. Communication is a key to organize management. In our country, most of the unskilled or semi-skilled work force which is site labours with little or no construction knowledge [8]. The problem in practicing safety practices is the language barriers between supervisor and foreign workers. Management's commitment is crucial in finding a practical solution to solve the problems. Based on the studied by Chin Keng, he found that there were lack of budget allocation on safety management and the cost of attending safety training is high [9].

There are two main reasons of unsafe behaviour at work site, which are lack of information about safety and poor attitudes towards safety [4]. Workers are encouraged to fully participate and give commitment towards safety training and the management can enhance the safety training in many ways such as safety meeting, safety courses and classes.Workers attitude in obeying work procedure and operating equipment and failure to use the personal protectives equipment are mainly the cause of construction accidents [4].

METHODOLOGY

Identifying Research Problem

The first objective which is identifying hazard in road construction is partially achieved by referring to the list of fatal accidents cases occurred in Malaysia on the website of Department of Occupational, Safety and Health (DOSH). The list is providing information on the causes of the accidents through the observation of the authority.

Primary and Secondary Data

The purpose of the literature review is to gather information and data from journals, articles, various website and previous case on relevant issues. Reading, analysis and review from these sources provide data and information to achieve the second objective which is study on factors contributing to hazard in road construction.Secondary data can be obtained from distribution of questionnaire and non-formal interviews to workers in road construction.

Distribution of questionnaire
The targeted respondents are basically workers involved in road construction.The data collected will be use to do the statistical analysis in order to achieve the objectives.

Non- formal interview
The objective of the interview is to listen and gain information on safety practice on road construction from the professional perspectives. Mainly, the question ask is based on their experiences and involvement in safety management.

Data analyzing
There is several method use in analysing the data collected from the questionnaire which are reliability test of the data using Cronbach Alpha, percentage frequency distribution, classification of risk using Risk Matrix from the Guideline for Hazard Identification, Risk Assessment and Risk Control (HIRARC) by the Department of Occupational, Safety and Health, Malaysia [10] and average index analysis**.**Referring to previous study by Hazmir (2015), the reliability test is conducted to measure the consistency of the data. It is the first step before any data analysing is done. The test is conducted using a excel spreadsheet to obtain the value of Cronbach's alpha (α). Percentage Frequency Distribution is use to display the percentage of data especially on the information of respondents. It is use to express the frequency of survey response. The result of the distribution is illustrated using table, pie chart or bar chart.

$$\text{Percentage (\%)} = \frac{\text{No of Respondents}}{\text{Total No of Respondents}} \times 100 \qquad \textbf{Eqn 1}$$

Risk is the determination of likelihood and severity of activities to determine the magnitude of the possible risk (Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC), 2008).Risk matrix is a very effective way of communicating the distribution of the risk throughout a plant and area in a workplace. Relative risk can be calculated using this formula:

$$\text{Relative Risk} = L \times S \qquad \textbf{Eqn 2}$$

L= likelihood
S= severity

The result of the multiplication is then classified based on the risk matrix. The risk matrix can be obtained from the Guidelines for HIRARC on table C or as same as the figure below:

	Severity				
Likelihood	1	2	3	4	5
5	**5**	**10**	**15**	**20**	**25**
4	**4**	**8**	**12**	**16**	**20**
3	**3**	**6**	**9**	**12**	**15**
2	**2**	**4**	**6**	**8**	**10**
1	**1**	**2**	**3**	**4**	**5**

High
Medium
Low

Figure 1: Risk matrix for section c accordance to guideline on HIRARC

Average Index analysis for each variable for each variable is calculated by using this formula:

$$\textbf{Average index} = \sum \textbf{ai . xi} / \sum \textbf{N} \qquad \textbf{Eqn 3}$$

Where: ai = Constant expressing the weight given to each response (1 to 5)
xi = The frequency of response
N = Total number of response

Table 1: Classification of frequency rating scale for section D and E

SCALE	SECTION D & E		Mean Index, MI
	PART 1	PART 2	
1	Not Implemented	Not effective	1.00 ≤ Mean Index < 1.50
2	Slightly Implemented	Slightly effective	1.50 ≤ Mean Index < 2.50
3	Moderately Implemented	Moderately effective	2.50 ≤ Mean Index < 3.50
4	Implemented	Effective	3.50 ≤ Mean Index < 4.50
5	Strongly Implemented	Strongly effective	4.50 ≤ Mean Index < 5.00

RESULTS AND DISCUSSION

Section C: To study the risk and hazard in Road Construction and Maintenance site.

Table 2: Result of risk in road construction and maintenance site

		Frequency	Severity	Risk
1.0 Accident cause by human	1.1 Default in handling machineries	3.47	3.43	11.90
	1.2 No usage of PPE	3.70	3.29	12.17
2.0 Accident cause by machineries	2.1 Damage in machineries	3.50	3.33	11.66
	2.2 No safety procedure	3.57	3.23	11.53
3.0 Accident cause by site environment	3.1 No usage of safety signboard	3.47	3.45	11.97
	3.2 No barrier separating site with the existing road	3.69	3.05	11.25

Section D: To identify the factors that contributing to Hazard in Road Construction and Maintenance Site

Table 3: Factors that contribute to hazard in road construction and maintenance site

1.1 Unskilled workers not apointed to be flagman
1.2 Unskilled workers do not attending any seminar on gaining knowledge to be flagman
1.3 No supervision by skilled worker when flagman is controlling the traffic
2.1 No safety signboard to warn the road users
2.2 Usage of only a safety signboard, excluding flagman during non-peak hour
3.1 Unskilled workers allowed to handle machineries
3.2 All activities involving heavy machineries not supervise by qualified person (engineers)
4.1 Workers are not provided with PPE eventhough not involved with usage of machineries
4.2 Workers do not wear safety reflective vest especially flagman
5.1 Detour road are not used as an alternative to usage of flagman

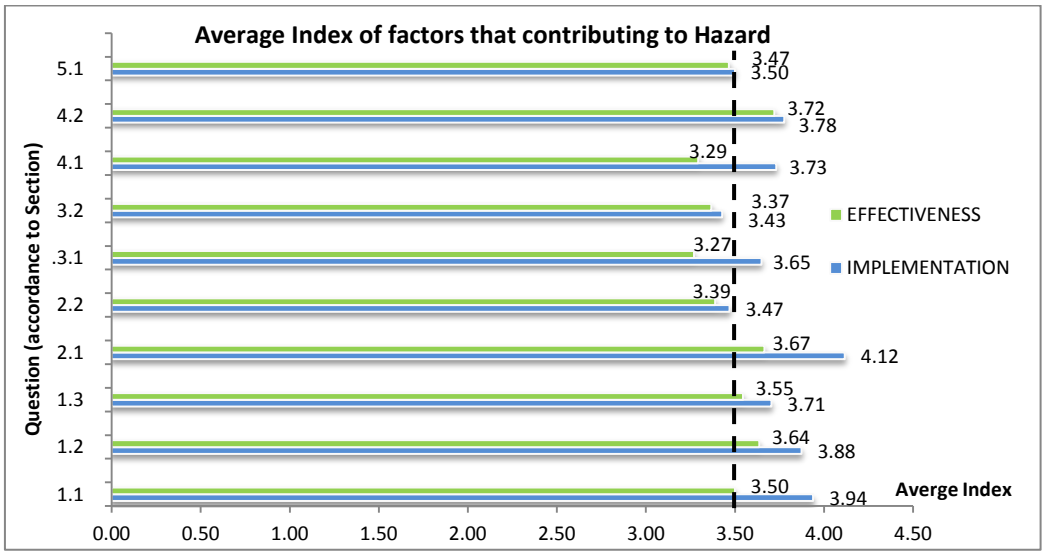


Figure 2: Average index of factors that contribute to hazard in road construction and maintenance site

Section E: To identify safety management that was practiced in Road Construction and Maintenance Site

Table 4: Practiced safety management on site

1.1 Safety checking
1.2 Safety meeting
1.3 Regulation board on safety issues on main entrance
1.4 Safety training and seminar
1.5 Communication among workers to increase understanding
2.1 Additional knowledge in safety on site
2.2 Avoiding perfunctory act on safety and handling machineries
2.3 Using the PPE in a correct manner

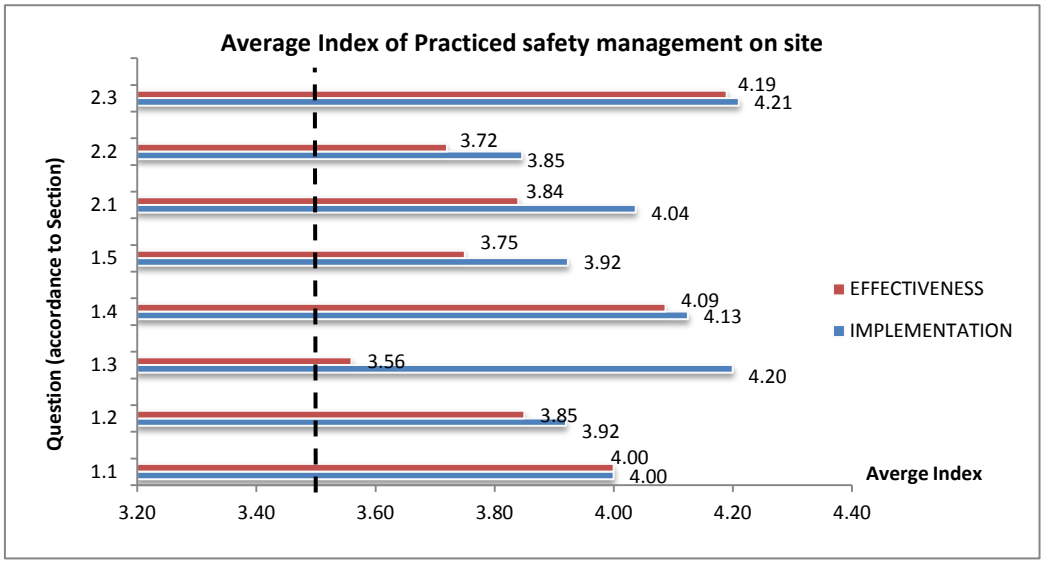


Figure 3: Average index of practiced safety management on site

DISCUSION

Section C: The overall element on the risk and hazard in road construction consider as medium/moderate risk based on the risk matrix with the range value of relative risk, R from 11.25 to 12.17. Only the element involves not using PPE falls under the high risk since the value of R exceeding 12, the maximum value for the medium/moderate risk.

Section D: The overall level of implementation of the entire factor is in the range of 3.43 to 4.12, which showing that most of the factor is implemented. While the level of effectiveness can be consider as effective since the average index of all factors falls in the range of 3.27 to 3.72.

Section E: The most effective practice on site is using the PPE in the correct ways/manner with the average index of effectiveness equal to 4.21, also one of the most implemented practices in site with the average index of 4.19. The respondent's answers on the employee's responsibility in obtaining additional knowledge in safety giving the average index of 4.04 towards the implementation and 3.84 for the effectiveness, indicating that it is effective in order to assure the safety on site.

CONCLUSION

Hence, to produce an effective safety management on road construction site, both parties plays very important roles. The management should focus on alerting the employees on safety issues through safety checking, safety meeting and safety training. There is no doubt that those three elements is the responsibility of the management. Other than that, the employees also required to follow all the instruction and rules in order to produce a safe working environment for example avoiding perfunctory act during handling machineries and always use the PPE. Communication among workers is important to increase the understanding on safety issues.

Limitation: There are few limitation need to be consider while conducting this study. One of it is time. The original plan was to distribute the questionnaire along with conducting the non-formal interview of each respondent to obtain their views or suggestion on how to improve the safety on site, especially from contractor's view. But all contractor are

not available during the questionnaire is distributed. Most of them are not in the office, it is time and money consumes to meet them directly on site.

REFERENCES

[1] Department of Occupational Safety and Health. (n.d.). Department of Occupational Safety and Health. Retrieved November 14, 2016, from Official Website Department of Occupational Safety and Health, Ministry of Human Resources: http://www.dosh.gov.my/index.php/en/

[2] Ganapthy, V. R., Subramaniam, S. K., Mohamad Diah, A., Suaidi, M., & Hamidon, A. (2010). Flagman and Risk Involved in Road Construction Site. International Journal of Sustainable Construction Engineering and Technology, 1-6.

[3] Abang Abdullah, D., & Chai, G. M. (2011). An Analysis of Accidents Statistics in Malaysian Construction Sector. 2010 International Conference on E-business, Management and Economics, IPEDR vol.3 (2011) © (2011) IACSIT Press, Hong Kong, 1-4.

[4] Abdul Hamid, A., Abd Majid, M., & Bachan Singh. (2008). Causes of Accidents at Construction Sites. Malaysian Journal of Civil Enginering 20(2) : 242 - 259, 1-18..

[5] Kamar, I., Mat Salleh, N., & Mamter, S. (2014). Contractor's Awareness on Occupational Safety and Health (OSH) Management Systemin Construction Industry. E3S Web of Conferences 3, 010119 (2014) (pp. 1-6). EDP Sciences 2014.

[6] Sundaraj, G. (2016). The Way Foward: Construction Industry Master Plan 2006-2015. The Inginuer, 4.

[7] Kuang Lee, C., & Jaafar, Y. (2012). A Study Based on Grade Seven (G7) Main Contractors' Perspectives. Prioritization of Factors Influencing Safety Performance n Construction Sites, 1-7..

[8] Vitharana, V., De Silva, S., & De Silva, S. (2015). Health Hazards, Risk nd Safety Practice in Construction Site. The Institution of Engineer, Sri Lanka, 1-10.

[9] Chin Keng, T., & Abdul Razak, N. (2014). case studies on the safety management at construction site. Journal of Sustainability Science and Management, 1-19.

[10] Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC). (2008). Department of Occupational Safety and Health, Ministry of Human Resources Malaysia.

Integration of Building Information Modeling (BIM) in UTM's Architecture, Engineering, Construction (AEC) Education Curriculum

Lai Le Yau, Chai Chang Sa'ar

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

cschai@utm.my

Keywords: Building Information Modeling; BIM Education; Construction Engineering.

ABSTRACT. The construction industry in Malaysia is adopting Building Information (BIM), this is very important for universities to keep on track and up to date by adopting new technologies in Architecture, Engineering and Construction (AEC) education curriculum. This study has discussed the integration of BIM in University of Technology Malaysia (UTM) AEC education curriculum in order to meet the requirements and standards of construction industry in near future. There were plenty of AEC based students did not recognize BIM due to lacking of information of BIM and it has not been taught in many universities yet. The objectives of this study were to determine the students' awareness regarding to BIM, identify the hindrance and propose recommendations of integrating BIM. Online and hand-on questionnaire surveys have been distributed to students while interview session with lecturers has been conducted in this study. The targeted questionnaire survey's respondents were the students from civil engineering, architectural, construction management, quantity surveying, electrical engineering, mechanical engineering and petroleum engineering courses. Principal component analysis has been used to analyze the students' perception while quantitative content analysis was used to analyze lecturer perception on BIM. From this study, it found that only 58 percent of students from AEC courses in UTM aware the existent of BIM, the major hindrances of BIM implementation were faculty time and resource to implement a new course and shortage of well-trained professional in faculty. Furthermore, students and lecturers have recommended training lecturers on BIM software and technology able overcome the hindrance of integration of BIM. When BIM has been implemented in Architectural, Engineering and Construction (AEC) education curriculum, the receivers of this education also gained benefits. This additional knowledge will make future graduates more valuable and desirable in construction related industries.

INTRODUCTION

In the past, computer aided drafting (AutoCAD) was the most advance modeling technique available to construction managers. It is now giving way to the more sophisticated technology of Building Information Modeling (BIM) [1]. BIM is a tool for the architectural design filed from two dimensions to three dimensions or beyond by creating intelligent, multi-dimensional building models [2]. Building Information Modeling is able to help in collision detection at early stage with pinpoint accuracy. The Construction Industry Development Board (CIDB) has been putting a lot of efforts to encourage construction companies to implement Building Information Modeling (BIM) system to their current or upcoming projects recently. CIDB has emphasized that whatever public projects worth above RM100 mil are required to implement the BIM by the first quarter of 2019 [3]. It is essential that the future or upcoming Architecture, Engineering and Construction (AEC) graduates to know the basic concepts of BIM. As a result, the graduates will be equipped with the necessary knowledge and skills of BIM before they enter into their professional career and ready to make contribution to the construction industry with BIM [4].

Problem Statement

The current industry has demanded for engineers with BIM skills, many universities around the world have begun their BIM academic programs. But adoption of BIM into education curriculum is not that easy. The hindrance is most of the universities lack of understandings of what skills are required in the industry. Furthermore, only few researches have been done on BIM-teaching methods, course contents, objectives and outcomes [4]. The universities across Malaysia were actually encountered a severe problem which was lack of concentration on overall construction engineering and management skills. Therefore, there is a must to introduce BIM education at university level so that it will be a lot easier for the students to apply BIM on projects when they enroll themselves into professional organization.

BIM was getting popular nowadays, universities in Malaysia such as UTM are required to determine the feasibility by offering relevant curriculum in the area of BIM theory and methods; for instances, replace an existing course, or advise a current course with a BIM component or input a new subject devoted to BIM theory and method. These are the factors that this research to be carried out.

Objectives

The aim of this study is to determine the feasibility of BIM implementation into construction education curriculum in University of Technology Malaysia (UTM), and the following objectives are to ascertain for this proposed research project:

1. To determine the awareness of students regarding to BIM technology.
2. To identify the hindrance of integrating BIM into AEC education curriculum.
3. To propose recommendations to overcome the hindrance of integrating BIM in University of Technology Malaysia.

Scope of Study

This study was only conducted in selected university which was University of Technology Malaysia. The targeted respondents were the students and lecturers from AEC related courses who were from civil engineering courses, architectural courses, construction management courses, quantity surveying courses, electrical engineering courses, mechanical engineering courses and petroleum engineering courses. Researcher has directly contacted and consulted those respondents and distributed the questionnaire which researcher has prepared earlier. Besides, online questionnaire has been delivered to those respondents who the researcher was not able to deal with. Besides, interview session has been prepared to targeted lecturers with BIM knowledge.

LITERATURE REVIEW

For decades, the world has enormously depend on digital design model for work progressing. A digital design model can help to visualize beforehand in a virtual world. It have brought convenience to the people, concurrent troubles can be reduced. BIM able to assist architecture, engineering, and construction (AEC) industries which providing the same approach to construction projects. The advantages if using BIM technology as listed in Table 1. While the hindrance of integrating BIM into AEC education curriculum has stated in Table 2 and Methods of implementing BIM module has been mention in Table 3.

Table 1: Advantages of BIM

Code	Advantages of BIM	Description	Reference
P1	Reduce overall project cost	BIM software has built-in cost estimating features that can indirectly reduce the overall project cost. BIM's capability of merging graphical and non-graphical data models which providing more accurate cost information	[5],[6]
P2	Help to detect conflict point before construction started	The BIM model can help all the engineers to detect potential failures, leakage and evacuation plans before or after the construction project. The errors, conflicts and change orders on site are able to be solved faster by using BIM.	[5],[7],[8]
P3	Enhance collaboration among stakeholders	All the parties to have a clearer vision and eventually decision can be done quicker and accurately	[9]
P4	Deliver information with greater transparency	In conventional construction method, there is a potential conflict of interests between parties because all have their self-interests, they will not be willing to share all the information all of the time. BIM can update information and shown in the functional model for every involved party.	[10],[11]
P5	Reduce overall project duration	Overruns on construction projects are worldwide problems. BIM can easily identify the problem and provide appropriate solutionsto avoid reworking.	[12],[13]
P6	Increase speed of delivering projects	BIM is a single repository to provide electronic reviews of every portion of building design. Delivery to the client can be expedited with these numerous electronic reviews.	[14]
P7	More sustainable and energy saving	Provide a platform for energy, lightening and acoustic analysis in a virtual model. Therefore, BIM improving the building quality and more eco-friendly to the environment	[15]
P8	Less waste is generated	BIM can avoid unnecessary extra work to be done which later may lead to wastage during construction. BIM can assist waste reduction effectively and resulting in higher rates of return.	[16]
P9	Improve documents management	All the stakeholders can browse through all the design information by using BIM easily and in detail. Better documents management, sharing and use of information by using BIM.	[17],[18],[19]
P10	More accurate design and visualization	BIM model can have better visualization how the building operates and to make adaptations, renovations, and maintenance to the building compared to conventional method.	[14],[20]

Table 2: Hindrance of integrating BIM into AEC education curriculum

Code	Hindrance of integrating BIM	Description	Reference
P11	Reluctance to change the current syllabus	Process of changing the syllabus needs to undergo certain requirements and conditions. It will very troublesome and require plenty of time and effort to rearrange the current syllabus.	[21],[26]
P12	Lack of the need for industry involvement	Plenty of universities do not offer BIM courses due to no common understanding of what exactly the industry are required, nor have no idea what should be included in the syllabus and method of teaching to be done for BIM.	[22],[26]
P13	Faculty time and resource to implement a new course stakeholders	It might be a challenge for faculty authorities to merge all course content into one.	[17]
P14	Shortage of well trained professional in faculty	BIM software is so complicated to be learnt, without the well-trained professionals or lecturers to teach and guide the student, students may just lose their interest in learning due to the complexity of BIM software	[23]
P15	Lack of collaboration between disciplines	Integrating BIM into construction education syllabus is required greater collaboration of three levels that is teachers, curricula, and universities.	[24]
P16	Lack of funding to implement BIM	The primary hurdles restricting higher level of usage of BIM are constant software upgrading, costs and education.	[25]
P17	Controversy over BIM concept still exists	Disagreement over BIM concept is concerned with the difference in viewpoints regarding whether BIM is a methodological process or a software tool.	[26]
P18	Lack of Accreditation Standards	Professional accreditation issue reflects the fact that most professional bodies required the curriculum to satisfy certain learning outcomes necessary for a discipline-specific professional.	[26],[27]
P19	There is no Demand from AEC Students	Students nowadays have lack of perception of opportunity and being passive	[28]

Table 3: Methods of Implementing BIM module

Code	Hindrance of integrating BIM	Reference
P20	Introduce Prerequisite courses that related to BIM	[27]
P21	Integrate BIM as one of the topic in particular courses	[29]
P22	Purchase BIM software and technology	[30]
P23	Slowly replace existing CAD class with BIM class	[17]
P24	Organize more competition that require BIM knowledge	[31]
P25	BIM workshop	[32]
P26	Training lecturers on BIM software and technology	[33]
P27	Raise the awareness of importance of BIM	[34]
P28	Collaboration between University and construction industry.	[35],[36]

METHODOLOGY

This study has been conducted over 103 students from civil engineering courses, architectural courses, construction management courses, quantity surveying courses, electrical engineering courses, mechanical engineering courses and petroleum engineering courses using Principal Component Analysis. Interview has been carried out with lecturer with BIM experience and Content Analysis was to use analyze the results obtained.

Principal Component Analysis

Principal Component Analysis (PCA) is one of the methods of Factor Analysis. PCA was conducted with SPSS16 to test the reliability of data collected in this study. The reliability test is used to show the consistency and stability in measuring a data sample. Cronbach's Alpha coefficient which has score of 0.70 and above is considered as acceptable in a study. KMO and Barlett's Test is measure for PCA. KMO value between 0.8 to 1 show the sampling is sufficient to test with Factor Analysis. Threshold coefficient at 0.7 is used for Principal Component Analysis which is indicated only high factor loading factors will be remained. Table 4 shows the Realiability Test and KMO test for this study.

Table 4: the Realiability Test and KMO test

Section	Description	N	Cronbach's Alpha	KMO
B	The advantages of BIM	10	0.971	0.938
C	Hindrance of integrating BIM into AEC education curriculum	9	0.787	0.815
D	Recommendation of implementing BIM in AEC education curriculum	9	0.884	0.868

Content Analysis

The reliability test of Content Analysis can be measured with the following formula:

$$PA = \frac{A}{n} \times 100 \quad \textbf{Eqn 1}$$

Where PA = percentage agreement, A = number of agreement and n = number of segments coded. The scores which are above 80 per cent would be acceptable based on the previous studies which have been done. If the reliability test below 80 per cent would be not valid and difficult to interpret.

RESULT AND DISCUSSION

Section B Part 1: General knowledge of BIM

Table 5: Have you heard about BIM?

Have you heard about BIM		Yes, but never use it, %	Yes, using it, %	No, this is first time hearing it, %	Total, %
Students' Courses	Architectural	20	60	20	100
	Civil Engineering	70	9	21	100
	Construction Management	0	0	100	100
	Quantity Surveyor	76	0	24	100
	Mechanical Engineering	0	0	100	100
	Electrical Engineering	0	0	100	100
	Petroleum Engineering	0	0	100	100
	Total	42	16	42	100

Table 5 illustrated 42% of students answered they have heard about BIM but never use it before and 16% have started using BIM. 42% answered totally never heard of it. This indicated that more than half of the respondents were aware of BIM. 60% of architectural students answered they have using BIM, this shows BIM has been implemented in their courses. Majority of civil engineering and quantity surveying students have heard about BIM but never use before, this can be understood some efforts were made by their faculty to introduce BIM to students. While other construction related courses such as Construction management, mechanical engineering, electrical engineering and petroleum engineering have not started to introduce BIM to their students yet due to all the students from particular courses have stated this was their first time heard about BIM.

Section B Part 2 (First Objective): BIM's advantages in construction industry

I. Principal Component Analysis

By looking at Table 6, the correlation value of P9 has shown the highest value with 0.930. This indicated the students believed the most significant advantage of BIM was it able to improve document management. Codes P4, P6, P8 and P10 have the correlation value above 0.9 which seemed to be extremely important. This have shown students aware that BIM was able to deliver information with greater transparency, increase speed of delivering projects, less waste will be generated and BIM can produce more accurate design and visualization.

Table 6: Advantages of BIM technology in construction industry

Code		Correlation value
P1	Reduce overall project cost	0.840
P2	Help to detect conflict point before construction started	0.881
P3	Enhance collaboration among stakeholders	0.843
P4	Deliver information with greater transparency	0.918
P5	Reduce overall project duration	0.885
P6	Increase speed of delivering projects	0.912
P7	More sustainable and energy saving	0.888
P8	Less waste is generated	0.904
P9	Improve documents management	0.930
P10	More accurate design and visualization	0.917

II. Content Analysis

The analysis has been carried out by using frequencies of category occurrence. The acceptance level of each factors must has at least 80 per cent which meaning that 4 out of 5 respondents must speak out the particular factors. Four factors have been extracted out of ten factors (refer to Table 7). The opinions from the lecturers were quite different with the students' opinion. Lecturers aware that BIM able to reduce overall project cost, can help to detect conflict point before construction started, and enhance collaboration among stakeholders and BIM can produce more accurate design and visualization.

Table 7: How well do lecturers aware the advantages of BIM technology in construction industry?

Criteria	Respondent					Frequency	%	Remarks
	1	2	3	4	5			
Reduce overall project cost	✓		✓	✓	✓	4/5	80	Accepted
Help to detect conflict point before construction started	✓			✓	✓	4/5	80	Accepted
Enhance collaborations among stakeholders	✓			✓	✓	4/5	80	Accepted
Deliver information with greater transparency					✓	1/5	20	Rejected
Reduce overall project duration	✓			✓	✓	3/5	60	Rejected
Increase speed of delivering projects	✓			✓	✓	2/5	60	Rejected
More sustainable and energy saving		✓			✓	2/5	40	Rejected
Less waste is generated		✓			✓	2/5	40	Rejected
Improve documents managements					✓	1/5	20	Rejected
More accurate design and visualisation	✓		✓	✓	✓	4/5	80	Accepted

Section C (Second Objective): Hindrance of integrating BIM into AEC education curriculum

I. Principal Component Analysis

From Table 8, six factors out of nine factors about the hindrance of integrating BIM were extracted from PCA. Factors P11, P17 and P18 have correlation value less than 0.7 which these factors were slightly less influence. P19 has the highest correlation value with 0.891, this indicated that students believed the problems were not from other aspects but within students themselves. Students themselves were not keen to learn the BIM technology. In the aspect of faculty, the shortage of well-trained professional in faculty was the major contribution to the hindrance of integrating BIM into AEC education curriculum. Therefore, P14 has the second highest correlation value of 0.819. Students also agreed that faculty time and resource to implement a new course, lack of collaboration across disciplines and lack of funding to implement BIM was also the barriers contributing to this issue.

Table 8: Hindrance of integrating BIM into AEC education curriculum

Code		Correlation value
P11	Reluctance to change the current syllabus	-
P12	Lack of the need for industry involvement	0.815
P13	Faculty time and resource to implement a new course	0.785
P14	Shortage of well-trained professional in faculty	0.819
P15	Lack of collaboration across disciplines	0.760
P16	Lack of funding to implement BIM	0.782
P17	Controversy over BIM concept still exists	-
P18	Lack of Accreditation Standards	-
P19	There is no demand from AEC Students	0.891

II. Content Analysis

Four factors have been extracted out of nine factors (refer to Table 9). The opinions from the lecturers were slightly different with the students' opinions. From the points of views of faculty, Lecturers strongly agreed that shortage of well-trained professional and faculty time and resource to implement a new course were the main hindrances to integrate BIM into current education curriculum.

Table 9: Lecturers' perspective about the hindrance of integrating BIM into AEC Education Curriculum

Category	Criteria	Respondent					Frequency	%	Remarks
		1	2	3	4	5			
Faculty	Reluctance to change the current syllabus						0/5	0	Rejected
	Faculty time and resources to implement a new course	✓	✓		✓	✓	4/5	80	Accepted
	Shortage of well-trained professional in faculty	✓		✓	✓	✓	4/5	80	Accepted
	Lack of collaboration across discipline	✓				✓	2/5	40	Rejected
	Lack of funding to implement BIM	✓		✓		✓	3/5	60	Rejected
	There is no demand from AEC students		✓				1/5	20	Rejected
Industry	Lack of the need for industry involvement	✓	✓				2/5	40	Rejected
	Controversy over BIM concept still exists	✓	✓	✓		✓	4/5	80	Accepted
	Lack of accreditation standards	✓	✓	✓		✓	4/5	80	Accepted

From industry's perspective, lecturers agreed that controversy over BIM still existing in the current world of construction. Much research needs to be done in order to clear the doubt about this new technology. Lecturers also believed that lack of accreditation standards was one of the hindrances. Most of the employers in construction industry still do not care about whether a graduate acquires the BIM skills in their study.

Section D (Third Objective): Recommendations to overcome the hindrance of integrating BIM

I. Principal Component Analysis

Principal Component Analysis (PCA) had extracted six out of nine recommendations in Table 10. P23 has the highest correlation value with 0.851, this have shown students agreed to slowly replace existing CAD class with BIM class. Regarding to high correlation value of P27 with 0.837, this indicated that students also believed that raise the awareness of important of BIM able to remove the barrier and successfully implement BIM in AEC education curriculum. P28 has achieved value above 0.8, this meant that students also totally agreed collaboration between university and construction industry can make a huge turning point about this issue.

Table 10: Recommendations to overcome the hindrance of integrating BIM

Code		Correlation value
P20	Introduce Prerequisite courses that related to BIM	-
P21	Integrate BIM as one of the topic in particular courses	0.734
P22	Purchase BIM software and technology	-
P23	Slowly replace existing CAD class with BIM class	0.851
P24	Organize more competitions that required BIM knowledge	-
P25	BIM workshop	0.763
P26	Training lecturers on BIM software and technology	0.763
P27	Raise the awareness of important of BIM	0.837
P28	Collaboration between University and construction industry	0.823

II. Content Analysis

Regarding to Table 11, six recommendations have been accepted which these recommendations have surpassed 80%. From faculty's perspective, all the lecturers who have been interviewed totally agree on training lecturers on BIM software and technology can solve this issue. 80% of the lecturers have suggested introducing prerequisite courses that related to BIM and purchase BIM software and technology during the interview session. From the industry's perspective, all the lecturers have recommended to organize more BIM workshop to the public and the students. Besides, all of them also suggested the construction industry should raise the awareness of important of BIM for the current situation or near future. Majority of the lecturers gave the same recommendation as students which were through collaboration between university and construction industry.

Table 11: Lecturers' recommendations to overcome the hindrance of integrating BIM

Category	Criteria	Respondent					Frequency	%	Remarks
		1	2	3	4	5			
Faculty	Introduce prerequisite courses that related to BIM	✓	✓	✓		✓	4/5	80	Accepted
	Intergrade BIM as one the topic in particular courses	✓			✓	✓	2/5	40	Rejected
	Purchase BIM software and technology	✓	✓	✓		✓	4/5	80	Accepted
	Slowly replace existing CAD class with BIM	✓					1/5	20	Rejected
	Training lecturers on BIM software and technology	✓	✓	✓	✓	✓	5/5	100	Accepted
	Organise more competitions that required BIM knowledge	✓	✓				2/5	40	Rejected
Industry	BIM workshop	✓	✓	✓	✓	✓	5/5	100	Accepted
	Raise the awareness of important of BIM	✓	✓	✓	✓	✓	5/5	100	Accepted
	Collaboration between university and industry	✓	✓	✓		✓	4/5	80	Accepted

CONCLUSION

Building Information Modeling (BIM) is intended moving forwards to BIM stage 2 by year 2020 led by Construction Industry Development Board (CIDB). There is a need for universities in Malaysia to meet the requirement of construction industry by producing more graduates with BIM skills. This study has been done by collecting the perceptions from students and lecturers in UTM regarding the objectives that have been set. Hence, the objectives have successfully been achieved.

In summary, BIM able to BIM able to reduce overall project cost, help to detect conflict point, enhance collaboration among stakeholders and provided more accurate design and visualization (objective 1). Faculty time and resource to implement a new course and shortage of well-trained professional in faculty were the significant hindrances of this issue (objective 2). The best recommendations were collaboration between university and construction industry, training lecturers on BIM software and technology and organize more BIM workshop able to overcome the hindrance of integrating BIM (objective 3).

REFERENCES

[1] Reddy, K. (2007). How BIM is speeding up the greening of healthcare design. *Healthcare Design*, 7,8.
[2] Farid J. Sabongi, M. C. (2016). The Integration of BIM in the Undergraduate Curriculum.
[3] Ramachandran, S. (2016, Jun 24). *Boosting BIM adoption rates*.
[4] Ali Abbas*, Z. U. (2016). Integration of BIM in construction management education. *International Conference on Sustainable Design, Engineering and Construction*, 151.
[5] Talebi, S. (2014). *Exploring advantages and challenges of adaptation and implementation of BIM in project life cycle*. Paper presented at the 2nd BIM International Conference on Challenges to Overcome.
[6] McCuen, T. L. (2008). Scheduling, estimating, and BIM: A profitable combination. *AACE International Transactions*, BIM11.
[7] LeFevre, M. (2011). No BIM for You: The Case for Not Doing BIM-Leverage Points, Reframing and Key Decision Factors In BIM Transformation. *Journal of Building Information Modeling*, 14-17.
[8] Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and management in engineering, 11*(3), 241-252.
[9] Autodesk. (2011). Realizing the Benefits of BIM
[10] Ceric, A. (2014). Strategies for minimizing information asymmetries in construction projects: project managers' perceptions. *Journal of Business Economics and Management, 15*(3), 424-440.
[11] Eastman, C. M.,Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*: John Wiley & Sons.
[12] Azhar, S., Nadeem, A., Mok, J., & Leung, B. (2008). *Building Information Modeling (BIM): A new paradigm for visual interactive modeling and simulation for construction projects*. Paper presented at the Proc., First International Conference on Construction in Developing Countries.
[13] Ishak, M. I. S. (2017). *BIM helps in cost reduction and project delivery time*. University of Nottingham.
[14] InfoComm. (3 Feb 2017). Building Information Modeling. *Considerations and Limitations of BIM*, 11. https://www.infocomm.org/cps/rde/xbcr/infocomm/BIM_Brochure.pdf
[15] Stumpf, A., Kim, H., & Jenicek, E. (2009). *Early design energy analysis using bims (building information models)*. Paper presented at the Construction Research Congress 2009: Building a Sustainable Future.
[16] Rajendran, P., & Gomez, C. P. (2012). *Implementing BIM for waste minimisation in the construction industry: a literature review*. Paper presented at the 2nd International Conference on Management, Malaysia.
[17] Wong, K., Wong, F. K., & Nadeem, A. (2011). Building information modelling for tertiary construction education in Hong Kong. *Journal of information technology in construction*.
[18] Palos, S. (2012). State-of-the-art analysis of product data definitions usage in BIM. *eWork and eBusiness in Architecture, Engineering and Construction: ECPPM 2012*, 397 [9] Autodesk. (2011). Realizing the Benefits of BIM
[19] Fischer, M. (2002). *PM4D final report*.
[20] Conover, D. (2009). An Introduction to Building Information Modeling (BIM). 8.
[21] Kiviniemi, A. (2006). Adopting innovation: building information models in the Finnish real estate and construction cluster.
[22] Sacks, R., & Pikas, E. (2013). Building information modeling education for construction engineering and management. I: Industry requirements, state of the art, and gap analysis. *Journal of Construction Engineering and Management, 139*(11), 04013016.
[23] Cheng, R. (2006). Questioning the role of BIM in architectural education. *AECbytes Viewpoint, 26*.
[24] Berwald, S. (2008). From CAD to BIM: The experience of architectural education with building information modeling *AEI 2008: Building Integration Solutions* (pp. 1-5).
[25] Panuwatwanich, K., Wong, M. L., Doh, J.-H., Stewart, R. A., & McCarthy, T. J. (2013). Integrating building information modelling (BIM) into Engineering education: an exploratory study of industry perceptions using social network data.
[26] LeFevre, M. (2011). No BIM for You: The Case for Not Doing BIM-Leverage Points, Reframing and Key Decision Factors In BIM Transformation. *Journal of Building Information Modeling*, 14-17.
[27] Denzer, A., & Hedges, K. (2008). From CAD to BIM: Educational strategies for the coming paradigm shift *AEI 2008: Building Integration Solutions* (pp. 1-11).
[28] Ahn, E., & Kim, M. (2016). BIM Awareness and Acceptance by Architecture Students in Asia. *Journal of Asian Architecture and Building Engineering, 15*(3), 419-424.
[29] Clevenger, C. M., Ozbek, M., Glick, S., & Porter, D. (2010). *Integrating BIM into construction management education*. Paper presented at the EcoBuild Proceedings of the BIM-Related Academic Workshop.
[30] Watson, A. (2010). *BIM-a driver for change*. Paper presented at the Proceedings of the International Conference on Computing in Civil and Building Engineering.
[31] Chegu Badrinath, A., Chang, Y. T., & Hsieh, S. H. (2016). A review of tertiary BIM education for advanced engineering communication with visualization. *Visualization in Engineering, 4*(1), 9.
[32] Barison, M. B., & Santos, E. T. (2010). *BIM teaching strategies: an overview of the current approaches*. Paper presented at the Proc., ICCCBE 2010 International Conference on Computing in Civil and Building Engineering.
[33] Zakaria, Z., Mohamed Ali, N., Tarmizi Haron, A., Marshall-Ponting, A., & Abd Hamid, Z. (2013). Exploring the

adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach. *International Journal of Research in Engineering and Technology*, *2*(8), 384-395.

[34] Sebastian, R., & van Berlo, L. (2010). Tool for benchmarking BIM performance of design, engineering and construction firms in the Netherlands. *Architectural Engineering and Design Management*, *6*(4), 254-263.

[35] Pavelko, C. (2010). *Building Information Modeling in Today's University Undergraduate Curriculum*.

[36] Zhao, D., McCoy, A. P., Bulbul, T., Fiori, C., & Nikkhoo, P. (2015). Building collaborative construction skills through BIM-integrated learning environment. *International Journal of Construction Education and Research*, *11*(2), 97-120.

Flying Variables for Construction Dronography Using Unmanned Aerial Vehicle-UAV

Muhamad Akmal Awang Hamat, Ali Keyvanfar

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

alikeyvanfar@gmail.com

Keywords: Dronography; 2D photo image; Best Time; Best Distance; RGB histogram.

ABSTRACT. Nowadays the use of UAV in 3D modelling of the built environment is increasing and expanding to vary sector including construction, geological, disaster management and etc. There is no research covering best flying variables for this purpose. This research aims to investigate the best time also the best distance that contribute to the quality of the 2D dronography image. This research also provides the effect of temperature, humidity, lux, cloudiness and wind speed (all this criteria is consider environmental variables) to the quality of 2D image taken by UAV. This research used case study data collection for 3 days, focusing in obtaining the 2D image of the building façade that is facing east. The 3 days duration of data collection is choose to increase accuracy of data for this study. This 2D image is captured based on distance where the variable are temperature, humidity, lux, cloudiness and wind speed for gap 1 hour. For 3 days of data collection, 900 picture has been taken and few sample is choosen undergo RGB histogram analysis. As result, best distance is 30 meter and time for UAV's construction photography is during 12 noon. The acceptable temperature, humidity, lux, cloudiness and wind speed to the quality of 2D image taken by UAV is 38.1˚, 55.5% Rh, 38107 lx, slightly cloudy condition and 0.1 m/s respectively. This research will help the UAV construction photographer that aims to design the 3D model of building in term of time and distance.

INTRODUCTION

This study explores about the flying variable for the dronograpy or UAV's photography using unmanned aerial vehicle (UAV) also known as drone, Remotely Piloted Vehicle (RPV), Micro Aerial Vehicles (MAV), Small UAV (SUAV), Remote Controlled (RC) Helicopter, Remotely Operated Aircraft (ROA) and Model Helicopter. In recent decades, we can see the use of UAV in Architecture, Engineering and Construction as risen. This is due to its flexibility to complete the messy, complicated task and fast-dropping price in market, make the drone more relevant to use in construction field nowadays. "The main advantage of an Unmanned Aerial Vehicle (UAV) system acting as a photogrammetric sensor platform over more traditional manned airborne or terrestrial surveys is the high flexibility that allows image acquisition from unconventional viewpoints" (Irschara et al. 2010). By attach simple camera to UAV make it become invaluable to fly through structure while capturing the imaged of the building that later can be used to gain the building information through 3D modelling of that building. One other thing that make UAV a "people choice" is that it really easy to be learn. The control mechanism of the UAV have been develop to become more automatic and event can be control through smartphone by using certain software.

Problem Statement

Nowadays UAV is rapidly use in many sector to do work like inspection, transportation, survey and etc. But among others function, the 3D modelling of the building is among the top function the UAV. 3D modelling using the UAV become demanding and relevant in industry nowadays because it more convenient and affordable. With a lot of software being developed now to help enhance the 3D model, the 3D model can be create in the sort duration of time. The problem in 3D modelling will rise due to the quality of the 2D image taken by the UAV will affected the 3D model of the building later. If the 2D image taken not in good quality like the contrast of the image or the completeness of the image taken, it later will affect the quality of the 3D model. The thing that lead to this problem is the lighting intensity and the distance of captured image. People who involve in UAV photography will have to find the best time to capture the image that will give the best contrast to 2D image taken and also the best distance that will contribute the best scene completeness to create 3D model of high quality.

A lot of research have been done regarding of 3D modelling of building using UAV nowadays. But they are more focusing on the use and application of the 3D modelling on the field work like surveying and inspection rather than the field experiment for the UAV's variables in 3D modelling scope. The research related to 3D work using UAV usually explaining the process in creating the 3D model and the method use without explaining and experiment with the variable. One research about Building with Drones: Accurate 3D Facade Reconstruction using MAVs (Shreyansh Daftry, 2015) have one variable related to distance, one of this research objective. In that research, the method use is Structure-from-Motion, the result shows that close photography give better quality to 3D model of building while distance give better scene completeness to 3D model. But that research not consider the effect of time (light intensity) to the 3D model. Other research that relate to 3D modelling of building is Application of Technical Measures and Software in Constructing Photorealistic 3D Models of Historical Building Using Ground-Based and Aerial (UAV)

Digital Images, (Aleksander Zarnowski, 2015). This research conclusion is more to improvement and guideline during UAV's photography in environment and technical aspect. From that, the finding that can support this research paper is about the lighting and weather. That research find out that the slightly cloudy weather reduce the tonal range of the images, where it will prevent the formations of sharp image. Besides that, when the sun is at right position, it will minimise the length of shadow and the size of the shaded area of the building.

Those research only mentioning the distance and time effect without do the details experiment about it. This is the reason why this study is been conducted, to provide a best distance and time for UAV to take picture to use for 3D modelling later. For UAV photography session, it has to obtain a good 2D image to produce a high quality of the 3D model. Good 2D image must have a good contrast and scene completeness and this is heavily related to time and distance. Time in a day will give the lighting effect to the 2D image taken by UAV, thus will give the dynamic range image to the 2D image contain. While for distance, it will affect the scene completeness of the 2D image. If the 2D image taken is lack in scene completeness, the 3D model cannot show all the part of the actual building.

Aim

The purpose of this study is to investigate best flying variable that is time and distance from object for UAV's construction photography. This research also considers the effect of temperature, humidity, lux, cloudiness and wind speed as environmental variables to 2D image captured.

Objectives

The objectives of this study are:

1. To identify the best distance for dronography from the façade of building that gives the best quality for 2D photo image.
2. To identify the best time for dronography to take picture that give the best result for 2D photo image
3. To investigate the best temperature, humidity, lux, cloudiness and wind speed for dronography

Scope of Study

This research will use UAV attachable DSLR camera Canon EOS 1100D. This study will be conducted only on east facing building façade. This meant that the photography session only captured one side of the building as the best altenative among other 17 angles. The histogramt of 2D photos taken interpreted as quality of output. The quality of image processing depends on the RGB histogram of 2D image taken. The distance of captured image that need to be analyse between drone and façade of building is 20m, 30m and 40m, gap of 10m will give the clear comparison. The time gap between each section of picture taken by UAV's is 1 hour. This will differentiate the quality of 2D image taken

LITERATURE REVIEW

Unmanned aerial vehicle (UAV) can be defined as a "small aircraft on which pilot is not boarded and it has a separate remote control operator on the ground and it is also called as drone meaning that it looks like a buzzing bee" (Sung-suk Choi, 2015). UAV also known as drone, Remotely Piloted Vehicle (RPV, Micro Aerial Vehicles (MAV), Small UAV (SUAV), Remote Controlled (RC) Helicopter), Remotely Operated Aircraft (ROA) and Model Helicopter. Definition obtain from dictionary describe UAV as "an aircraft without a pilot that is controlled by someone on the ground, used especially as hobby" (Cambridge Dictionary.org). According to the UVS (Unmanned Vehicle System) International definition, an Unmanned Aerial Vehicle (UAV) is "a generic aircraft design to operate with no human pilot on board" (http://www.uvs-international.org/).

Dronography is a photography session by using UAV. The UAV is attached with camera enable it to take picture and video. The idea of using UAV for photography is to take a picture from whole new angle that is unreached or difficult to reach by manual photographer. In construction, the ability for UAV to fly high and capturing image make the works in construction site very easy. It help to reach high place and captured the image for inspection, surveying and monitoring purpose. Other than that, the image taken by UAV also can be used to generate 3D model either site view, geological of places and even the building model

Unmanned aerial vehicle or known as drone before become friendly use by people, it is use in military as deploy unit of bomb by military. During early 2000s the use of drone is start to expanding to other sectors like construction, archaeology, geology, traffic and etc. Due to its micro size, easy handling mechanism and simple camera that attach to the drone, all the other sector see drone as "must-have" technology and since it has become more domestic, people tend to call it as UAV.

These day, the UAV not only use as hobby, but also involve in daily work of serious field. UAV is very versatile and user friendly, and with the attachment of simple camera on UAV has make the potential of UAV bigger. The work like inspection, survey and safety all can be done by UAV, and beside that, one of the biggest asset of UAV that it can be promising alternative for imaging and 3D modelling (Fabio Remondino, 2016). The ability of the UAV to fly and capturing image make it a very valuable asset in 3D modelling of the building façade, whole building, city, archaeology site, surveying and mapping. There are a few program use to generate the 3D model like open-source software such as

Meshlab, freeware such as 123D Catch and licensed software such as Agisoft PhotoScan Pro, it is now cost effective to utilize photogrammetry in any project (Kim Changyoon, 2015).

Through 45 journals, the Table 1 (Appendix) provide the finding of the UAV to each aspect in construction like 3D modelling, safety, surveying, monitoring, transportation, contour crafting, and inspection and from that also the taxonomy in Figure 1 been build. From 44 journals, 14 of it do research on 3D modelling, 5 on safety, 6 on surveying, 4 on monitoring, 11 on transportation, only 1 on contour crafting and 12 on inspection. Then from that finding, one taxonomy is constructed to show the application of UAV in the construction (Figure 1)

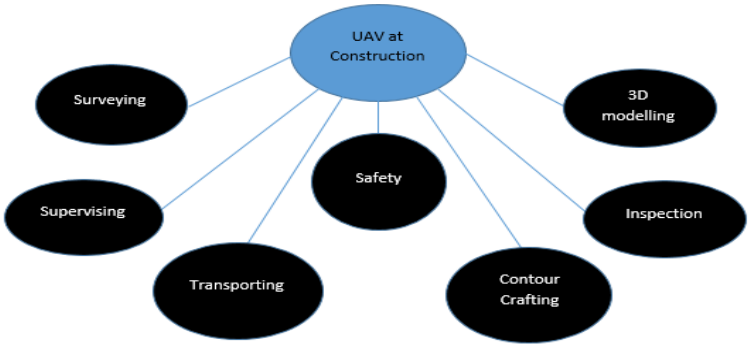


Figure 1: Taxonomy of research conducted on application of UAV in construction

UAV has a future potential that can be innovate and expand more. For year 2015 only, the sales of drone in the world increase to 167% compare to two years before, the overall drone sold around the world during 2015 is reached 4.3 million, at cost approximately $1.7 billion. According to Kleiner Perkins Claufield and Byers, the American venture capital firm, during 2015 the US, Europe and China become the top three drone consumer list with 35, 30 and 15 percent of the world UAV purchases are from them. This shows that why UAV-related study is needed for future sake.

METHODOLOGY

Three phases of framework or flow of work had been planned. Basically each phase was shaped to fulfil the needs of each objectives of the research. Each process involve different steps, activities and outcome.

First Phase: Literature Review on Methodology

In this phase, the aim was to study the past variables. There are a lot of variable used by other researcher such as the type of camera use for photography, image redundancy, angle of image and etc. After conducting a literature review through 44 journals, the finding from that study is the variable like best distance and best time is less use and explained in the past research. The environmental effect also is not been mention and related to the 2D image taken.

Second Phase; Field Work and Data Collection

The aim of this phase to do the data collection by conducting field work (Figure 2), its take 3 days of full commitment. As initial step, the building need to be choose as model (Figure 3) that have wide free space about 45m from the façade of that building. Then all the require equipment need to be setting up like UAV, thermometer (to check the temperature of surrounding), digital device (to check the humidity and wind speed) and etc. After all the equipment ready, the data collection is start.

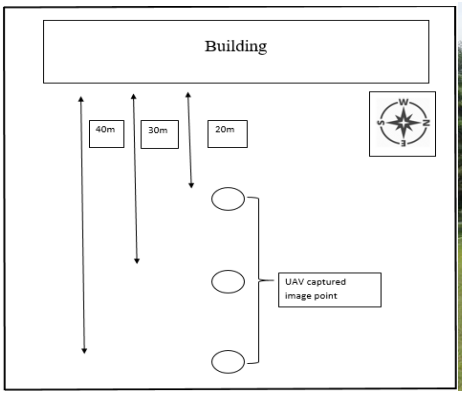


Figure 2: Field work plan

Figure 3: Eco Home, UTM

Field work procedure;

1. Punch nail at the tip of measuring tape, pull the measuring tape until it reach 20 meter from building façade, taped the ground as a mark.
2. Then continue pull the tape until it reach 30 and 40 meter distance, mark it. The mark location must be in one straight line.
3. For the start of every hour, set a tripod at marked area, attach the UAV attachable camera to the tripod.
4. Start at 20m distance, before photography session start, record the temperature, ultraviolet and wind speed data by using digital instrument and light intensity by using Lux meter apps.
5. After data recorded, take 10 shot picture of the building.
6. Repeat step 4 and 5 for 30 and 40 meter distance.
7. Then repeat step 3, 4, 5 and 6 for every hour. This field work will be conduct from 8 a.m. to 5 p.m. for 3 days.

Data required for this study obtained from field work is recorded and tabulate. Data obtained is record in two ways, for 2D imaged taken by UAV's attachable camera is stored in computer and for distance, time, temperature, humidity, lux, cloudiness and wind speed is record in form of table for all 3 days as shown in Table 2, 3 and 4 (Appendix).

For all table, data of temperature, humidity, lux and wind speed is in average value that include data for 20 meter, 30 meter and 40 meter distance on each of time gap. For unrecorded data, it is due to rainy condition. Rainy condition will prevent the field work from being conducted due to the intolerant-water equipment used during the field work.

Third Phase: Data Analysis

After all the data collection is done. All the pictured taken by UAV will be entered to image processing software to find the best quality photo via correlation analysis. Then the software will generate the histogram analysis of image obtain from field work for each distance point in 1 hour gap session. Then later, the 2D image will be sort in order of the quality after being analyse using the RGB histogram. The term quality there refer to the 2D image that have the high dynamic range image (many distinct values). As a result, it will provide the best 3D model of building façade due on the best time and distance. Besides that, the temperature, humidity, lux, cloudiness and wind speed effect during that time will be declared acceptable to conduct the UAV photography session.

In this research, the image processing software used is image color summarizer. This software will summarize the colour on the image. Output from this software will produce a report contain of color cluster, image cluster partition, histograms and color space and channel statistic table. One of the output is RGB histogram, from this the quality image can be determined. Contain of pixel and intensity of three basic color; red, blue and green can be seen from this histogram.

Data analysis procedure;

1. Insert input into software; 2D image and other requirement (refer Figure 4.2) for data of the 1st day of field work start with 8 a.m. 30 meter distance (the distance act as control variable)
2. Process the image and keep the output as record
3. Repeat step 1 and 2 for other time session for 1st day of field work
4. Repeat step 1, 2 and 3 for 2nd and 3rd day of field work (with 30 meter distance as control variable)
5. Combine and sort all the data obtain from software for all days of filed work
6. Determine the best quality of 2D image by using RGB histogram and channel statistic table.
7. After obtain 1 picture that has the best quality, mark that time session. That time session will be consider the best time to take picture for 3D modelling using UAV. Also the temperature, humidity, lux, cloudiness and wind speed during that time is consider acceptable to conduct the UAV photography session.
8. After that, to find the best distance, repeat step 1 and 2 using data from that best time but different distance (20 and 40 meter).
9. Then compare the histogram of the distance (20, 30 and 40 meter) and the one with high statistical value will become the best distance.

DATA ANALYSIS AND RESULT

Data analysis is a process of extracting, inspecting, transforming and modelling data that later can be used to suggest conclusion and support decision making from useful information obtained. This process is a crucial process that will conclude the whole research and study. For data analysis, it divided into two, first step is to identify the best time and environmental variables and for second step is to identify best distance. Figure 4 is as flow diagram for data analysis. Legends; DV= Dependent variables, IV= Independent variables, CV= Control variables.

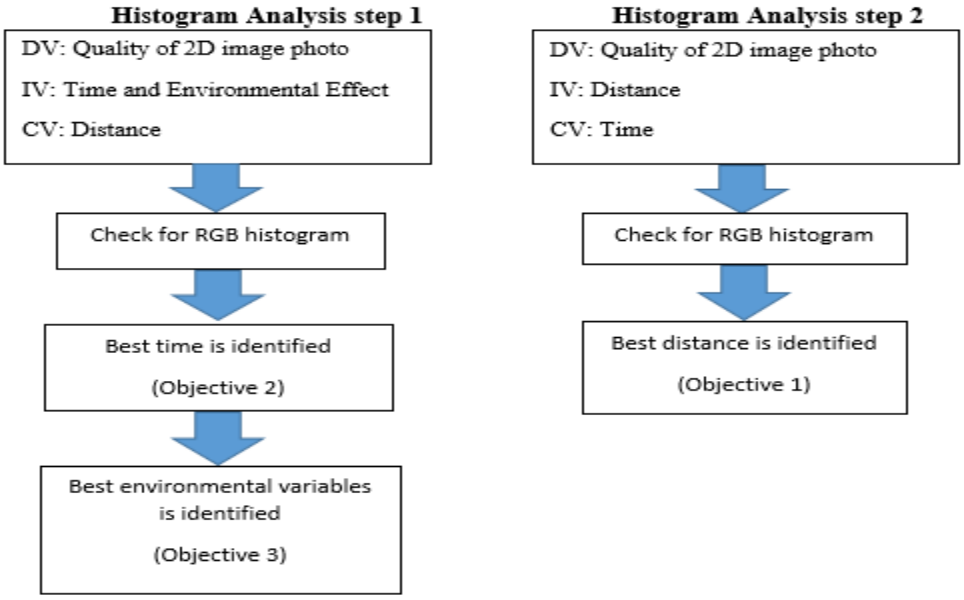


Figure 4; Flow diagram for data analysis

Phase 1; Best Time Identification

For initial step, the image taken during field work has been stored in computer in form of folder sort by the days of field work. Then by using image color summarizer software, analyze all the picture one by one by follow the order of time session then the days of the field work. To done this, one condition has been placed where for each time session only pick one distance as control variable to choose the best time.

After done all the time session data analysis for three day of the data collection with a same distance use as control variable (for this study use 30 meter distance) and gather all the report from the software. The next step is to short the RGB histogram of the data from low to high dynamic range image.

As a result, the best time session to conduct UAV's photography session for 3D modelling is on 12 p.m**.** This can be proved by the RGB histogram of this time session and the color statistic table (refer Figure 4). The RGB histogram for 12 p.m. on 2nd day of field work show a high number of pixel distribution for red, blue and green in that picture compare to other and the color statistic table also show high average number for red, blue and green color. This shows that image taken during 12 p.m. has a high dynamic range image. Thus, all the data for temperature, humidity, lux, cloudiness and wind speed is acceptable for UAV's photography session (refer Table 3). RGB histogram after 12 noon is not practical because for the east facing side of building, the sun postion after 12 noon is behind the building facade. The building facade will be covering by shadow this time. Even the RGB histogram is high for after 12 noon, due to that reason it will not be considered.

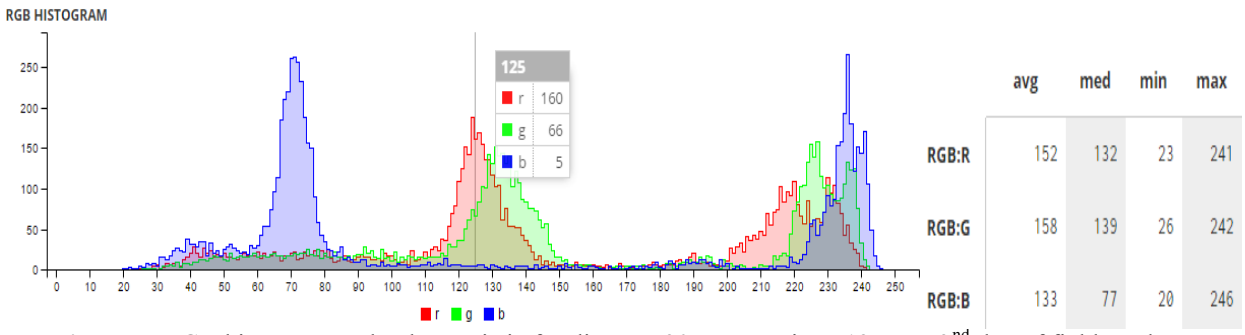


Figure 4; RGB histogram and color statistic for distance 30 Meter, Time: 12 p.m., 2nd day of field work

Phase 2; Best Distance Identification

The best distance can be identified by using time as control variables. If before this, 30 meter distance is set as control variables to identify the best time. For best distance, 12 p.m. time session of the 2nd day of field work is set as control variable. Since the best time is already identified, the scope is become smaller. To obtain the best distance, the imaged that need to be analyze is under session 12 p.m. of 2nd of field work only. The input for image color summarizer software is image for 20 and 40 meter distance only. Since the data for 30 meter is already analyze (Figure 4).

For best distance, since it will influence in the scene completeness of the 3D model, the result goes to 30 meter distance. The RGB histogram and color statistic table for 40 meter distance maybe a bit higher (refer Figure 5) compare to 30 meter but it is not practical. This is because RGB histogram for 40 meter is considering the color surrounding of the building more compare the color of the building itself.

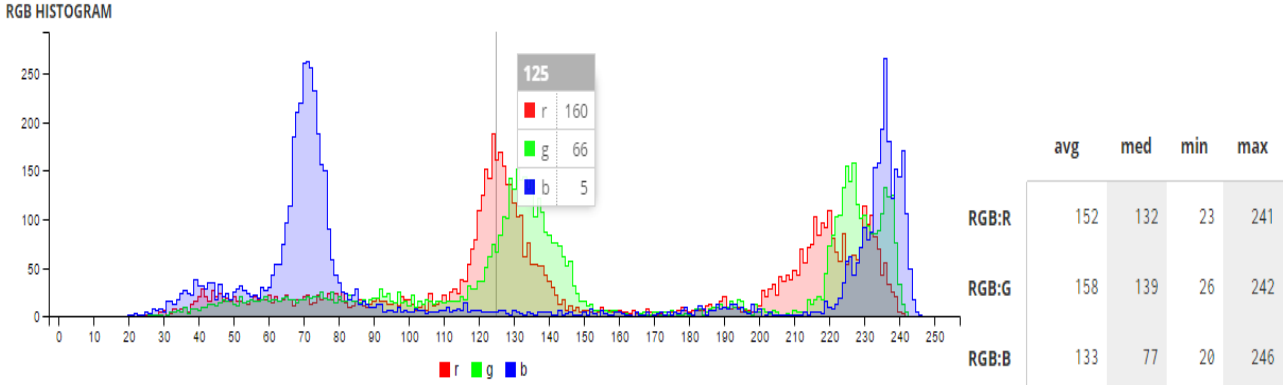


Figure 4; RGB histogram and color statistic for distance 30 Meter, Time: 12 p.m., 2nd day of field work

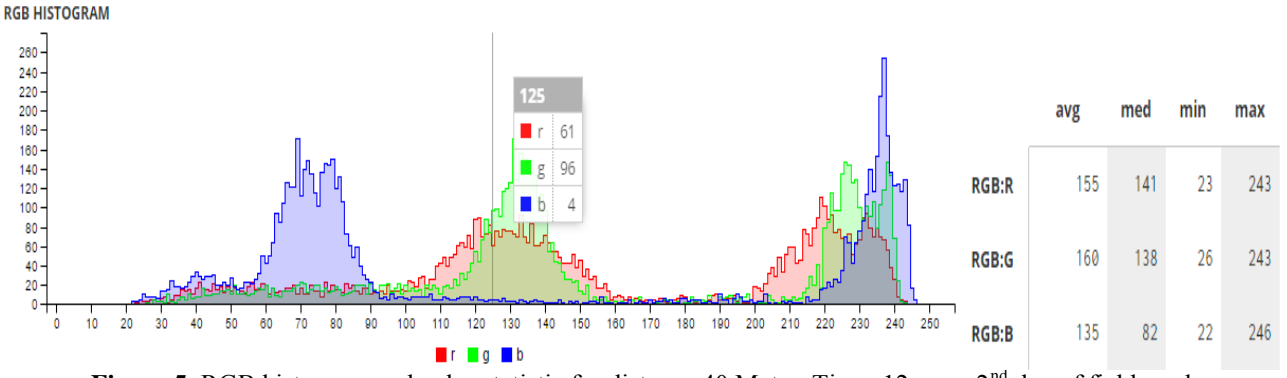


Figure 5; RGB histogram and color statistic for distance 40 Meter, Time: 12 p.m., 2nd day of field work

CONCLUSION

This research presents the best time and distance for UAV's 2D image photo and also the acceptable value of temperature, humidity, lux, cloudiness and wind speed during UAV photography.

1. After image analysis, the best time that give high dynamic range image is 12 p.m. 2nd day of data collection. This is because in RGB histogram shows a widest distribution of pixel for three basic color that is red, blue and green.
2. 2D image photo best taken distance is 30 meter. After image analysis, the result shows an increasing distribution of pixel in RGB histogram as the distance increase. This is not practical because when the distance increase, the software considering the color surrounding of the building more to the color of the building itself. So by considering the image completeness and also the high amount of color statistic, 30 meter distance is more practical and acceptable.
3. For best environmental variables which is temperature, humidity, lux, cloudiness and wind speed, the data that is captured are 38.1˚, 55.5% Rh, 38107 lx, slightly cloudy condition and 0.1 m/s respectively.

REFERENCES

[1] Sung-suk Choi, E-k. K. (2015). Building Crack Inspection using Small UAV

[2] F. Remondino, L. B. (2011). UAV Photogrammetry For Mapping and 3D Modelling – Current Status and Future Perspective

[3] Shreyansh Daftry, C. H. (2015). Buiding with Drones: Accurate 3D Façade Reconstruction Using MAVs

[4] Aleksander Zarnowski, A. B. (2015). Application of Technical Measures ans Software in Construction Photorealistic 3D Models of Historical Building Using Fround – Based and Aerial (UAV) Digital Images

[5] Changyoon Kim, H. M. (2015). Design of a 3D Model Viewer For Managing Drone-Based 3D Reconstruction Model of Disaster Site

APPENDIX

Table 1: Finding through journals

REF	3D	SF	SV	MT	TP	CC	IP
1							
2			■	■	■	■	
3	■						
4							■
5	■						
6		■					
7							■
8	■						
9	■						
10				■			
11							■
12				■			■
13		■					■
14							■
15							■
16					■		
17	■						
18					■		
19					■		
20	■						
21	■						
22	■						
23	■						
24	■						
25	■		■				
26	■		■				
27							■
28							■
29	■						
30							■
31							■
32		■					■
33		■					
34		■					
35				■			
36			■				
37			■				
38					■		
39			■				
40					■		
41					■		
42					■		
43					■		
44					■		
45					■		
Total	14	5	6	4	11	1	12

Legends:
SF= safety,
SV= surveying,
MT= monitoring
IP= inspection
TP= transporting,
CC= contour crafting,
REF= reference

Table 2: First day of data collection

Time	Temperature	Humidity (%)	Lux (lx)	Cloudiness	Wind Speed (m/s)	RGB histogram (Average pixel for 30 meter)		
						R	G	B
8.00	31.2	75.2	9587.3	Cloudy	0	148	149	121
9.00	35.5	63.7	18914.3	Not Cloudy	0.1	154	150	121
10.00	31.8	68.1	8347.7	Cloudy	0.3	149	154	130
11.00	33.0	65.3	26265.3	Cloudy	0.3	152	155	124
12.00	36.9	56.5	80741.7	Not Cloudy	0.7	150	153	124
1.00	35.6	62.5	35144	Not Cloudy	0.2	149	153	132
2.00	39.4	52.2	69623.3	Not Cloudy	0.1	159	159	123
3.00	33.8	65.2	9040.3	Slightly Cloudy	0.6	152	158	136
4.00	36.5	58.8	22107.3	Not Cloudy	0.1	161	161	133
5.00	33.4	65.2	7339.3	Not Cloudy	0	160	161	139

Table 3: Second day of data collection

Time	Temperature	Humidity (%)	Lux (lx)	Cloudiness	Wind Speed (m/s)	RGB histogram (Average pixel for 30 meter)		
						R	G	B
8.00	28.8	78.5	4874.7	Cloudy	0	142	144	119
9.00	30.2	74.9	15179.7	Cloudy	0	143	148	125
10.00	32.8	70.9	25483.7	Not Cloudy	0	150	155	129
11.00	38.0	53.9	62781.7	Not Cloudy	0.1	152	158	136
12.00	38.1	55.5	38107	Slightly Cloudy	0.1	152	158	133
1.00	45.4	46.8	94480	Not Cloudy	0	159	163	133
2.00	38.0	55.8	34568.3	Slightly Cloudy	0.3	148	154	132
3.00	37.5	51.8	27077.7	Slightly Cloudy	1.0	160	163	134
4.00	35.1	61.2	16519.3	Slightly Cloudy	0	153	160	141
5.00	36.7	59.3	7546.3	Not Cloudy	0	158	157	135

Table 4: Third day of data collection

Time	Temperature	Humidity (%)	Lux (lx)	Cloudiness	Wind Speed (m/s)	RGB histogram (Average pixel for 30 meter)		
						R	G	B
8.00	Not Recorded	Not Recorded	Not Recorded	Rainy	Not Recorded	No data	No data	No data
9.00	32.7	73.6	13274	Not Cloudy	0.2	156	156	127
10.00	35.6	63.7	30828.3	Cloudy	0	150	156	134
11.00	33.1	67.9	16825.3	Cloudy	0	144	150	129
12.00	Not Recorded	Not Recorded	Not Recorded	Rainy	Not Recorded	No data	No data	No data
1.00	Not Recorded	Not Recorded	Not Recorded	Rainy	Not Recorded	No data	No data	No data
2.00	Not Recorded	Not Recorded	Not Recorded	Rainy	Not Recorded	No data	No data	No data
3.00	30.0	76.7	9268	Cloudy	0	142	148	129
4.00	30.8	74.6	10261.7	Cloudy	0	148	154	133
5.00	33.1	75.1	9972.3	Cloudy	0	147	152	125

Building Energy Consumption: A Case Study in Faculty of Civil Engineering, Universiti Teknologi Malaysia

Vynotdni, Khairulzan Yahya, Zaiton Haron

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

khairulzan@utm.my

Keywords: Building Information Model; Space-Activity-Appliances Model; Internal factor; External factor; Electricity Energy Usage Intensity

ABSTRACT. The concern on energy consumption in buildings is increasing worldwide. Energy consumption is one of the measuring tools used to access building performance. During the design stage, a building is analysed to evaluate its performance by the designer. The tools used by designers to assess energy usage mostly focus only on the external factors such as building envelope, climate and orientations. However, there is always a significant discrepancy between simulated and actual energy use. The reason is occupants' behaviour and activity are not included in the design state analyses. This study aims to investigate on the influence of both internal and external factors separately in energy consumption of a building. The Revit Architecture 2017, a Building Information Model tool is used to calculate energy usage in terms of external factors while Space-Activity-Appliances Model is used to calculate energy consumption in terms of internal factors. Block M47, a building in Faculty of Civil Engineering, Universiti Teknologi Malaysia was chosen for this case study. In 2015, this building had highest Electricity Energy Usage Intensity of 14.3 kWh/sm. It is the building with highest Electricity Energy Usage Intensity in Faculty of Civil Engineering since then. Results have shown that internal factors such as occupants' behaviour and appliances cause the higher energy consumption which was around 14.42kWh/sm while the external factors only cause energy consumption of 10.67kWh/sm.

INTRODUCTION

The building sector consumes the most energy worldwide which is around 40%. Awareness on consuming energy has increased rapidly in this decade. Environmental issues are popping up here and there. There are many issues like global warming, depletion of raw non-renewable sources and the rise of seawater level. Effective alternatives must be taken to reduce the energy consumption in building sector. Architectural design processes towards "green" building, in which the domain of technology and aesthetics are being integrated while environmental performance and potential impacts are being assessed.

Problem Statement

A building's performance can be assessed by its energy consumption to operate. The Building Information Model (BIM) tools that are used to simulate and analyse energy consumption usually focus on external factors such as climate, materials used, orientation and design. Most of the tools available in the current market do not make allowance for occupants' behaviour and electrical equipment used in a building during the design phase as they are complex and uncertain. However, it has a significant role in determining the energy consumption [5; 6]. Many researchers are becoming aware of the discrepancy between original energy design and performance gap [7]. Regardless of how the building is designed to cater higher efficiency in energy consumption, if the occupants are irresponsible in consuming energy, then the energy usage is going to be high.

Objectives

The objectives of this study are:

1. To assess the whole building using the BIM tool in terms of energy consumption for external factors
2. To assess the whole building using the Space-Activity-Appliances (SAA) Model in terms of energy consumption for internal factors
3. To evaluate the actual energy consumption with the values obtained from the assessments of the BIM and the SAA Model

Scope of Study

This study aims to investigate the influencing factor that causes higher energy consumption in a building. The Block M47, a building in Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM) was chosen for this case study. In 2015, this building had an Electricity Energy Usage Intemsity (EEUI) of 14.3 kWh/sm. It is the building with highest EEUI in Faculty of Civil Engineering since then. The scope covers the calculation of energy consumption in Block M47 using BIM and SAA Model for external and internal factor respectively.

LITERATURE REVIEW

Energy efficiency is explicitly addressed in the Ninth Malaysia Plan [1]. This plan focuses on energy saving features in the industrial, domestic sectors and commercial sectors. The energy efficient building consumes the minimum amount of energy to provide indoor thermal comfort, healthy and comfortable space for the human occupation which includes moisture conditions, indoor air quality and lighting. The ideal energy maintains the best indoor environment for living with the minimum cost of energy [12].

The building performance is the capability of a building to achieve its design purpose while not imposing negative impacts on the environment and its users. There are many criteria to analyse building's performance such as architectural design values, building science, efficient energy and sustainability. Architectural design values influence architects and designers when they make their decision. The decision of architects has the major impact on a building's performance. The building envelope, building material, ventilation and air-conditioning systems, heating, acoustic, natural and electrical lighting, passive strategies, indoor air quality, renewable energy and fire protection are areas included in building science. It is used to predict the capability to optimise the building performance of the buildings.

A building consumes energy to keep the occupants comfortable in terms of illumination, heating, cooling and ventilation. In addition, climate, equipment used, occupant behaviour and indoor environment also contribute to energy consumption. The sustainable building must be able to give benefits such as healthy environment to the society while giving less impact to the environment. It must also cost fairly to build and operate.

The energy efficiency is to reduce the amount of energy used to provide products and service. The climate, the building-related characteristics and building service systems and operation are external factors which influence the energy consumption of a building. Meanwhile, the building's occupants' behaviour and activities, user-related characteristics, the social and economic factors and the indoor environmental quality required are internal factors which influence the energy consumption of a building.

There is always an uncertainty caused by occupant behaviour in energy consumption which has a significant discrepancy between actual and predicted energy usage. In actual condition, occupancy and occupant behaviour leave impact over thirty percent energy waste against building's designed performance [5]. Occupant behaviour modeling is explicitly cumbersome than occupancy detection. Occupants generally behave in two ways such as adaptation to the indoor environment and occupants themselves. Stochastic modelling focuses the application of probability to model actual situations in which uncertainty is present. The occupants behave in a random way, which make this stochastic modelling an effective way to model and estimate occupancy status and related energy consumption [5].

Current BIM tools mostly analyse building performance using the external factors. These factors are including the climate, building envelope, orientation and heating, ventilation and air-conditioning (HVAC). All these are important to conserve energy. The building insulation and envelope will aid to reduce heat transfer between conditional and unconditional boundaries. Climate plays an important role in determining the type of electrical appliances will be used in a building to maintain thermal comfort. Apart from all of these, orientation has the impact on energy consumption too. A designer should not only look into the aesthetic purpose of a building but also the orientation in order to reduce energy consumption.

BIM accounts multidisciplinary information and creates an opportunity for life cycle assessment of building performance to be carried out during the design phase [11]. During BIM design phase, a designer can select and place the materials that the intended building made up of for all the members. The type of HVAC also can be chosen. The Green Building eXtensible Markup Language (gbXML) schema is used to aid the transfer of building information saved in CAD-based BIM. The energy model has 3 main components based on gbXML Schema such as spaces, surfaces and zones. The spaces are discrete volumes of air that experience heat gain or loss. The heat changes are due to both internal and external environment. The surfaces are the paths of heat transfer to or from each space, including surfaces between the external environment and the interior spaces. Lastly, the zones are the groups of spaces used to create some commonality between those spaces [4].

The EnergyPlus is capable of some remarkable features such as combining the heat and mass transfer model that accounts for air movement between zones and having up to date types of fenestration models such as electrochromic glazing and controllable window blinds [2]. On the other hand, Autodesk Revit is able to assess a building's life cycle (from the grave to cradle) [11].

METHODOLOGY

The BIM and SAA Model were used to assess energy consumption in terms of external and internal factor respectively. The factor that influence the energy consumption was obtained by comparing with the actual EEUI value obtained from Electrical Billing Management System of UTM.

Energy consumption using external factors such as climate, building envelope and orientation was determined using BIM tool which is Revit Architecture 2017 (Revit'17). There are 3 stages in calculating energy consumption using this factor.

Stage 1. The drawing plan for each level of Block M47 has been obtained from Pejabat Harta Bina (PHB). Meanwhile, some extend of consideration were taken to choose the type of HVAC system for the building.

Stage 2. The building has been simulated using Revit'17 based on the real data. After the simulation, type of materials for various components such as floor, wall, window, ceiling and door were loaded. The orientation of the building was considered in the 3-D simulation as it affects day lighting and shadows of the building. The Block M47 faces west direction. The location, building type and type of HVAC of the building were selected.

Stage 3. The energy model was created in Revit's gbXML schema and assessed. The EEUI is extracted from the results. Finally, EEUI per month was calculated from the extracted value in kWh/sm.

Later, the energy consumption using internal factors like occupant's behaviour and electrical appliances was determined using the SAA Model, a model that was adapted from stochastic model of [13]. The SAA Model focuses only on modelling actual situations in which uncertainties are present as the occupants behave in a random way and does not include probability of occurrence of events. The basic idea of this simulation is to obtain energy consumed in a space when an activity is performed using electrical appliances. A lecturer's room was chosen as an example. The activity performed is office work. The service unit for the office work is in hour/day. The total time taken for this activity in a day, the frequency of this activity in a month and quantity of appliances were determined.

The lights, air-conditioner and fan were assumed to operate throughout the service unit. The approximate energy consumption (kWh) used by each appliance was estimated. The service unit was then quantified by multiplying the frequency of the activity in a month, quantity and approximate energy consumption of each appliance. The quantified value is the energy consumption in a space for a month. All the equations were adopted from Zaraket [13] and modified according to the suitability of this study. The energy consumption in a month per space was expressed by following equation:-

$$P_S = n_1 \times n_2 \times n_3 \times [(n_4 \times P_L) + (n_5 \times P_{AC}) + (n_6 \times P_F)] \quad \textbf{Eq. 1}$$

Where,
P_S = Optimum energy consumed in a month per space (kWh)
n_1 = Service unit (hour/day)
n_2 = Frequency of service unit per week (day/week)
n_3 = Frequency of service unit per month (week/month)
n_4 = Quantity of lights used in a space during an activity
P_L = Estimated energy consumption of a light (kWh)
N_5 = Quantity of air-conditioner used in a space during an activity
P_{AC} = Estimated energy consumption of an air- conditioner (kWh)
N_6 = Quantity of fan used in a space during an activity
P_F = Estimated energy consumption of fan (kWh)

The optimum energy consumed per area of building was expressed by following equation:-

$$P_{AA} = \Sigma P_S / A \quad \textbf{Eq. 2}$$

Where,
P_{AA} = Optimum energy consumed per area of building (kWh/sm)
A = Area of the building (sm)

In this study, the average percentage of wasteful behaviour was obtained from questionnaire and survey. This value was found synonymous to the percentage of wastage in energy. So, it was multiplied with optimum energy consumed per area of the building and then added with optimum energy consumed per area of the building. The percentage of occupants with wasteful behaviour from questionnaire was expressed by following equation:-

$$x_1 = (N_W/N_T) \times 100\% \quad \textbf{Eq. 3}$$

Where,
x_1 = Percentage of occupants with wasteful behaviour from questionnaire (%)
N_W = Total number of questions with answers that show wasteful behaviour of participants
N_T = Total number of questions answered by all the participants

The percentage of classrooms with lights, air-conditioner or fans on without occupants during lunch hour in a day was expressed by following equation:-

$$X_2 = (N_{ON}/N_c) \times 100\% \quad \textbf{Eq. 4}$$

Where,
X_2 = percentage of classrooms with lights, air-conditioner or fan on without occupants during lunch hour in a day (%)
N_{ON} = Number of classrooms with lights, air-conditioner or fan on without occupants during lunch hour in a day
N_c = Total number of classrooms in the building

The average percentage of classrooms with lights or air-conditioner or fans on without occupants during lunch hour in a month was expressed by following equation:-

$X_{2avg} = (\Sigma X_2)/n_d \times n_W$ **Eq. 5**

Where,

X_{2avg} = average percentage of classrooms with lights or air-conditioner or fans on without occupants during lunch hour in a month (%)

n_d = Number of days of surveying

n_w = Number of weeks in a month

The average percentage of wastage of energy in the building was expressed by following equation:-

$x_{avg} = (x_1 + x_{2avg}) /2$ **Eq. 6**

Where,

x_{avg} = Average percentage of wastage of energy in the building (%)

The total estimated energy consumption was expressed by following equation:-

$P_T = [1+ (x_{avg}/100)] \times P_{AA}$ **Eq. 7**

Where,

P_T = EEUI per month (kWh/sm)

In summary, the calculation of energy consumption based on internal factor was divided into 4 stages as following.

Stage 1. The data on types and energy consumed by the lights and air-conditioner were obtained from PHB, UTM while the energy consumed by the fan is taken from [10]. In addition, the quantity of lights, and air-conditioner and fans in each space were surveyed.

Stage 2. The questionnaire on awareness of energy consumption was distributed to 204 occupants randomly to determine the percentage of wasteful occupants. Meanwhile, a survey was done to obtain the percentage of wasteful occupants in real situation. The number of classrooms with lights, air-conditioner or fan on without occupants was calculated at lunch hours (1-2p.m.) on weekdays throughout a week. All the results from survey and questionnairewere were tabulated. The average percentage of wasteful occupants was found analogous to percentage of energy wasted in a month.

Stage 3. Then, the data of time taken for activity performed by lecturers, postgraduates, undergraduates and survey unit staff were surveyed. The time taken for lectures and tutorials were obtained from Faculty of Civil Engineering. All the collected information were tabulated.

Stage 4. The model was simulated and the EEUI (kWh/sm) was calculated.

Finally, the values obtained from both model assessments were then compared with the actual EEUI value.

RESULTS AND DISCUSSION

First of all, the BIM simulation for the chosen building was done. The 2-D floor plan layout for each level of Block M47 was obtained from PHB, UTM and used to develop 3-D model in Revit'17. The orientation of the building was considered in the 3-D simulation as it affects day lighting and shadows of the building. The Block M47 faces west direction. The type of material for all the components and fenestration of the building was chosen during simulation based on observation and justification. The components of the buildings are roof, exterior walls, interior walls, ceilings, floors, staircase, doors and column while fenestration is windows. Figure 1 shows energy model of the Block M47 in gbXML Schema.

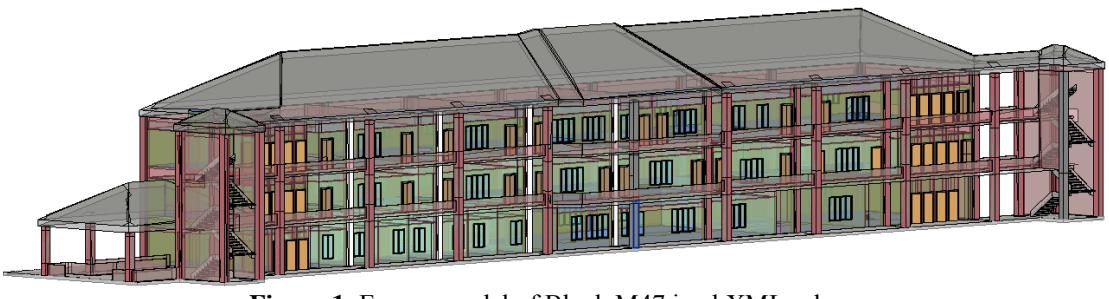


Figure 1: Energy model of Block M47 in gbXML schema

The central Variable Air Volume, electric resistance heat, chiller 5.96 coefficient of performance was chosen as HVAC for this model. This type actually focuses more on cooling load than heating load compared to other available choices. This was proven as there was no heating load during analysis. Typical buildings in Malaysia need cooling loads compared to heating load. This HVAC system have water cooled centrifugal chiller with coefficient of performance of 5.96, chilled water coil, forward curved fan with Variable Speed Drive and efficiency motor and open, atmospheric pressure cooling tower with variable speed fan and 2.8-degree Celsius approach [8]. The Revit'17's internet mapping was used to locate the building's location during energy modelling. The location is necessary to locate the nearby weather station as it will determine cooling design temperature throughout the year. The nearby weather station to the Block M47 was weather station 1451208_2006 (exact location is unknown).

Once the energy modelling was completed, the energy analysis took place. The EEUI obtained from this analysis was 133kWh/sm/yr. This value was divided by 12 to obtain the average EEUI per month. The Block M47's average EEUI per month was 11.08 kWh/sm while the highest EEUI recorded in 2015 was 14.3kWh/sm. The difference between actual and obtained EEUI per month was around 3.22kWh/sm.

Then, SAA Model simulation for the chosen building was done. The Block M47 had various spaces, each with a different purpose. There were mainly lobby, classrooms, lecturers' rooms, survey unit room, postgraduates' cubicles, A.H.U. room, switch room, utility room, toilets, 'surau', corridor, computer room and walk space. For an example, besides being the waiting area, the lobby also used as the workplace by students where they to do their assignments or revision.

The study is interested in 'service unit' or the time taken to perform each activity in a day. The service unit for all spaces except classrooms were obtained by survey while the service unit for classrooms were obtained from the classrooms' schedule of Faculty of Civil Engineering.

The type and quantity of lights, air-conditioner and fan used in each space were determined. The data on types of lights was obtained from PHB, UTM while the quantity of lights in each space was surveyed. There were two types of lights such as Phase-Locked Loop (PLL) 18w and Fluorescent 36w being used in this building. The PLL 18w lights consume 23w/hr while the Fluorescent 36w lights consume 44w/hr [3]. Moreover, the quantity of fan in each space was surveyed. The average power consumed by a fan is 63w/hr [10].

The survey found out the average percentage of classrooms and corridor with lights, air-conditioner or fan on without occupants during lunch hour in a day which reflected the average percentage of wasteful occupants' behaviour. Furthermore, the questionnaires on occupants' behaviour towards energy consumption were given randomly to undergraduates, lecturers, postgraduates and staff. The sample size was 204 where the population size was 810 with confidence level of 90% and margin of error of 5%. The respondents answered all the 12 questions in the questionnaire. Their answers were the reflection of their actual concern towards energy consumption. The number of respondents shown less concern towards energy consumption for each question was determined.

The model was simulated using all the formulas stated in methodology section. However, the lecturers' rooms shared a centralised air conditioner. So, the energy consumption of air- conditioner was calculated as one unit for all lecturers' room. The same method was used for the postgraduates' cubicle and computer room as they shared a centralised air-conditioner. The model measured the optimum energy consumption and wastage of electricity due to wasteful occupants' behaviour in the building. The average EEUI obtained from this model was 14.42kWh/sm while the highest EEUI recorded in 2015 was 14.3kWh/sm. The difference between actual and obtained EEUI month was around 0.12kWh/sm.

In brief, the BIM Model gave a value of 11.08kWh/sm while the SAA Model gave a value of 14.42kWh/sm. From the results, it was proven that the internal factors such as occupants' behaviour and appliances cause the higher energy consumption in Block M47.

The SAA Model has shown that the optimum energy consumption to be 10.67kWh. This value was closer the value obtained from BIM Model. The difference between was due to other appliances that were not included in the model. When the average percentage of wastage of energy of 35.19% was added to the model, the result was very close to the actual value. The occupancy and occupant behaviour leave impact over thirty percent energy waste against building's designed performance in actual condition [5]. All of these prove that SAA Model is a feasible model which can analyse a building's energy consumption in terms of internal factors such as occupants' behaviour and appliances.

Finally, this case study also proves that there is a distinct discrepancy in between the actual and obtained value of energy consumption from BIM tools as most of the available tools does not consider internal factors such as occupants' behaviour and appliances used. This discrepancy leads to inefficient design, unwanted expenses and harmful effects on the environment.

CONCLUSION

The conclusions made from this case study were as following:-

1. When the results from BIM Model and SAA Model were compared with highest EEUI recorded in 2015 which was 14.3kWh/sm, it was proven that the internal factors such as occupants' behaviour and appliances caused the higher energy consumption in Block M47.

2. The study showed that there is 35.19% of energy wastage per month due to wasteful behaviour of the occupants.
3. This case study also proved that there is a distinct discrepancy in between the actual and obtained value of energy consumption from BIM tools as most of available tools does not consider internal factors such as occupants' behaviour and appliances used.
4. The SAA Model is a feasible model which can analyse buildings' energy consumption in terms of internal factors such as occupants' behaviour and appliances even though uncertainties are present.

REFERENCES

[1] Abu-Bakar, M. N., & Yahya, K. B. (2015). Study on Energy Consumptions for the Commercial Buildings using Energyplus . *Innovative Science, Engineering & Technology, 2*(5).

[2] EnergyPlus. (n.d.). EnergyPlus. Retrieved 14 May, 2017, from https://energyplus.net/

[3] Haq, M. A., Hassan, M. Y., Abdullah, H., Rahman, H. A., Abdullah, M. P., Hussin, F., & Bandi, M. (2013). Energy Saving in Lighting From T5 Lamp Retrofits – A Case Study. Putrajaya: IEEE Student Conference on Research and Development (SCOReD).

[4] gbXML. (2017). About gbXML. Retrieved 13 May, 2017, from http://www.gbxml.org/About_GreenBuildingXML_gbXML

[5] Jia, M., Srinivasana, R. S., & Raheem, A. A. (2017). From occupancy to occupant behavior: An analytical survey of data acquisition technologies, modeling methodologies and simulation coupling mechanisms for building energy efficiency. *Renewable and Sustainable Energy Reviews, 68*, 525-540.

[6] Korjenic, A., & Bednar, T. (2012). Validation and evaluation of total energy use in office buildings: A case study. Automation in Construction, 23, 64-70.

[7] Niu, S., Pan, W., & Zhao, Y. (2016). A virtual reality integrated design approach to improving occupancy information integraty for closing the building energy performance gap. Sustainable Cities and Society, 27, 275-286.

[8] Revit, A. (2017). *About the Energy Model*. Retrieved April 14, 2017, from Autodesk Revit 2017: http://help.autodesk.com/view/RVT/2017/ENU/?guid=GUID-5D7C8522-4DC2-4618-AEC9-2555CB276B2D

[9] Revit, A. (2017). *HVAC Systems*. Retrieved April 14, 2017, from https://knowledge.autodesk.com/search-result/caas/CloudHelp/cloudhelp/2017/ENU/Revit-Analyze/files/GUID-38A9EB5B-8631-43B4-9AD6-6F532BC860D8-htm.html

[10] Schmidt, K., & Patterson, D. J. (2001). Performance results for a high e• ciency tropical ceiling fan and comparisons with conventional fans Demand side management via small appliance e• ciency. *Renewable Energy, 22*, 169-176.

[11] Shoubi, M. V. (2013). *Building performance assessment in terms of energy consumption using building information modeling*. Johor Bharu.

[12] Zadeh, A. F. (2013). *Energy efficient residential buildings assessment using Building Information Modeling*. Johor Bharu.

[13] Zaraket, T. (2014). Stochastic activity-based approach of occupant-related energy consumption in residential buildings . Engineering Sciences [physics].

Waste Management on Construction Site

Nabila Najad Ajlan, Aziruddin Ressang

Faculty of Civil Engineering, Universiti Teknologi Malaysia

aziruddin@utm.my

Keywords: Waste Management; Construction Site; Wastage

ABSTRACT: The rapid developments in Malaysia Construction Industry need a good management. Management is very important especially in the construction site. By providing high quality and good management, for all the work on site the construction can be carried out according to plan. There are 4 levels methodological studies identify problems, data collection, data analysis and conclusions. The purpose of this study was to study the sources of construction waste, factors influenced the construction waste and method or ways to reduce waste construction at a construction site. Information and data related to this study taken by distributing questionnaires to the respondents who handle and involved project in Johor Bahru. Methods of statistical analysis were used analyse and get the results to the normal construction sites and the effectiveness of the methods used to reduce construction waste at the construction site. Method auditing to review is an effective method to reduce construction waste in construction site.

INTRODUCTION

Malaysia is the one of the country that well known as developing country that having many activity namely construction and there are many construction project that develop in everywhere in Malaysia especially in capital city, Kuala Lumpur and developing city such as Johor Bahru. The construction industry is crucial because the role that is plays as major indicator and determinant of domestic performance in the economy [1]. As Malaysia in the process of industrialisation, the construction industry is important because it provides the economic and social infrastructure for industrial production and reproduction. The implication by develop either the structure or infrastructure, the generation waste will become increases and following the problems with the disposal of this waste.

Waste management is the process of treating solid waste and offers variety of solutions for recycling items as a valuable resources and the item cannot be recycle belong to trash that called as garbage. Waste management in the building industry in Malaysia has become a major environmental issue and this issue has been playing around the media but there are little action taken in controlling the waste generation. The waste can be minimized if there is a proper method of managing construction waste on site. Therefore, in order to improve the management of waste on site, the current practice of construction waste management needs to be identified so that, any lacking on the practice could be improved. That is the purpose of this study and will be explain in detail.

Problem Statement

Nowadays, in the challenging era, our country facing a lot of developing project regarding to the construction sector become one of the industry that considered to be major productive sector that means this industry in increasing trend throughout the year. This sector is essential for development of the nation. It is among the top of three of major economic sectors [2]. The other two sectors being agriculture and manufacture, which contribute to the national output. However, Malaysia face many issue about the construction waste management that affect and give the problem to the people in the surrounding. This is because construction waste has a major impact on the environment.

From the Figure 1 specifies the solid waste generated in Peninsular Malaysia in year 2007. The type of generators are from households, commerce and institutions, industrial, construction, public places and special waste. Construction sector (41%) gives the highest generated waste rather than other sector such as household, commerce and institutions (34%), industrial (25%), special waste (9%) and public places (1%). It's figured that the culture in construction industry has not been health as the waste generation is in increasing trend among other industry. So, by the increasing of housing demand and many infrastructure project amount led to increasing of waste generated in the country. It is crucial to identify the root of problem in every issue that to be solved. Currently in Malaysia, there is very limited research being conducted on the issue of construction waste. Construction waste in the form of building debris, rubble, earth, concrete, steel, timber and mixed site clearance materials, arising from various construction activities (Shen, 2004). There are the proper way that should applied to solve this problem and regarding the factors that affecting the root of this issue. Sulzakimin (2015) highlighted that the challenge is to solve matter regarding the needs of citizen in a sustainable manner, so as to generate continuing development and activities that meet the needs of the organisation and its stakeholders today while protecting, sustaining and enhancing the human and natural resources that will needed in the future [3].

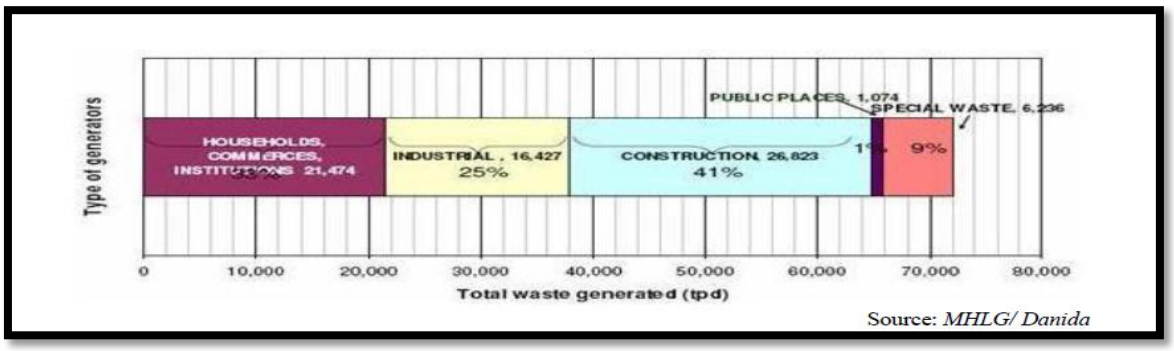


Figure 1: Solid Waste Generated in Peninsular Malaysia year 2007 [4]

Aim and Objective of Study

This research was studied to identify the waste on the construction site and the method/ step in minimization and reduction of waste on the construction site. To achieve the aim of the study following the objectives that have been identified. Hence, the objectives of this study are:

1. To study source of waste on construction site
2. To study factors influenced construction waste
3. To propose method/step to reduce construction site waste

Scope of Study

This study focused on the following study focuses on the following scope:

1. Questionnaires were distributed by hand is concentrated in Johor Bahru.
2. The groups of respondent were selected among parties involved in construction industry such engineer, project manager and contractor.

LITERATURE REVIEW

Waste defined as the unwanted and leftover of the material that produce from the construction site that could make loss in terms of money, time and quality. Generally, waste is defined as a substance or object which is disposed of by the provisions of laws [1]. This wastage also could give the effect to the environment and human. However, this could be minimized by the various ways that could against waste management.

Waste management is the one of the management system that responsibility to handle and organize the wastage from the human activity. It is crucial to manage the waste properly and the problem become more serious if the management do not take action immediately. Waste management is defined as the discipline associated with the control of generation, recovering, processing and disposal of wastes in a manner that is concordance with the best principles of human health, economic, engineering, and aesthetic and other environmental considerations [5].

However, there are probably factors effecting construction waste that faced by construction team or workplace such as human, organization support and time constraint. These factors are common barrier to another implementation of waste approach on construction site. But there are many problem solving practicable theories as well to tackle and reduce the impact of source and effect.

RESEARCH METHODOLOGY

In order to achieve the objective of the study, methodology of study is illustrated which consists of five stages representing five chapters on this study.

1. Firstly, problem statements were identified by looking at current waste management approach in construction site and what constraint happen faced. Based on the problem statement, formation of objective, title selection and scope of the study then were determined.
2. The second stage is the conduction of detail data and information collection.The set of questionnaire build through comprehension on literature review (Chapter 2) divided into four sections which section A, B, C and D to achieve the objective above.
3. In the third stage, frequency analysis technique was used in section A in order to obtain the general information of respondents, such as the role of the respondents in the construction project.Reliability test using Cronbach's

Alpha is conducted to provide an indication of the average correlation among all the responses.The test was applied to data collected in sections B, C, and D of the questionnaires

4. Then Result analysis of primary data collected from the respondent answered questionnaires using The Relative Important Index (RII).Relative Important Indexcomputed as:

$$\text{Relative importance index (RII)} = \sum\omega / (A*N)$$

where,
ω = the weight which respondents give to each attribute and ranges from 1 to 5 using the same likert scaling method
A = is the highest value for attributes which is 5 in this likert scaling
N = is the total number of respondents

Table 1 and Table 2 shows the likert scale for section B, C and D respectively [6, 7]

Table 1: RII on 5-point Likert scale (Section B of Questionnaire)

Scale	Severity	RII
1	Very low	$0.0 < RII \leq 0.2$
2	Low	$0.2 < RII \leq 0.4$
3	Moderate	$0.4 < RII \leq 0.6$
4	High	$0.6 < RII \leq 0.8$
5	Very high	$0.8 < RII \leq 1.0$

Table 2: RII on 5-point Likert scale (Section C and D of Questionnaire)

Scale	Level of Affecting	RII
1	Not affected at all	$0.0 < RII \leq 0.2$
2	Slightly affected	$0.2 < RII \leq 0.4$
3	Moderately affected	$0.4 < RII \leq 0.6$
4	Affected Influenced	$0.6 < RII \leq 0.8$
5	Extremely affected Influenced	$0.8 < RII \leq 1.0$

5. In the fourth stage, data interpretation, data discussion according to sequence of objectives has been analysed.
6. In the fifth stage, conclusion and recommendation of the study will be discussed.

RESULT AND DISCUSSION

This purpose of study is related to waste management towards construction project vicinity in Malaysia. The questionnaire distribution was focused in Johor. Result analysis based only on 23 set of answered questionnaire from 50 set being distributed.

Finding 1: level of rate on type of waste on site

Table 3: Reliability Statistics of rate on type of waste on site

Cronbach's Alpha	N of Items
0.923	11

Table 4 below shows the result analysis for section B which is required to achieve the objective 1. In this section B, there are eleven item in this question.The summary of the reliability statistics for all items combined in Section B is in the range of 0.923 which is excellent

Table 4: Overall Ranking of the Construction Waste analysed using RII (Section B)

Types of Waste	RII	Level
Lumber and Wood	0.70	High
Plastic packaging	0.62	High
Brick	0.62	High
Metal	0.56	Moderate
Aggregate	0.56	Moderate
Cement	0.55	Moderate

Table 4: Overall Ranking of the Construction Waste analysed using RII (Section B)… Continue

Concrete	0.54	Moderate
Tile	0.50	Moderate
Mortar	0.48	Moderate
Cardboard	0.43	Moderate
Glass	0.40	Moderate

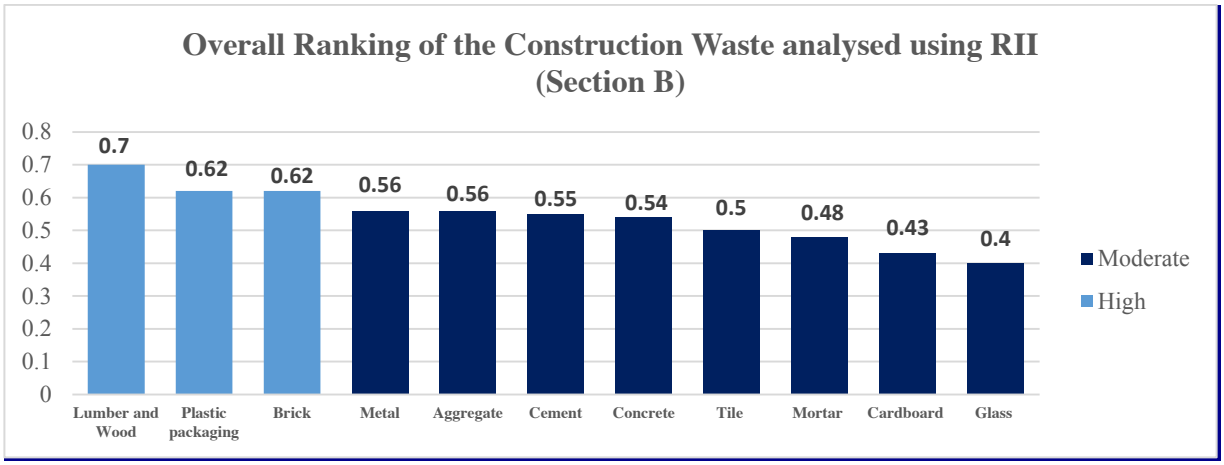


Figure 2: Ranking of the Construction Waste analysed using RII (Section B)

Figure 2 shows the ranking of average index of 11itemconstruction waste onsite. The result from Relative Important Index (RII), the highest index is 0.7 which is lumber and wood, and the least index from this ranking is 0.4 which is glass

Finding 2: level of source of construction waste on site

Table 5: Reliability Statistics for level of source of construction waste on site

Cronbach's Alpha	N of Items
0.704	7

Table 6 below shows the result analysis for section C which is required to achieve the objective 1. In this section C, there are seven item in this question. The summary of the reliability statistics for all items combined in Section B is in the range of 0.704 which is acceptable.

Table 6: Overall Ranking of the Causes of Construction Waste analysed using RII (Section C)

Section C (Source of Construction Waste)	RII	Level
Inexperience worker	0.77	Affected influenced
Improper handling	0.77	Affected influenced
Double handling	0.68	Affected influenced
Inadequate shelter	0.64	Affected influenced
Design changes	0.64	Affected influenced
Wrong order	0.63	Affected influenced
Lost/ stolen	0.59	Moderately Affected

Figure 3 shows the ranking of average index of 7item source ofconstruction waste onsite. The result from Relative Important Index (RII), the highest index is 0.77 which is inexperience worker and improper handling, and the least index from this ranking is 0.59 which is lost/stolen

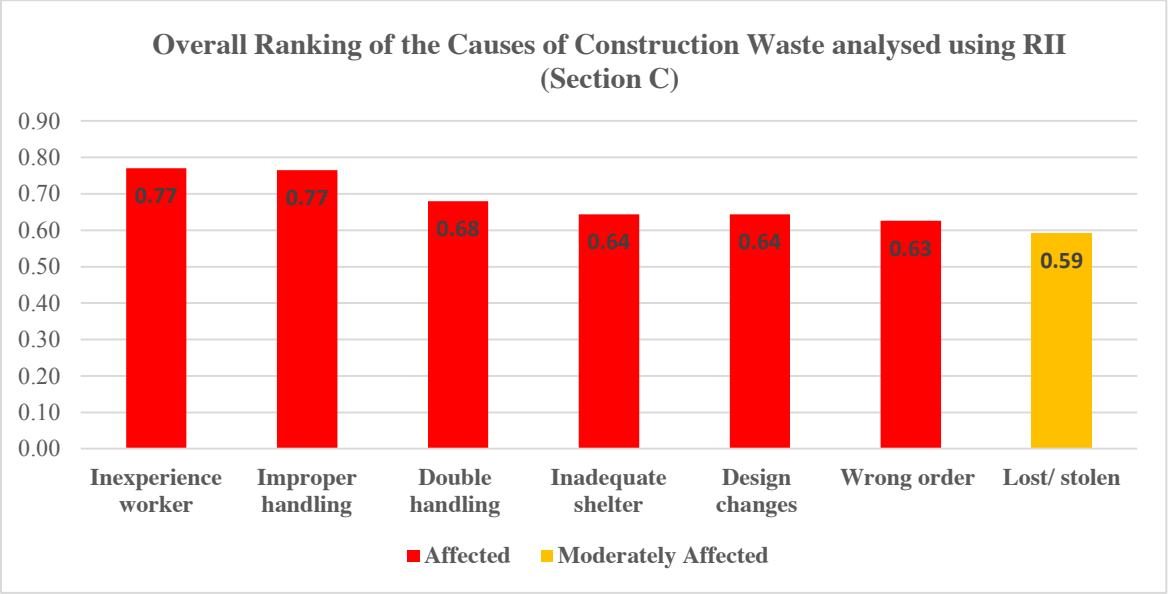


Figure 3: Overall Ranking of the Causes of Construction Waste analysed using RII (Section C)

Finding 3: level effect of causes affecting construction waste

Table 7: Reliability Statistics for level factors affecting construction waste

Cronbach's Alpha	N of Items
0.792	14

Table 8 below shows the result analysis for section D which is required to achieve the objective 2. In this section D, there are fourteen item in this question. The summary of the reliability statistics for all items combined in Section B is in the range of 0.792 which is acceptable.

Table 8: Ranking of the Factors Influenced Construction Waste analysed using RII

Section D (Factors Influenced Construction Waste)	RII	Level
Poor site management	0.83	Extremely affected
Inefficient management	0.81	Extremely affected
Communication problem	0.76	Affected influenced
Lack of knowledge about construction	0.76	Affected influenced
Lack of attitude and behaviour among workers	0.75	Affected influenced
Lack of awareness among workers and community	0.75	Affected influenced
Poor supervision	0.74	Affected influenced
Poor information quality	0.72	Affected influenced
Lack of recycle facility	0.72	Affected influenced
Inefficient construction method	0.69	Affected influenced
Poor of appropriate technology	0.64	Affected influenced
Mishandling material	0.64	Affected influenced
Insufficient instruction about handling	0.63	Affected influenced
Wrong Material	0.63	Affected influenced

Figure 4 shows the ranking of Relative Important Index of 14item factors affecting construction waste onsite. The result from Relative Important Index (RII), the highest index is 0.83 which is poor site management, and the least index from this ranking is 0.63 which is wrong material

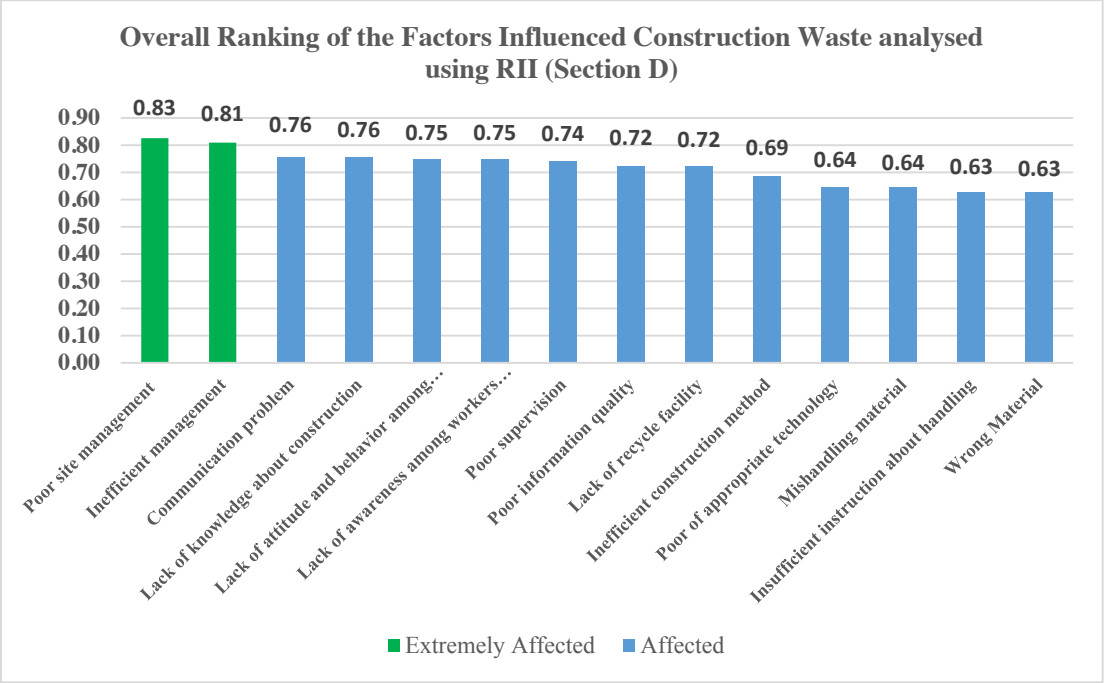


Figure 4: Ranking of the Factors Affecting Construction Waste analysed using RII

CONCLUSION AND RECOMMENDATION

Objective 1: To study source of waste on construction site
The first objective of this study has been achieved through the result analysis in result & discussion. So based on the result, the highest index is 0.7 which is lumber and wood, and the least index from this ranking is 0.4 which is glass Meanwhile,the highest index is 0.77 which is inexperience worker and improper handling, and the least index from this ranking is 0.59 which is lost/stolen.

Objective 2: To study factors affecting construction waste
From the result on the section, the highest index is 0.83 which is poor site management, and the least index from this ranking is 0.63 which is wrong material.

Objective 3: To propose method/step to reduce construction site waste. The thirdly objective of this study has been achieved based on the finding from the first and second objective. There are the important factors that cause producing construction waste on site. Moreover, the factors should be focus and give attention by contractor, so that the wastage on site could be decrease.

The recommendation of this study can be done by measuring the other of main causes that cause poor organization and planning on construction site and study also can be made about waste form that applies to any materials at construction sites and identify methods to cope with the handling and storage methods appropriate for each material.

REFERENCES

[1] Abdul Razak Bin Ibrahim, M. H. (2010). An investigation of the status of the Malaysian construction industry. *An International Journal*, 294-308.
[2] Ahmad, H. K. (2010). *Strategic Solid Waste Management : Malaysian approach*.
[3] Sulzakimin M., T. S. (2015). Sustainable Development at Malaysian Local Governments : Staff's Awareness & Constraints. *Journal of Humanities and Social Science*.
[4] Muhammad A.E., M. I. (2012). The Construction and Demolition Wastes in Klang Valley, Malaysia. *Journal of the Malaysian Institute of Planners*, 99-124.
[5] Tchobanoglous, G. (2003). *Handbook of Solid Waste Management*. New York: Mc Graw Hill.
[6] Cheung, S. O., Suen, H. C. H., and Cheung, K. K. W. (2004). PPMS: A Web-
[7] Based Construction Project Performance Monitoring System, Automation in Construction. 13, 361 - 376.
[8] Ugwu and Haupt (2007). Key Performance Indicators and Assessment Methods for Infrastructure Sustainability - A South African Construction Industry Perspective, Building And Environment. 42, 665 - 680.

Adoption of Building Information Modeling in Project Planning Risk Management

Melissa Mujan Mering, Eeydzah Aminuddin

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

eeydzah@utm.my

Keywords: Building Information Modeling; Project Planning; Risk Management.

ABSTRACT. This paper presents the adoption of Building Information Modeling (BIM) in project planning risk management. BIM had been introduced by the Public Works Department (PWD) since early 2007 in Malaysia. CIDB had taken proactive actions by organizing awareness programs and workshops to promote the adoption of BIM throughout the construction industry. Threats to the project's objectives and opportunities are project risk. The origins of the threats are uncertain and they are present in all projects. Risks that have been identified and analysed are known risks and it is possible to plan for them. However, although project managers may address unknown risks by applying a general contingency based on past experience with similar projects, these unknown risk cannot be managed.

INTRODUCTION

The management of the risk of a project is one of the important roles undertaken by a project manager. However, if the risk management is not discussed from the starting of the project, this duty is notably complicated and no longer efficient. An efficient and effective risk management approach needs a systematic and proper methodology and, more importantly, knowledge and experience.

One of the major industries that contribute to Malaysian economy is the construction industry. Through provision of basic infrastructure, the industry continues to support social development. Although with the implementation of BIM that can overcome many problems in construction projects, its applications remains in its infancy. Construction players play a big role in realizing the benefits of BIM in order to help them improving the implementation of construction processes. It is true that BIM is still in the early phase of introduction in Malaysian construction industry [1]. Even though BIM is seen as an expensive technology to be implemented, but it has proven to provide a lot of solution.

Problem Statement

Risks are presence in any construction projects. There are many various stages of risks and it must first be planned on what risks the principal would like to reverse with appropriate methods and how costly these methods are. Because of that, the risks, possible risk costs, methods and costs of the methods must be determined and finding suitable methods must be done in order to avoid errors in the future.

Theoretically, risk is defined as a positive or negative deviation of a variable from its expected value. In general terminology, risk is understood only as a loss. Construction projects are exposed to risks at the time of their coming into existence. Risk is an unexpected event that takes place during the process of construction projects [2]. In fact, risk in construction industry has been the main of alertness because of time and cost overruns associated with construction projects. Cost overruns, delays, and reduction of quality of projects are the common negative effects of risk inherent to construction projects. Failure to control such risks might further result in damage of reputation, financial loss, and loss of future business.

By adopting risk management, potential risks linked with a project and acknowledging to those risks can be identified to reduce them to an acceptable extent. On this basis, decisions are made in the hope of having eliminated all risks and used all chances. This means recognizing potential risks and avoiding a threat by reducing their negative effects.

Objectives

The objectives of this study are:

1. To identify the traditional risk management practices and its function
2. To determine the best function of BIM in risk management.
3. To investigate the efficiency of adopting BIM-based risk management during the project planning phase.

Scope of Study

The main aspect of the present study is to discover the risk management in BIM. As most researchers focus on BIM Model itself, studies done on analysing the BIM-based risk management is very limited especially in Malaysia. Respondents selected are not only those who utilize BIM, but also those who understand and apply the concept of risk

management in construction. Based on the aim and objectives, this study will focus more on the planning phase. Hence, this study will be conducted in Malaysia.

LITERATURE REVIEW

In projects that implement BIM, the visualizations can be made from previously produced models, in contrast to the traditional projects, in which the building visualization had to be made from the very start. With the speedy development of theory and computer applications over the last few years, BIM has achieved a remarkable awareness in the construction industry. There is a compelling increase of the implementation of BIM to support planning, design, construction operation and maintenance phases [3]. BIM is becoming a systematic method [4], and process that is changing the project delivery, designing [5] and the communication and organisational management of construction [6] instead of being just considered as a technology.

Planning is a basic part of contracting and the construction process. When doing proper planning, appropriate materials are secured, delivered and installed. Without proper planning, the final finished product, which is the building, would not come together.

Other than that, risk can be identified then be eliminated or reduced through planning process. A general checklist should be formed to help the participants in addressing all possible areas involving risk. This is why it is best to address on what to plan first.

There are several negative impacts for participants in a project when there is no effective project risk management. This is because of the deficiency of preventive measure taken to prevent risks and uncertainty in any project presents. For this, it is the effort for a research to establish risk management systems that are based on knowledge to support risk management in construction projects.

METHODOLOGY

Despite having all of the information from the literature review, a further research is still needed in order to achieve the study's aim and objectives. In order to obtain data, respondents selected are not only those who utilize BIM, but also those who understand and apply the concept of risk management in construction. A quantitative approach is adopted in this research as it is more reliable and objective. It reduces and restructures a complicated problem to a limited number of variables. The questionnaire is parted into four parts. Section A is the respondent's personal details, Section B is to identify the risk management practices, Section C is to determine the best functions of BIM in risk management and Section D is used to investigate the efficiency of adopting BIM-based risk management during the project planning phase.

RESULTS AND DISCUSSION

Respondents Personal Details

70 questionnaires were sent through email and only 46 respondents answered the questionnaires. However, there were only 30 questionnaires that were considered valid as they were answered completely, indicating 42.86% of response rate.

Figure 1 shows the respondent's background. There were 60% respondents from civil and structure, 13% were quantity surveyor, 10% were mechanical and electrical, 7% were architect. Other than these, the other 10% were from turnaround engineering, construction management and safety, health and environment.

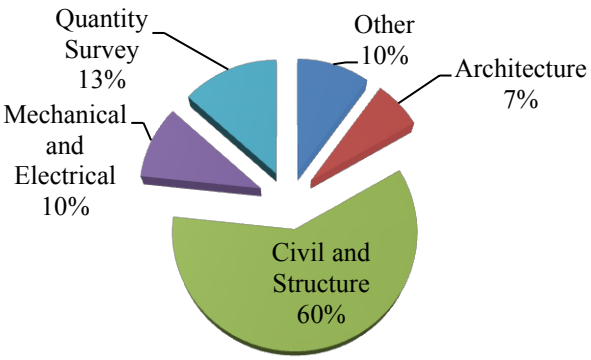
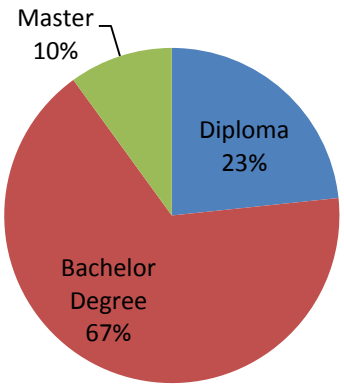


Figure 1: Respondent's Professional Discipline

One's education level is usually related to their management level. Most diploma level entries are usually at the level of junior executive. However, this is also depending on theirs years of experience in the industry. Those who

handle risk management are usually those who have bachelor degree and higher level. This is because risk management requires more attention and only be managed by the professionals. Figure 2 and Figure 3 show the respondent's education level and management level respectively. The respondents were mostly bachelor degree graduate in which they sit on the middle executive level.



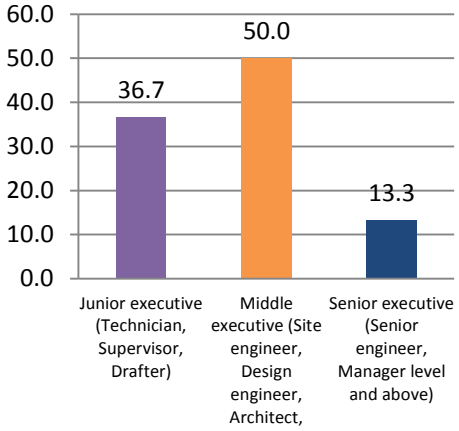
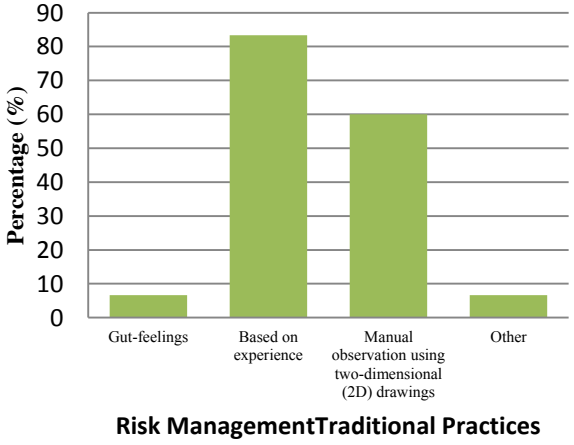


Figure 2: Education Level

Figure 3: Management Level

Risk Management Practices

Traditional risk planning relies on gut-feelings, based on experience and manual observation using 2D drawings. There are some respondent who mentioned that it is based on analysis and five whys method. One of the five whys method is drawing based, depending on what type of activity that is going to be conducted. For example, crane lifting activities and piping replacement. From Figure 4, many identify risk based on experience. However, there were some issues that they encountered during the implementation of traditional methods. This can be seen in Figure 5.



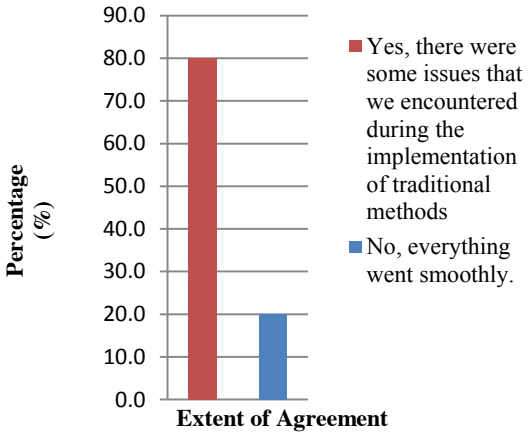


Figure 4: Risk Management Traditional Practices

Figure 5: Collaboration Issues Practices Using Traditional

Throughout the project lifecycle, risks can be changed. However, this can only happens when the controls are in match. Although risks are always treated as challenges, it poses opportunities as well. Respondent were asked to indicate their extent of agreement in relation to the position of their company towards handling risks. They were given four choices which were accepting risks, avoiding risks, reducing risks and transferring risks. According to Table 1, the descriptive statistics showed that most company preferred to reduce risks, with variance value of .478. With variance value of 1.253, avoiding risks seem to be difficult to be done as it can caused quality risks, personnel risks, cost risks and dateline risks. Table 2 is the Kaiser-Meyer-Olkin and Bartlett's Test (KMO) in which it was recorded that the value is .677 where this means that the data collected were reliable.

Table 1: Descriptive Statistics of the Agreement Relation to the Position of Company towards Handling Risks using Traditional Method

	Mean	Std. Deviation	Variance
Transferring risks	3.0667	1.11211	1.237
Avoiding risks	3.3000	1.11880	1.252
Accepting risks	3.3333	.84418	.713
Reducing risks	4.0667	.69149	.478

Table 2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.677
Bartlett's Test of Sphericity	Approx. Chi-Square	10.985
	df	6
	Sig.	.089

Best Function of BIM in Risk Management

According to the data collected in Table 3, BIM was seen to be more useful in providing better tracking of cost control and cash flow with variance of .178. This can concludes that BIM has many uses in project planning as the tracking of cost control and cash flow give impact on the project cycle to be completed on time. As BIM is still considered new in Malaysia, it is still not up to the level of managing the facilities. This can be seen related to the variance value of .322 where BIM was considered also useful but with standard deviation of .56765, not many picked on this potential.

Table 3: Descriptive Statistics of the Agreement in relation to the Potential Benefits of using BIM

Code	Potential Benefits	Mean	Std. Deviation	Variance
P1	Decreases costs of utility demand and demolition	4.0000	.47140	.222
P2	Manages facilities proactively	4.1000	.56765	.322
P3	Provides better tracking of cost control and cash flow	4.2000	.42164	.178
P4	Identifies schedule phasing issues	4.3000	.48305	.233
P5	Enables project manager and contractor to see construction work sequence, equipment and materials	4.3000	.48305	.233
P6	Enables generation of takeoffs, counts and measurements directly from a 3D project model	4.4000	.51640	.267
P7	Facilitates better communication and increase design effectiveness	4.5000	.52705	.278

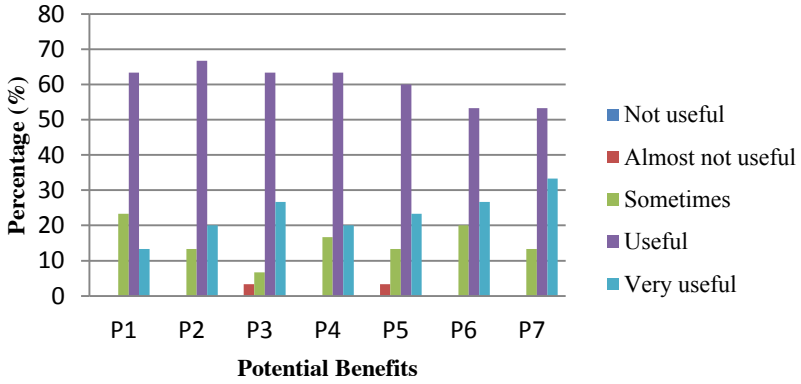


Figure 6: Bar Chart of the Extent of Agreement in Relation to the Potential Benefits of using BIM

Table 4 is the Kaiser-Meyer-Olkin and Bartlett's Test (KMO) in which it was recorded that the value was .712 where this means that the data collected were reliable

Table 4: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.712
Bartlett's Test of Sphericity	Approx. Chi-Square	138.768
	df	21
	Sig.	.000

As regards to Table 5, 5D cost estimation or cash flow modeling had been chosen as the almost always effective way for managing risk with the variance value of .178. 5D cost estimation or cash flow modeling benefit risk management in planning, controlling and managing budget and cost reasonably.

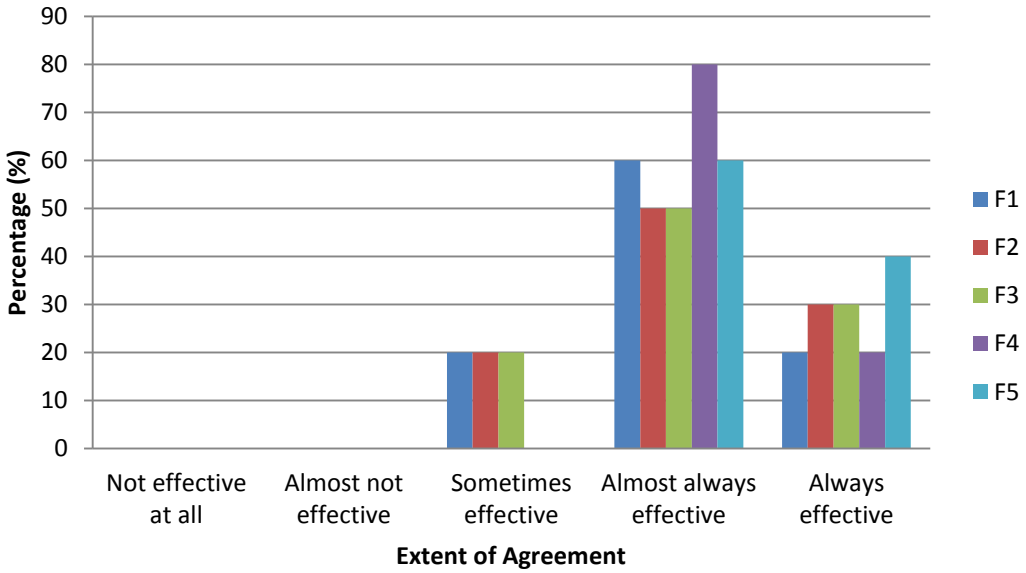


Figure 7: Bar Graph of the Percentage of the Extent of Agreement in Relation to BIM as a Systematic Way for Managing Risks

Table 5: Descriptive Statistics of the Agreement in Relation to BIM as a Systematic Way for Managing Risks

Managing Risks	Mean	Std. Deviation	Variance
Collaboration and communication facilitation	4.0000	.66667	.444
3D visualisation	4.1000	.73786	.544
Risk scenario planning	4.1000	.73786	.544
5D cost estimation or cash flow modeling	4.2000	.42164	.178
4D construction scheduling/ planning	4.4000	.51640	.267

Table 6 is the Kaiser-Meyer-Olkin and Bartlett's Test (KMO) in which it was recorded that the value was .575 where this means that the data collected were reliable.

Table 6: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.575
Bartlett's Test of Sphericity	Approx. Chi-Square	110.163
	df	10
	Sig.	.000

BIM-based Risk Management in Project Planning Phase

Without any doubt, risks exist in various stages of the project. The project lifecycle and the performance of the risk management have a forward impact on the project's successfulness. There are many factors that can lead to a successful BIM-based technology in risk management during the project planning phase.

In reference to Table 7, there were two factors that mostly benefit a BIM-based technology which were formwork plan with integrated fall plan and design for safety model check.

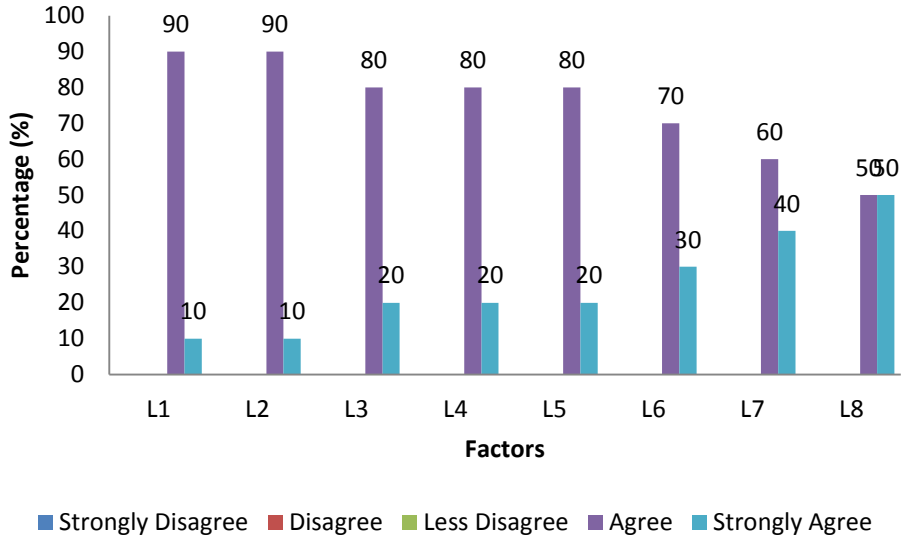


Figure 8: Bar Chart of Factors Lead to a Successful BIM-based Technology in Risk Management

Table 7: Descriptive Statistics of the Factors Lead to a Successful BIM-based Technology in Risk Management

Code	Factors	Mean	Std. Deviation	Variance
L1	Formwork plan with integrated fall protection	4.1000	.31623	.100
L2	Design for safety model check	4.1000	.31623	.100
L3	Hazard identification	4.2000	.42164	.178
L4	Reducing construction fatalities	4.2000	.42164	.178
L5	Safety protective equipment planning	4.2000	.42164	.178
L6	Minimizing documentation errors	4.3000	.48305	.233
L7	Replacing traditional delivery method with more integrated methods	4.4000	.51640	.267
L8	Reduced rework	4.5000	.52705	.278

Table 8 is the Kaiser-Meyer-Olkin and Bartlett's Test (KMO) in which it was recorded that the value was .768 where this means that the data collected were reliable.

Table 8: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.768
Bartlett's Test of Sphericity	Approx. Chi-Square	117.005
	df	28
	Sig.	.000

CONCLUSION

This research addressed the topic of risk management and BIM, investigating the efficiency of adopting BIM-based risk management during the project planning phase. The objectives of this research were achieved throughout the process of literature review and questionnaires filled out by BIM experts and also those who understand and apply the concept of risk management in construction.

The implementation of BIM in the AEC industry has been encouraged by the Malaysian Government to facilitate achievement of the vision of the CIDB Master Plan as well as the nation's 2020 vision through an increase in key performance indicators (KPIs) and productivity.There are many benefits that each construction players can achieved with the adoption of BIM. Organization itself should educate their employees about the technology.

REFERENCES

[1] Latifi, A.A., Mohd, Suzila., Brahim, Juliana., (2007). Application of Building Information Modeling (BIM) in the Malaysian Construction Industry: A Story of the First Government Project. Universiti Tun Hussein Onn Malaysia.

[2] Smith, N. J. (2006). Managing Risk in Construction Projects (Second Edition), 3-4.

[3] Volk, R.; Stengel, J.; Schultmann, F. (2014): Building Information Models (BIM) for Existing Buildings-Literature Review and Future Needs - Automation in Construction 38, 109-127.

[4] Porwal, A and Hewage, K N (2013) Building Information Modeling (BIM) Partnering Framework for Public Construction Projects. "Automation in Construction", 31(1), 204-214.

[5] Liu, W.P., Guo, H.L., Li, H., Li, Y. (2014): Factors Constraining the Development of Professional Project Management in China's Construction Industry. Int. J. Project Manage. 22, 203-211.

[6] Hardin, B. (2011). BIM and Construction Management: Proven Tools, Methods, and Workflows. John Wiley & Sons, Indiana, USA.

The Challenges of Building Information Modelling Implementation in Malaysia

Po Jia Chuan, Chai Chang Sa'ar

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

cschai@utm.my

Keywords: Building Information Modelling; Benefits; Challenges; Solutions.

ABSTRACT. Building Information Modelling (BIM) was first introduced in Malaysia in 2009 and has known to be a revolution of the construction industry that enhances a more systematic, manageable and sustainable construction management process. However, slow implementation of BIM has caused construction industry in Malaysia to become less capable with the global stage that has been advanced in BIM. Besides, the solutions that were ineffective to solve the slow BIM implementation issue only caused time and money has been wasted without much progress. Due to these reasons, the aim of this study is to explore the reasons behind the low implementation rate of BIM in Malaysia. The key objectives of this study are set to identify the benefits of BIM, to determine the challenges and to proposed solutions for slow BIM implementation in Malaysia. In order to achieve the objectives, questionnaires survey was done throughout the AEC players in Malaysia and most significant benefits, factors and solutions had been identified. As a result, the most significant benefit of using BIM that is expected from the industry is time reduction. Furthermore, the main challenges to implement BIM in Malaysia are subjected to cost, process and policy of implementation and lastly the most significant solutions are giving incentives by government, mandate BIM in works, and establish new procurement process. In conclusion, the objectives of this study have achieved. This study hopefully will give a clearly guidance for the government as well as the private sectors to increase the implementation of BIM in Malaysia.

INTRODUCTION

BIM is a new process of management whereby a shared 3D model that contains information database is used as the main reference for all works [1]. BIM have been proved by world wide of it efficiency of handling construction projects and able to provide a more sustainable works throughout the entire construction process [4]. BIM is still considering new in the construction industry in Malaysia and the implementation of the new piece of technology is very low [20]. As a result, studies on challenges and solutions shall find out in order to increase the usage of BIM in Malaysia.

Problem Statement

With the increase usage of BIM throughout the world, implementing BIM is a must in the future so that Malaysia able to compete with other countries in global stage. Fail to adopt BIM may hurt the performance of construction field in future since the tradition way of managing the construction is slowly being eliminate [9].

Other than that, since there are many challenges of implementing BIM in work, sorting out the most significant challenges will help to find the right direction to solve the problems [7]. Hence, time and money can be saved by applying the most effective solutions to solve the issue.

Aim and Objectives

The aim of this study is to find out the reasons and solutions behind the slow implementation of BIM in Malaysia. The objectives of this study are:

1. To identify the benefits of BIM.
2. To determine the challenges of BIM adoption in Malaysia.
3. To propose BIM adoption measures for improvements.

Scope of Study

This research is focused on finding the benefits, most concerned problems and solution in order to increase the implementation of BIM in Malaysia. The targeted respondents come from construction companies that are new to BIM and are consisted of stakeholders, such as consultant, contractor, architect, developer that are actively involved in construction industry. However, the questionnaires survey has been restricted in Malaysia

LITERATURE REVIEW

Building information modelling (BIM) is an intelligent and efficient process, which provide tools and insight for architecture, engineering and construction professionals based on a 3D-model, so that a more efficient plan, design, construction and management of buildings and infrastructure can be produced [1].

According to a previous finding, the uses of BIM can be categorised into 5 different main usages, which are "Gather", "Generate", "Analyse", "Communication" and "Realize" [2]. "Gather" is to collect and organize information of a facility, "Generate" is to create and record down information about the facility, "Analyse" is to test the elements to have better understanding on it, "Communication" is to present information within stakeholder and lastly "Realize" is to use the facility information to control a physical element. These 5 categories of BIM functions help to provide a higher level of efficiency, communication and collaboration and are far more advance and beneficial compare to the traditional paper-based tools to manage a construction projects.

Benefits of BIM

BIM provide a lot of benefits through it's useful functions and abilities. The benefits that users obtained is based on the BIM stage level (Bew-Richards BIM Maturity Model). In overall, there are a few main benefits that have found and listed in Table 1:

Table 1: Benefits of BIM

No	Benefits	Explanation	Reference
1	Better estimation	BIM allows model based cost estimation where BIM compatible software programmes use parameters and rules to determine the geometry, non-geometry properties and features of objects	[6] [7] [8] [9]
2	Clash Detections	Clash detection function in BIM helps to eliminate clashes of design and rectify the clashes before works start.	[1] [6] [10]
3	Better Visualization	Using BIM allows a user to see a structure building through isolate, filter any area or element of especial interest, photo-like renderings or even animated walk through the structure 3D model that have built.	[11] [12] [13]
4	Communication improvement	The 3D model is more efficient to present and to explain and this make sure the stakeholders to fully understand every part of the buildings and change the way of interaction between them.	[9] [14] [15] [16]
5	Quality increase and control	BIM allows the construction teams to consistently refining and adjusting their portions according to the project specification and changes in design during the planning stage.	[16] [17] [18]
6	Coordination Improvement	3D models that used in BIM contains all the data requires for a building including contractual details, design specification, partial relationships, architecture design, landscape design, construction and installation designs as well as bills of quantities and cost estimates etc.	[14] [19]
7	Cost reduction	BIM able to reduce cost up to 30% due to better transparency and efficiency in the planning and construction.	[7] [9] [10]
8	Construction Time Reduction	BIM to produce a better accuracy in scheduling and planning (5D BIM). Other than that, clash detection functions also help to reduce reworks that are time consuming.	[1] [6] [8]

Challenges of BIM

Challenges of BIM can be group into 5 main categories, which are people, process, cost, technology and policy. Some of these challenges are interrelated, and makes the problems to become complicated. By referring to previous studies, the 5 main challenges have been stated in Table 2.

Table 2: Challenges of Implementing BIM in Malaysia

No	Category	Challenges	Reference
1	People	• People reluctant to change	[7] [8]
		• Industry reluctant to change	[20] [21]
		• Do not get support from senior leadership	[22]
2	Process	• Do not prefer data sharing	[7] [23]
		• Design process shift to front cause more planning works	[24]
		• Business process of an organization may change due to different in process	
3	Technology	• Slow internet speed	[25] [26]
		• Not enough BIM professionals and human resources	[27] [28]
4	Cost	• High cost in upgrading hardware	[1] [23]
		• BIM software expensive and hard to get	[29] [7]
		• High operational cost	[30]
5	Policy	• Ownership of 3D model is not stated in current contract form	[31] [32]
		• Liability of each stakeholders is not clear	

Solutions

Solutions to increase the implementation of BIM have been explored and are summarised in Table 3:

Table 3: Solutions to Solve Low Implementation of BIM

No	Category	Aim	Proposed Solutions	Reference
1	Promotion Seminars and Roadshows.	To correct the perception of the construction players about the BIM.	• provide risk assessment • conducts awareness, training and education • shows examples of success case	[7] [30] [33]
2	Financial support	To solve the cost issues	• Incentives for BIM implementation companies • Vendor support	[7] [30] [33]

Table 3: Solutions to Solve Low Implementation of BIM…Continue

3	Technical guidance	To solve the limitation of technical resources of BIM	• Import professionals that have advance in BIM • Register with international bodies eg. BuildingSMART • Provide standardised BIM guideline • Government as mediator of information exchange	[7] [23] [30] [34]
4	Government Policy	Enforcement that push construction industry to use BIM in works	• Mandate BIM in construction works • Standardised the BIM process	[7] [23] [33]
5	New contract form	To solve the legal issues	• To form new contract form • To form new procurement process	[30] [32]

METHODOLOGY

The main objective of the study to find out the expected benefits of using BIM in works by construction players in Malaysia. In addition, challenges of adopting BIM are also studied and solutions were proposed. The research methodology mainly consisted of questionnaires survey distribution. The distributed Likert scale questionnaires was the main sources of data for analysis and software SPSS 16 has been used as the main tool to analyze the results. The method of analysis was Factor Analysis whereas to test for reliability of the data, Reliability Test was conducted.

Factor Analysis

Factor analysis consists of a number of statistical method which make a complex set of data to become a simpler one [35]. It reduces and condenses original variables into smaller number of factors with least information lost [36]. Factor loading that greater than 0.7 indicative of well-defined structure and factors that has value less than 0.7 are considered less significant and will be eliminated. To test whether Factor Analysis is appropriate to conduct in this study, Kaiser-Meyer-Olkin (KMO) and Bartlett's Test are used to measures the sampling adequacy. The KMO value must greater than 0.5 as it is the minimum acceptable range [37] whereas Bartlett's test of significant should have value lower than 0.05 to make sure variables are correlated to each other.

Reliability Test

Reliability test is used to measure the reliability and consistency of the questionnaires [38]. Cronbach Alpha (α) is used to test for the consistency of the questionnaires and judge the extent either a set of test items can be considered as measuring a single latent variable. In order words, the main concept of reliability is to measure in terms of the ratio of true score variance to observe score variance. The value of Cronbach Alpha must be exceeding 0.7 in order to consider successful and acceptable.

As a result, Kaiser-Meyer-Olkin Measure (KMO) of Sampling Adequacy and Bartlett's Test of Sphericity and reliability test for the data that had been collected were shown in Table 5. Since the Cronbach's alpha values exceeded 0.7, KMO value greater than 0.5 and Bartlett test value less than 0.05 in all sections, the data was able to conduct factor analysis and were considered reliable.

Table 5: KMO, Bartlett Test and Reliability Test Results

Section	1 Benefit of BIM	2 Challenges of implementing BIM	3 Solutions of Implementing BIM
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.589	0.603	0.811
Bartlett's Test of Sphericity	0.000	0.000	0.000
Cronbach's Alpha	0.700	0.741	0.943

RESULTS AND DISCUSSION

Based on Table 4, the respondents comprise 47.83% of civil and structure consultant, 15.2% of contractor, 6.5% of architecture, 8.70% of mechanical and electrical consultant, 8.7% of local authorities, 6.5% of surveyor and 6.5% of developers. Form the total of respondents, most of them have working experienced less than 5 years and mostly are junior executive in managerial level and unfortunately only 4.4% of total respondent have BIM hands on experience. Even though Civil and Structure Consultant has shown to be the majority, the other professions still had a certain contribution on the overall (among stakeholders) results based on the objectives.

From the result, most of the respondents in every profession have heard about BIM but never use it before. There were only 19.6% of the respondents are currently using BIM in their works but 8.7 % of the respondent never heard of BIM before. Civil and structure appeared to have the most BIM users, yet the percentage is still very low and comprise only 8.7% of total respondents. This shows that BIM in Malaysia is still under infant category since the implementation is low in every profession. However, the awareness of BIM has shown some improvement if compare with previous study. This explained that, efforts on BIM promotion through seminars and conferences that have done by the

government previously have shown a positive result which are beneficial in the effort to increase the implementation of BIM in Malaysia.

Table 4: Cross Tabulation of Awareness of BIM, Profession, Working Experience and BIM Hands on Experience.

		Working Experience	Architect			Civil & Structure			Mechanical & Electrical			Quantity Surveyor			Developer			Contractor			Local Authority			Sum (%)
			Awareness of BIM			Awareness of BIM			Awareness of BIM			Awareness of BIM			Awareness of BIM			Awareness of BIM			Awareness of BIM			
			A %	B %	C %	A %	B %	C %	A %	B %	C %	A %	B %	C %	A %	B %	C %	A %	B %	C %	A %	B %	C %	
BIM hands on experience	0 - 2 years	<5 years	2.2	0.0	0.0	19.6	4.3	0.0	6.5	0.0	0.0	4.3	0.0	0.0	4.3	0.0	0.0	0.0	2.2	0.0	2.2	0.0	0.0	45.7
		6 to 10 years	2.2	0.0	0.0	6.5	0.0	4.3	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.2	2.2	0.0	21.7
		10 to 15 years	2.2	0.0	0.0	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.9
		16 to 20 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		20 to 25 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.2	0.0	0.0	0.0	0.0	0.0	4.3
		> 25 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	4.3	0.0	0.0	0.0	0.0	8.7
	3-6 years	<5 years	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
		6 to 10 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		10 to 15 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7 - 10 years	<5 years	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
		6 to 10 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		10 to 15 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	>10 years	<5 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		6 to 10 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		10 to 15 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	2.2
Sub-Total			6.5	0.0	0.0	34.8	8.7	4.3	8.7	0.0	0.0	4.3	2.2	0.0	4.3	0.0	2.2	6.5	6.5	2.2	6.5	2.2	0.0	100
Total			6.5			47.8			8.7			6.5			6.5			15.2			8.7			100

Legend:
A=Yes, I have heard about it but never use it before. B=Yes, I am using it. C=No, this is my first time heard of it.

Next, based on the votes of respondents regarding to BIM functions that appreciated the most, 3D visualization had the highest vote. This mainly due to all the stake holders need that function in order to have better visualization on a project. Besides, cost estimating and structure analysis have the same amount of vote which was 15.38% and have the second most vote in the bar chart. This shows that BIM have already been agreed by most respondents that helps increase the accuracy of cost estimations and providing better structure design.

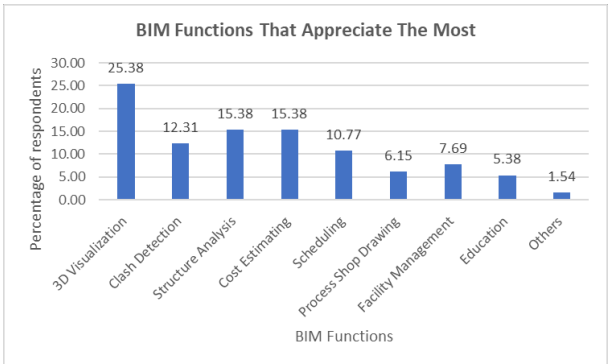


Figure 1: Bar Chart of BIM Functions that Appreciate the Most

Finding 1: Benefits of BIM

Table 6: Principal Component Matrix on BIM Benefits

No	Benefits	Factor Loading
1	BIM able to shorten the project duration.	0.897
2	3D model in BIM provides a better visualization of a building	0.872
3	BIM helps to improve communication among team and others stakeholders.	0.810
4	BIM able to reduce total project cost.	0.759
5	BIM gives a better quantity take-off estimation.	0.751
6	BIM helps to increase quality of a building through improvement of design consideration.	0.726
7	BIM provides better storing and searching of information.	-
8	The function of clash detection in BIM helps a lot in reducing cost time and quality of a project.	-

From the result that have been analyzed, two out of ten factors have been eliminated due to factor loading less than 0.7. The two factors were "BIM provides better storing and searching of information" and "the function of clash detection in BIM helps a lot in reducing cost time and quality of a project". The main reason these factors were eliminated was the respondents may not know well about these functions, procedures and their potentials benefits since most of them do not have any BIM hands on experience before.

For the ranking of the most significant benefits that analysed from the result, "BIM able to shorten the project duration" was ranked first with factor loading of 0.897. This result reflected the respondents may have some knowledge about BIM functions through attending seminars and conference.

Next, "3D model in BIM provides a better visualization of a building" was ranked number two with factor loading of 0.872. This shows that stakeholders need a better visualization of a building badly, so that a better detail can be seen for planning, managing and construction propose. The factor is then followed by "BIM helps to improve communication among team and others stakeholders", which have factor loading of 0.810. It is true that that BIM may be a new and useful tool for respondents to improve communication since most of them have faced ineffective communication before. There were others benefits that were analysed as significant from the result. These results were shown in Table 6 and should not be eliminated due to high loading factor.

Finding 2: Challenges of BIM

Table 7: Principal Component Matrix on Challenges Implementing BIM in Malaysia

No	Factors	Factor Loading
1	Cost of upgrading the hardware that compatible to BIM software is high.	0.887
2	BIM workflow is different with the current management process.	0.861
3	BIM workflow causes changes of business process.	0.859
4	Cost of obtaining a BIM software is high.	0.853
5	Ownership of the built-up 3D model is not clear and is not stated in the contract.	0.807
6	The internet speed in my site is too slow. / There is no internet in my site.	0.803
7	I do not prefer to share my important data of a project with others stakeholders.	0.789
8	Cost of learning BIM is high.	0.782
9	Liability of every stakeholders in building-up 3D model is not clear and is not stated in the contract.	0.771
10	Industry reluctant to change.	0.753
11	BIM will give a lot of works during the planning stage.	0.723
12	The top management team do not support in BIM.	-
13	BIM is hard and new for me.	-
14	BIM causes higher operational cost.	-

In Table 7, 14 factors that were listed in the questionnaire and voted by respondents using Likert scale method, 3 factors had scored factor loading less than 0.7 and has been eliminated due to less significant. These factors were "The top management team do not support in BIM", "BIM is hard and new for me" and "BIM causes higher operational cost". High operation cost of BIM was unexpectedly eliminated as refer from the result and it may cause by most of the respondents do not start implement BIM yet and therefore unfamiliar with the operation cost that will be charged.

For the ranking of the most significant benefits that analysed from the result, "cost of upgrading the hardware that compatible with BIM software is high", "BIM workflow is different with the current management process" and "BIM workflow causes changes of business process" were ranked first, second and third with factor loadings 0.887,0.861 and 0.859. The ranking was continued with "Cost of obtaining a BIM software is high" and "Ownership of the built-up 3D model is not clear and is not stated in the contract.", which were ranked in fourth and fifth placed. Based on the ranking result, cost issues were mention again and indicates that cost is the main challenge that need to be solved. Other than that, legal issues were also part of the challenge that need to be solve since it had high factor loading value. There were also others challenges that were considered important and are stated in Table 7 with factor loading greater than 0.7.

Finding 3: Proposed Solutions to Boost the Implementation of BIM in Malaysia

Table 8: Principal Component Matrix on Solutions to Implement BIM in Malaysia

No	Factors	Factor Loading
1	Incentives for BIM implementation. e.g. Tax exemption	0.893
2	Mandated BIM in public sector.	0.873
3	Establish new procurement process.	0.844
4	Vendor support. e.g; reduce the price of BIM software.	0.831
5	Provide new legal and insurance	0.830
6	Provide example of success cases in Malaysia with information.	0.813
7	Standardized the common practice of BIM.	0.803
8	Registration with international bodies. e.g: BuildingSMART.	0.803
9	Import foreign professionals which are advance in BIM.	0.775
10	Conduct awareness, training and educations seminars with lower price.	0.773
11	Provide BIM guideline.	0.756
12	Provide risk assessment of BIM.	-
13	Government as mediator for information exchange.	-
14	Prefer graduates or new employees that have BIM knowledge.	-

Proposed solutions to increase the implementation is based on the results of the questionnaire survey that have conducted. For solutions that government or local authority that can be done, methods of giving incentives for BIM implementation. e.g. Tax exemption, mandate BIM in public sector and establish new procurement process should be listed as the main solutions since their factor loading was the highest (0.893, 0.873 and 0.844 according to Table 8). These solutions tackle the main challenges that have studied from Table 7 directly and they should able to give a significant positive affect to increase the implementation rate of BIM in Malaysia.

For the private sectors that have interest to implement BIM, they can register themselves with international bodies (e.g. BuildingSMART) for technical consultation, or import foreign professionals which are advance in BIM to boost up the implementation. These two methods have factor loading value greater than 0.7 which shows significant in solving the slow implementation of BIM problems. However, an overall conclusion can be made was government support to push the private sector to implement BIM in Malaysia is still the main key to solve the issue as most of the solutions that are significant (shown in Table 8) requires government or local authority to become the mediator. For the private sectors, giving support to the government is also crucial since the solutions that have been proposed need the collaboration of both parties to success.

CONCLUSION

This research has successfully explored the perspective of construction players in Malaysia on the implementation of BIM. The questionnaires survey distributed has been successfully harvested and analysis has been done well to find out the results based on the objectives. As a result, objectives that have been set have achieved.

From the results, BIM was expected to shorten the project duration, provides a better visualization of a building and improve communication among stakeholders. Other than that, cost, process and policy are the 3 main challenges and the government strategy has play the most important role in order to increase the implementation rate in Malaysia.

Significant Of Study

The significant of this study is giving clearer guideline for the local government authority to solve the issue. By knowing the most concern challenges, the local government authority or CIDB able to take action prior to the challenges based on the result.

Other than that, the companies and the local authorities may collaborate together in order to make BIM easier to adopt. While they have known each other's problems and concerns, suitable solutions for both parties will give them a more convenient situation in adopting BIM and lastly boost up the implementation of BIM in Malaysia.

REFERENCES

[1] AUTODESK, "What Is BIM | Building Information Modeling | Autodesk." [Online]. Available: http://www.autodesk.com/solutions/bim/overview.

[2] R. G. Kreider and J. I. Messner, "The Uses of BIM: Classifying and Selecting BIM Uses," *Pennsylvania State Univ*., no. September, pp. 0–22, 2013.

[3] H. Ashcraft and D. R. Shelden, "BIM Implementation Strategies," *Present. Gehry Technol*., 2014.

[4] I. Czmoch and A. Pękala, "Traditional design versus BIM based design," *Procedia Eng*., vol. 91, no. TFoCE, pp. 210–215, 2014.

[5] M. Gheisari and J. Irizarry, "Investigating Human and technological requirements for successful implementation of a BIM-based mobile augmented reality environment in facility management practices," *Facilities*, vol. 34, no. 1/2, pp. 69–84, 2016.

[6] "Construction Research Congress 2012 © ASCE 2012 778," pp. 778–786, 2012.

[7] Z. Zakaria, N. Mohamed Ali, A. Tarmizi Haron, a J. Marshall-Ponting, and Z. Abd Hamid, "Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach.," *IJERT Int. J. Res. Eng. Technol*., vol. 2, no. 8, pp. 384–395, 2013.

[8] D. Migilinskas, V. Popov, V. Juocevicius, and L. Ustinovichius, "The benefits, obstacles and problems of practical bim implementation," *Procedia Eng*., vol. 57, pp. 767–774, 2013.

[9] S. Azhar, "Building Information Modelling :Trends, Benefits, Risks, and Challanges for the AEC Industry.," *Leadersh. Manag. Eng*., vol. 11, no. Bazjanac 2006, pp. 241–252, 2011.

[10] Association of Construction and Development.org, "Clash Detection in BIM Modeling : Construction & Development Article by," 2017. [Online]. Available: http://www.associationofconstructionanddevelopment.org/articles/view.php?article_id=10780. [Accessed: 12-Jan-2017].

[11] C. A. Hunt, "The Benefits of Using Building Information Modeling in Structural Engineering," pp. 31–37, 2013.

[12] P. Bynum, R. R. A. Issa, and S. Olbina, "Building information modeling in support of sustainable design and construction," *Am. Soc. Civ. Eng*., vol. 139, no. 1, pp. 24–34, 2013.

[13] D. Bryde, M. Broquetas, and J. M. Volm, "The project benefits of building information modelling (BIM)," *Int. J. Proj. Manag*., vol. 31, no. 7, pp. 971–980, 2013.

[14] A. Grilo and R. Jardim-Goncalves, "Value proposition on interoperability of BIM and collaborative working

environments," *Autom. Constr.*, vol. 19, no. 5, pp. 522–530, 2010.
[15] R. Sebastian, "Changing roles of the clients, architects and contractors through BIM," *Eng. Constr. Archit. Manag.*, vol. 18, no. 2, pp. 176–187, 2011.
[16] L. Chen and H. Luo, "A BIM-based construction quality management model and its applications," *Autom. Constr.*, vol. 46, pp. 64–73, 2014.
[17] Jorge Carmona and Kathleen Irwin, "BIM: who, what, how and why - Facilities Management Software Feature," 2007. [Online]. Available: http://www.facilitiesnet.com/software/article/BIM-Who-What-How-and-Why--7546. [Accessed: 25-May-2017].
[18] J. Schade, T. Olofsson, and M. Schreyer, "Decision- making in a model- based design process," *Constr. Manag. Econ.*, vol. 29, no. 4, pp. 371–382, 2011.
[19] I. Czmoch and A. Pękala, "Traditional design versus BIM based design," *Procedia Eng.*, vol. 91, no. TFoCE, pp. 210–215, 2014.
[20] W. I. Enegbuma and K. N. Ali, "Hypothesis Analysis of Building Information Modelling Penetration in Malaysian Construction Industry," *Proc. CIB World Build. Congr.*, 2013.
[21] A. Werner, "An attributional explanation of individual resistance to the introduction of information technologies in the workplace," *Behav. Inf. Technol.*, vol. 15, no. 5, pp. 331–335, 1996.
[22] L. Khemlani, "CORENET e-PlanCheck : Singapore's automated code checking system," *AECbytes - Build. Futur.*, vol. October, pp. 1–8, 2005.
[23] J. Rogers, H.-Y. Chong, and C. Preece, "Adoption of Building Information Modelling technology (BIM)," *Eng. Constr. Archit. Manag.*, vol. 22, no. 4, pp. 424–425, 2011.
[24] L. Crawford *et al.*, "September 2007 How Standard Are Standards : An Examination of Language Emphasis in Project Management Standards Innovation Alignment and Project Network Dynamics : An Integrative Model for Change Jobs Requiring a Capacity for Engineering Systems Thinking ," *Proj. Manag. J.*, no. September, 2007.
[25] A. R. Bin Ibrahim, M. H. Roy, Z. Ahmed, and G. Imtiaz, "An investigation of the status of the Malaysian construction industry," *Benchmarking An Int. J.*, vol. 17, no. 2, pp. 294–308, 2010.
[26] The Star, "Developers to be required to use BIM on govt projects of RM100mil and up - Business News | The Star Online," 2016. [Online]. Available: http://www.thestar.com.my/business/business-news/2016/11/17/developers-to-be-required-to-use-bim-on-govt-projects-of-rm100mil-and-up/.
[27] U. Tunku and A. Rahman, "A STUDY OF BUILDING INFORMATION MODELING (BIM) IN MALAYSIA CONSTRUCTION INDUSTRY TEO XIAO QIN A project report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor (Hons.) of Quantity Surveying Faculty of Engineering and Science," 2012.
[28] A. Info, "Australian Journal of Basic and Applied Sciences Implementation of Building Information Modeling (BIM) in Malaysia Construction Projects Life-Cycle," vol. 9, no. April, pp. 121–124, 2015.
[29] Ehsan Shourangiz, *The Development of Automated System for Evaluating Design Changes Fee Using ... - Ehsan Shourangiz - Google Books*. Johor Bahru: Universiti Teknologi Malaysia, 2012, 2012.
[30] M. Harris, A. I. C. Ani, A. T. Haron, C. Preece, and A. H. Husain, "Prioritizing Building Information Modeling (BIM) Initiatives for Malaysia Construction Industry," *XXV Int. Fed. Surv. Congr.*, pp. 1–9, 2014.
[31] CREAM, "A Case Study of BIM Implementation in Malaysia," *Cream*, pp. 1–27, 2011.
[32] B. G. R. Andre, "Building Information Modeling (BIM): Special Contract Issues," 2011.
[33] CIDB, "Malaysian Construction Research Journal," vol. 4, no. 1, 2009.
[34] "Home | buildingSMART | buildingSMART |." [Online]. Available: http://buildingsmart.org/. [Accessed: 28-May-2017].
[35] P. Kline, "An Easy Guide to Factor Analysis," 1994. [Online]. Available: https://books.google.com.my/books?hl=en&lr=&id=jITsAgAAQBAJ&oi=fnd&pg=PP1&dq=principal+factor+analysis&ots=TVvA9-fDoa&sig=1SzWVqLzKubniHVeju-MmNQCDDY&redir_esc=y#v=onepage&q=principal factor analysis&f=false. [Accessed: 06-Feb-2017].
[36] Hair, J.F. Jr. , Anderson, R.E., Tatham, R.L., & Black, W.C. (1998). Multivariate Data Analysis, (5th Edition). Upper Saddle River, NJ: Prentice Hall.
[37] A. Gie Yong and S. Pearce, "A Beginner's Guide to Factor Analysis: Focusing on Exploratory Factor Analysis," *Tutor. Quant. Methods Psychol.*, vol. 9, no. 2, pp. 79–94, 2013.
[38] C. Grigg and P. Wong, "The IEEE reliability test system -1996 a report prepared by the reliability test system task force of the application of probability methods subcommittee," *IEEE Trans. Power Syst.*, vol. 14, no. 3, pp. 1010–1020, 1999.

Implementation of Value Engineering on Design Stage in the Construction Project

Siti Zubaidah Isak, Rosli Mohamad Zin

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

roslizin@utm.my

Keywords: Value Engineering; Design Stage; Construction Project; Job Plan.

ABSTRACT. Value Engineering (VE) is vital in the construction project in order to improve the value of a project. The proper application of VE method is expected to deliver the best in achieving the actual value of a project life cycle in terms of cost saving and quality of the project. Construction of buildings has the sequence of stages that starts from formulation stage, planning and design stage, construction and controlling stage and closing stage [1]. Each of the stage is essential, especially during the planning and design stage. Inefficiencies in the planning and decision made by the stakeholders will lead to higher construction cost. This paper presented a study that has been conducted to investigate the existing practice of VE on the design stage, and, the roles of the stakeholders involved during the implementation of VE. In addition, the degree of knowledge or understanding of VE concept was also identified. A set of questionnaire had been distributed to different practitioners in the construction industry. The results indicated that the level of VE implementation on design stage was slightly high. For the first objective of the study, according to, the respondents or the discipline of the respondents, the most popular technique implemented was the consultant team would prepare the conceptual design report which record the basic design concepts for the preferred option. For the second objective, it could be seen that the respondents shared the same views on the roles of stakeholders which they agreed or strongly agreed upon the roles of client, project manager, and consultant but uncertain with the facilitator's roles. Furthermore, the results from the third objective showed that, the degree of knowledge or understanding of respondents toward the VE concept was slightly high.

INTRODUCTION

Value Engineering (VE) was discovered from the term of Value Analysis (VA) which happened since the Second World War. VE began when General Electric Co. experienced a shortage of manufacturing production due to the lack of skilled labor and difficulties in obtaining supplies of raw materials. In 1954, VE had been introduced to the industry, but only at the beginning of 1960, VE has been practiced in the construction projects [2]. The implementation of VE on design stage is very important but it is not commonly practiced yet in Malaysia. Therefore, this research is an attempt for further studies on VE specifically on design stage where it can be implemented on the construction project in Malaysia.

Problem Statement

According to Fathoni (2013), the level of awareness of VE for sustainable construction in Malaysia, have shown that the frequency of applying VE in the construction projects regardless sustainable or not was still low, where only 38% of respondents had applied VE in their construction project. In addition, the majority of the respondents' knowledge about VE were quite good where 59% of them had a good understanding of the concept of VE. But, this did not prove that VE is popular in the construction industry in Malaysia where only small percentage, 28% of respondents had shown that they had undergone formal training on VE and the rest were not [3].

VE should be performed as early as possible before commitment of funds approval of systems, services, or design in order to maximize the end results. Thus, to promote the application of VE in the construction industry in Malaysia, it is crucial to understand the current state of its application in the industry, especially during the design stage.

Objectives

The objectives of this study are:

1. To investigate the existing practice of Value Engineering (VE) on the design stage;
2. To identify the roles of the stakeholders involved during the implementation of Value Engineering (VE);
3. To identify the degree of knowledge or understanding of Value Engineering (VE) concept.

Scope of Study

This research focused on studying the level of implementation of VE onto some of the construction projects that has been selected in the state of Johor and Kuala Lumpur. This study only covered on the design stage and did not comprise in the bidding phase, material selection phase or construction project phase. The data for this study were collected through questionnaire survey form. The questionnaire was focused on the existing practice of VE that has been

practiced on the design stage as well as respondents' knowledge and understanding of the roles of stakeholders and the concept of VE in the construction industry.

LITERATURE REVIEW

According to the Institute of Value Management Malaysia, Value Engineering is the term used to describe value techniques that are adopted during the detailed design stage at the minimum of 35% progress of the project [4] According to Kelly and Male (1991), VE acts as an oriented effort to attain optimum value in product, system or service by providing necessary functions at the lowest cost [5]. On the other hand, VE is a creative, organized approach which aiming to optimize cost and performance of a facility or system [6]. Hence, VE is one of effective management in construction projects in establishing a clear project objective.

"The Job Plan outlines specific steps to effectively analyze a product or service in order to develop the maximum number of alternatives to achieve the products or services has required functions". [7] The Value Engineering Job Plan was introduced by Larry Miles, which contain six phases that is called Value Analysis (VA) Job Plan. Nowadays, with the current changes and needs of the construction project, the original system has been improved to a new system in order to overcome the current constraints. Now, the Value Engineering Job Plan has eight phases which are [8]:

i. Preparation Phase: Phase that occurs before initiate the formal value study where scope, objectives and project information of the study will be gathered and defined.
ii. Information Phase: All essential facts will be gathered and considered to bring a basic level of project understanding including its challenges and constraint.
iii. Function Analysis Phase: Establish the relationship between the cost and performance of the function for the next study.
iv. Creative Phase: Provide detail assessment of the design aspects that can be improved during the implementation of VE to increase the project value
v. Evaluation Phase: Prioritizes ideas for development by focusing on those with the highest potential performance improvement and cost savings.
vi. Development Phase: Validate idea concepts by comparing to the original design concept and select the best alternatives for improving the value.
vii. Presentation Phase: Present the alternatives value and design suggestions to the stakeholders and draft the report.
viii. Implementation & Follow Up Phase: Obtain implementation commitments and follow-up

METHODOLOGY

The main objective of the research is to investigate the existing practice of VE on the design stage, in addition to identify the roles of the stakeholders involved during the implementation of VE and also to identify the level of knowledge or understanding of VE in the construction project.

A questionnaire survey was designed and distributed to the respondents to ensure information related to the implementation of VE in the Malaysia construction industry could be collected and analyzed. The questionnaire was focused on the respondents' opinions in relation to the implementation of VE on their current project, opinion on stakeholders' roles and their understanding toward the concept of VE. The respondents consist of the contractor and the consultant with the minimum level of education at least a bachelor of degree.

Primary Data

Questionnaire. The collection of data required is through the distribution of questionnaires to the two groups of respondents, which were the contractor and the consultant. The respondents would be selected based on their involvement (directly or indirectly) during the implementation of VE in the construction project. This method was used to analyze the objectives of this study. Moreover, the validity of this method is higher compared to the data gathered from the articles, journals or reading from the internet.

Secondary Data

Literature Review. Secondary data is the data obtained from the desk of study method or data collected by other researchers where the data can be obtained from various sources [9]. The benefit of this method is it gives an impact on time and cost saving for collecting the information and data [10].

Data Analysis

Relative Index Method (RI). The data collected from the questionnaire was analyzed using the Relative Index (RI) method. This RI method has been used by Nesan (1997) in the same context of an application. RI was calculated using the following formula [11]:

$$\text{Relative Index} = \frac{\sum 1n1+2n2+3n3+4n4+5n5}{\sum (n1+n2+n3+n4+n5)}$$

Where: n_x = no. of respondents
1, 2, 3, 4,5 = ordinance scale of importance

RESULTS AND DISCUSSION

Background of the Respondents

In this section, the questions were in the form of the years of experience, the level of education and different disciplines of respondents in the construction industry. From the total of 40 respondents, 31 of the respondents (77.5%) were from the contractor field and the other 9 respondents (22.5%) were from the consultant field. Most of the respondents have less working experience, where only 22.5% of the respondents have been working in the construction industry for more than 10 years. Furthermore, in order to obtain satisfactory results of the study, the groups of respondents selected were those who posses at least a bachelor of degree. The findings showed 87.5% of the respondents have bachelor degree whereas 12.5% own a master degree.

From figure 1, 29 respondents (72.5%) agreed that the project that they were currently involved in had implemented VE at the design stage. Whereas, 11 respondents (27.5%) agreed that their projects did not perform any VE during the design phase.

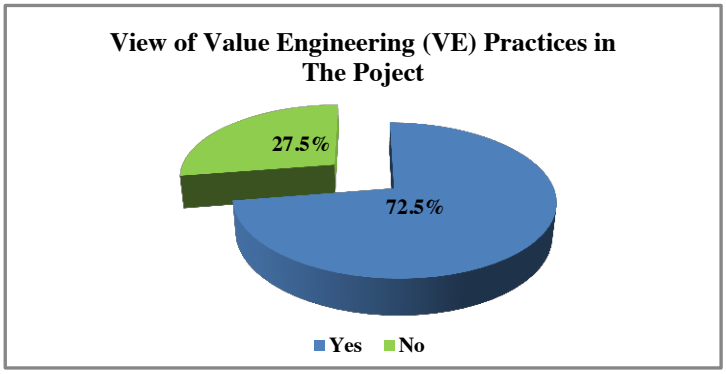


Figure 1: Views of Value Engineering (VE) practices in the construction projects

Result From The Objectives

In this section, the respondents were asked to answer the statements for objective one (1) based on their current construction project and for the other objectives, they were asked to answer the statements based on their own opinion and understanding. The analysis focused on two sections. The first analysis was conducted by referring to the respondents while the second analysis was analyzed by following the disciplines of the respondents either from the contractor or the consultant field. The results and analysis of the questions are further elaborated in the figures and tables below.

The Existing Practice of Value Engineering (VE) on The Design Stage

For the first objective, eleven questions were designed based on the literature review. Results were demonstrated in the following figures. As it seems clear from the figure 2 below, eleven methods of VE practices on the design stage have been analyzed among all respondents. According to the obtained data, almost all respondents (93.10%) believed that the preparation of conceptual design report to clients by consultants has been practiced in their current project. On the other hand, there is a method that was least applied by all respondents where only 58.62% indicated that they would review the existing VE practice as guidelines. Furthermore, based on the analysis found, more than 80% of all respondents implemented the other practices too which is between 82.76% to 89.66%.

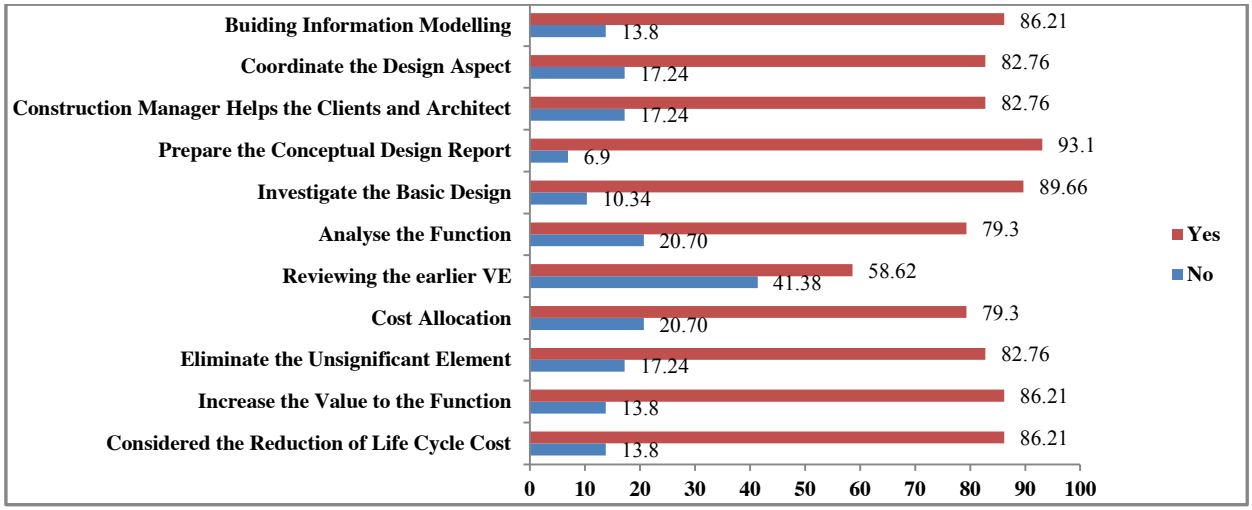


Figure 2: The existing practice of value engineering (VE) on the design stage by all respondents

Based on the figure 3 and 4, the analysis was made by following the disciplines of the respondents whether they were from the contractor or in the consultant field. The result indicates that a small number of the contractors (45%) conducted further investigation towards the basic design concepts that can be applied in the detailed design stage. In addition, other practices were also popular among them with the percentage in between 70% to 95% of them practicing it.

On the other hand, from the survey responses by the consultant, all of respondents (100%) believed that all the practices that have been implemented in their projects except for construction manager will help the client and architects to determine the potential cost saving, energy efficiency, and building enhancements and the design elements that have no significance in the project will be eliminated with only 77.88% have implemented it. Supporting this, 88.89% agreed that the function of each design need to be analyzed to ensure there is no duplication of design will happen.

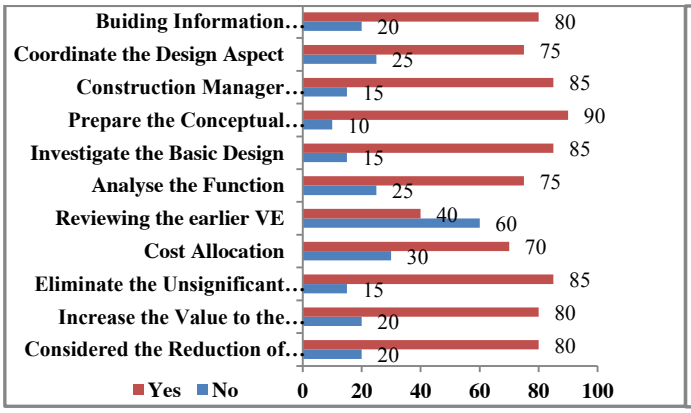


Figure 3: The existing practice of value engineering (VE) on the design stage by the contractor

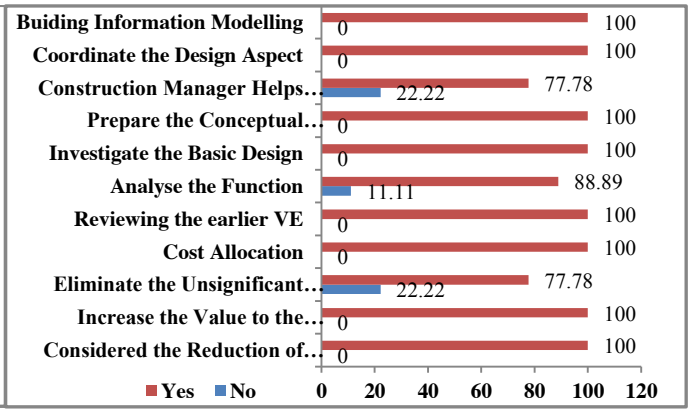


Figure 4: The existing practice of value engineering (VE) on the design stage by the consultant

The Roles of the Stakeholders Involved During the Implementation of Value Engineering (VE) in the Construction Project

Table 1 shows the results of the analysis of the respondents' opinion regarding on the roles of the stakeholders involved during the implementation of VE. Based on the relative index shown, be it from all of the respondents or by following the group of the respondents, they agreed on the client's roles and strongly agreed on the project manager's roles. Besides that, for the facilitator's roles, the analysis made for all the respondents and contractors showed that they were uncertain but on the other hand, the consultants have agreed on that statement. Additionally, from the survey responses, the consultant were strongly agreed on consultant's roles while the analysis made for all respondents and the contractor, they agreed with the statement.

Table 1: The roles of the stakeholders involved during the implementation of VE

	The Role of The Stakeholders	Respondent	Ordinance Scale 1	2	3	4	5	R.I	Categorie
1.	Facilitators are professionals who have a lot of experience and are highly skilled in managing the implementation of Value Engineering (VE).	All Respondents	0	7	14	17	2	3.35	Not Sure
		Contractor	0	6	9	15	1	3.35	Not Sure
		Consultant	0	1	3	4	1	3.56	Agree
2.	Clients must play an active role in providing information for the needs and constraints of the project.	All Respondents	0	0	3	20	17	4.35	Agree
		Contractor	0	0	2	17	12	4.32	Agree
		Consultant	0	0	1	4	4	4.33	Agree
3.	Project Manager must have a high efficiency in directing and managing the Value Engineering (VE) practice.	All Respondents	0	0	0	16	24	4.60	Strongly Agree
		Contractor	0	0	0	14	17	4.55	Strongly Agree
		Consultant	0	0	0	3	6	4.67	Strongly Agree
4.	The consultant is someone who is responsible in terms of cost reduction, engineering, and additional value in design elements.	All Respondents	0	0	6	18	16	4.25	Agree
		Contractor	0	0	6	14	11	4.16	Agree
		Consultant	0	0	0	4	5	4.56	Strongly Agree

The Degree of Knowledge or Understanding of Value Engineering (VE) Concept

Table 2 below has described the degree of knowledge or understanding of respondents VE concept. It shows that be it from all of the respondents or by following the group of the respondents, most of the respondents were agreed with all the statements given except for statement number six and seven. For the statement where VE can reduce the life cycle costing of a project, the analysis shows that all respondents and the consultants were unsure with the statement but conversely, the contractor agreed with the statement. On the other hand, only consultants were uncertain whether VE can improve communication between the stakeholders involved during the implementation of VE while the contractors and all respondents came to an agreement according to this matter.

Table 2: The degree of knowledge or understanding of VE concept

	Knowledge on VE	Respondent	Ordinance Scale 1	2	3	4	5	R.I	Categorie
1.	VE can increase the value of a construction project.	All Respondents	0	0	7	23	10	4.08	Agree
		Contractor	0	0	5	17	9	4.13	Agree
		Consultant	0	0	3	6	0	3.67	Agree
2.	VE plays a big role in the reduction of costs of the whole project.	All Respondents	0	1	6	23	10	4.05	Agree
		Contractor	0	1	3	19	8	4.10	Agree
		Consultant	0	0	2	5	2	4.00	Agree
3.	VE can add an additional value to the function of an element in the construction design.	All Respondents	0	2	7	23	8	3.93	Agree
		Contractor	0	2	2	20	7	4.03	Agree
		Consultant	0	0	3	4	2	3.89	Agree
4.	VE is very important in order to meet the needs and improve the satisfaction of the clients.	All Respondents	0	2	4	23	11	4.08	Agree
		Contractor	0	2	2	20	7	4.03	Agree
		Consultant	0	0	3	3	3	4.00	Agree
5.	The implementation of VE can be used in any stage of the development cycle of the project design.	All Respondents	0	2	10	22	6	3.80	Agree
		Contractor	0	1	8	16	6	3.87	Agree
		Consultant	0	0	4	5	0	3.56	Agree
6.	VE can reduce the life cycle costing of a project.	All Respondents	0	3	18	16	3	3.48	Not Sure
		Contractor	0	2	12	14	3	3.58	Agree
		Consultant	0	2	4	3	0	3.11	Not Sure
7.	VE can improve communication between the stakeholders involved in the implementation	All Respondents	0	2	10	23	5	3.78	Agree
		Contractor	0	1	7	19	4	3.84	Agree

	of VE.	Consultant	0	2	2	4	1	3.44	Not Sure
8.	Usually, the implementation of VE will give most of its benefit in early stages of development and design concept.	All Respondents	0	4	8	20	8	3.80	Agree
		Contractor	0	2	6	18	5	3.84	Agree
		Consultant	0	2	2	2	3	3.67	Agree
9.	VE give an opportunity to explore the possible alternatives in order to cut the cost.	All Respondents	0	2	7	19	12	4.03	Agree
		Contractor	0	1	4	17	9	4.10	Agree
		Consultant	0	1	2	2	4	4.00	Agree
10.	VE is a method to reduce the high cost and low efficiency in construction projects.	All Respondents	0	4	11	15	10	3.78	Agree
		Contractor	0	3	7	13	8	3.84	Agree
		Consultant	0	1	3	3	2	3.67	Agree
11.	VE can be implemented in all stages of the project.	All Respondents	0	2	8	20	10	3.95	Agree
		Contractor	0	2	7	14	8	3.90	Agree
		Consultant	0	0	1	5	3	4.22	Agree
12.	VE work plan is essential for the implementation of the VE methodology.	All Respondents	0	0	9	22	9	4.00	Agree
		Contractor	0	0	7	17	7	4.00	Agree
		Consultant	0	0	1	7	1	4.00	Agree

CONCLUSION

Based on the results from the analysis above, there are some conclusions that can be drawn. Through the questionnaire that was distributed, it can be concluded that the level of VE implementation on design stage was slightly high and popular among the construction projects. A total of 29 out of 40 respondents with the percentage of 72.5% agreed that the project that they were currently involved had implemented VE in the design stage. This shows that the implementation of VE was effectively put into practice in the construction projects compared to the studies that had been conducted previously by Fathoni in 2013 where only 38% of respondents implemented VE in their construction projects [3].

In addition, from the survey responses, it was found that most of the respondents had less working experience. 54.84% of the respondents had been working on the construction project for less than five years, while 25.81% had been working in between 5 to 10 years. This percentage was relatively high compared to the 22.5 % of respondents that had been working more than 10 years and above. The finding was significantly affected the outcome for the first objective of this study where respondents inclined to not answer the question given based on the actual situation in the construction industry. For the first objective, the most popular technique carried by all the respondents and the contractors were the consultant team will prepare the conceptual design report for the client which record the basic design concepts for the preferred option, both with the percentage of 93.10% and 90%. Besides, the least method implemented by all respondents and the contractors was reviewing the existing Value Engineering (VE) practice as guidelines. However, it was different for the consultants, where all of the methods stated in the questionnaire were popular among them with the percentage between 77.8% to 100% of them have implemented VE in their projects.

For the second objective, through the findings from the analysis, it can be seen that the respondents shared the same views on the roles of stakeholders. All respondents and the respondents from different discipline, agreed or strongly agreed upon the roles of client, project manager, and consultant. However, only the consultant agreed that facilitators are highly in skills and have a lot of experience to manage VE while the contractors and other respondents were uncertain with this statement.

Lastly, the findings from the third objective showed that the degree of knowledge or understanding of respondents towards the VE concept was slightly high. It was proven that even though the majority of the respondents' had less than 10 years of experience working on the construction project, but their understanding of VE concept were terrific. Hence, the researcher can conclude that the process of VE provides many benefits to the construction industry. It acts as opportunity to the stakeholders to explore possible alternatives in order to improve project valu, deal with the problems of values and functions, clarify the project's objectives, implement the recommendations adopted into the design and lastly provide feedbacks on the results of the study (Kelly, Male and Graham, 2004). In a nutshell, this research is expected to increase the implementation of VE on design stage in the construction project in Malaysia.

REFERENCES

[1] Kohli, Uddesh & Chitkara, (2007). *Project Management Hanbook- For Engineers, Construction Professionals and Business Managers*, West Patel Nagar, New Delhi: Tata McGraw-Hill Publishing Company Limited.

[2] Palmer., Kelly J. & Holistic. (1996). *Appraisal of Value Engineering in Construction in United States*, *Journal of Construction Engineering and Management* (Vol. 122).
[3] Fathoni U., Zakaria C. M. & Rohayu C. O. (2013). Value Engineering Awareness Study For Sustainable Construction in Malaysia. *International Conference on Energy and Environment*.
[4] *Institute of Value Management Malaysia*. (2006). Retrieved May 26, 2017, from ivmm.org.my: http://ivmm.org.my/v1/value-engineering/
[5] Male, S. and Kelly, J. (1991). *Value Management and Economic Management of Projects*. The Building Economist Publication.
[6] Dell I'sola, A.J. (1982). *Value Engineering in the Construction Industry*, Van Nortstrand Now York.
[7] SAVE International. (1998). Value Methodology Standard. *SAVE International Conference*.
[8] LLC, B. (2010). *bremmerllc*. Retrieved May 25, 2017, from http://bremmerllc.com/wp-content/uploads/2010/09/SAVE-Job-Plan.pdf
[9] Naoum S., (2003). An Overview into the Concept of Partnering, *International Journal of Project Management*.
[10] Ghauri P. N. & Kjell G. (2005). Research Methods in Business Studies: A Practical Guide. Financial Times Prentice Hall, 2005
[11] Nesan, L.J. (1997), *A Generic Model for Effective Implementation of Empowerment in Construction Contractor Organisation*,Ph.D Thesis, University Of Wolverhampton.

The Readiness of Project Stakeholders if SHASSIC is Being Made Mandatory in 2020

Wan Afiq Azwan Wan Othman, Abdul Rahim Abdul Hamid

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

rahimhamid@utm.my

Keywords: SHASSIC; Safety and Health; Accident; CIDB; Construction

ABSTRACT. Safety and Health Assessment System In Construction - SHASSIC was developed in 2006 by the Construction Industry Development Board (CIDB) Malaysia, which is an approach or method to evaluate the performance of contractors or developers in practicing safety and health at the workplace or construction site. The system is implemented in line with the increase of accidents in construction projects throughout the country. SHASSIC implementation is still low and not comprehensive because it is not an obligation but CIDB plans to make it mandatory by 2020. Therefore, this study was undertaken to identify knowledge about SHASSIC among the party in the construction industry, identify the readiness of contractors or developers if required SHASSIC by 2020 and to generate measures to enhance the readiness of the parties concerned. The method used in this study is through the distribution of questionnaires and interview the parties involved. The data obtained will be analyzed based on the analysis of the frequency distribution and the average index in turn presented in charts, graphs and tables as appropriate. The results are obtained shows that only minority who have already implement SHASSIC for their project. However, through the survey, these companies already have implemented the features towards SHASSIC requirement. All strategies proposed to increase the implementation of SHASSIC among project stakeholders in construction industry were agreed by the respondents. Among the top strategies are to more awareness campaign, monetary incentives by government and recognition by CIDB to the organization that implement SHASSIC.

INTRODUCTION

Safety and Health Assessment System in Construction or SHASSIC is one of the CIDB initiative to overtake the safety and health issue in construction whereby the number of accident cases occurred are very high. The accident cases may involve fatal cases or cause permanent disability. It will also affect the project flow as the company will short of employer and maybe the construction site need to be closed temporarily for investigation. To avoid such cases, CIDB have introduced SHASSIC which it will act as the main safety and health assessment in each construction project in Malaysia. 2020 is the year whereby SHASSIC will be fully implemented by the project stakeholders in Malaysia.

With three elements that are going to be checked and monitored, SHASSIC will obviously cover most aspect that usually lead to accident occurred in construction site and also as a monitoring party for workers' health aspect. In addition, the project that have been assessed by accredited officer from CIDB will be graded according to number of stars given from the acquired marks. A higher marks given to certain project indicates that the project have managed the elements of high-risk and hazardous in site construction and the file are well documented. This paper briefly discuss about implementation of SHASSIC, followed by the preparedness among project owners and also ways to increase the awareness of SHASSIC implementation among contractors and developers in Malaysia.

Problem Statement

Accidents in construction activity keep occur around the world even there are many ways taken to improve the construction safety system. Considering the aspect of health which also need to give attention due to the implication of the activity in construction. Obviously, in past few years it lifts the construction sector as one of the sectors that contributed to the highest number of accidents in Malaysia.

Construction Industry Transformation Programme (CITP) have addressed four strategic thrusts whereby one of them is 'Quality, Safety and Professionalism'. It has been addressed as there are limited emphasis on quality and assessments; with limited safety awareness as well as added regulatory constraints within the industry. The expected outcomes of this strategic thrust in terms of safety aspect is "more than 50% reduction in worksite fatalities and injuries".

Therefore, in 2006, Construction Industry Development Board (CIDB) have introduced Safety and Health Assessment System in Construction or also known as SHASSIC in order to keep monitoring the safety and health aspect in construction. However, during 2015, a total of 129 (2014, 118) construction projects managed to be assessed using SHASSIC [1]. For the past few years of its existence, SHASSIC are not being fully implemented by the responsible party for each construction project in Malaysia. Recently, CIDB has announced that SHASSIC will be mandatory in 2020 for every construction project registered and developed in Malaysia. This decision made by CIDB shows that they are committed to continuously improve the safety and health aspect in Malaysia.

Objectives

The objectives of this study are:

1. To study the knowledge of construction party towards SHASSIC assessment.
2. To identify the readiness among project owners, developers and contractors if SHASSIC being made mandatory in 2020.
3. To propose strategies in increasing the implementation of SHASSIC among project stakeholders in the construction industry in Malaysia.

Scope of Study

This study is carried out to identify current scenario of SHASSIC implementation and the project stakeholders' readiness if SHASSIC are mandatory in 2020. This study will be conducted randomly around Malaysia among the contractors, developers, safety and health officers and parties which involve in safety and health issue. For those project that have implement SHASSIC, the analysis and data about the marks accredited only can be obtained through the company's record system. Interviews with few parties involved in construction and also survey questionnaire are been distributed to obtain the data for this research.

LITERATURE REVIEW

By any relevant measures, construction is a not a safe industry [2]. The safety and health practices are two characteristics that being evaluated progressively [3]. It shows that it is a must for a construction to undergo safety assessment in order to avoid problems occurred during construction process. The unsafe situation that exist in construction industry will lead to the loss of workmanship and million ringgit properties every year in a country [4]-[5].

Current accident statistic in construction industry really shows that the responsible party need to take it seriously in order to reduce the number of accident occurred. When the number of accident cases reduced, it will save lot of financial expenditure towards the workers welfare. Occupational safety and health is a discipline that emphasizes the protection of safety, health and welfare of workers, organizations and other parties involved in a project such as client, supplier and the public [6].

Despite many initiatives and ways being implemented over the years, real and substantial issues still persist in the construction industry. These were including limited levels of safety awareness and enforcement in this industry. An industry transformation is required in order to accelerate the development of the Malaysian construction industry and prepare it to meet the future demands of the economy. Thus, the Ministry of Works with CIDB has spearheaded the development of Construction Industry Transformation Programme (CITP). CITP have introduced four strategic thrusts in order to guide the transformation and continued development of the construction industry [7].

SHASSIC is worked by Construction Technical Committee on Safety and Health in Construction with the assistance of Construction Industry Development Board, (CIDB) Malaysia to assess and evaluate the safety and health performance of contractors or developers in construction [8]-[9]. In November 2008, it was published as Construction Industry Standard or CIS 10:2008. SHASSIC focused on the safety and health management and practices of contractors for various aspects of the construction work activities [10]. It shall cover COSH management system and practices during construction work activities, particularly work activities covered under Occupational Safety and Health Act, 1994 (OSHA, 1994), Factories and Machinery Act, 1967 and Machineries (Safety, Health and Welfare) Regulation, 1970 (Revised 1988), OHSAS 18001 : 2007 and MS 1722 (Part 1) : 2005 [11]-[12].

There are ways of promoting SHASSIC for project stakeholders in order to make it mandatory in 2020 as a possible figure. One of the ways is through mass media whereby it have enables hundreds and thousands of people to communicate each other [13]. In addition, promotion through campaign also can be an effective way like CIDB have done before which is QSR (Quality Safety Roadshow). Meanwhile, incentives and awards recognition should be introduced in safety and health aspect in order to motivate the project stakeholders in maintaining or improving their current safety and health performance.

METHODOLOGY

The method used to complete the finding is by using two approaches. First, literature reviews have been finished by collecting information on articles, published books, research papers, journals and websites. This approach is applied in order to support the finding about SHASSIC implementation readiness and also to answer the third objective which is strategies to increase the SHASSIC implementation among project stakeholders in the construction industry in Malaysia. This approach is known as content analysis whereby it is defined as any method used to make the inference based on the objectives and systematic identification current behavior of a message [14].

Second, by conducting survey using questionnaires generated by Google Form and also by printed hardcopy. This method is used to identify the readiness level in implementing SHASSIC and also the current safety and health management applied. The data collected is to answer the objectives of the study whereby it included respondents' knowledge about SHASSIC, company's readiness towards implementing SHASSIC and strategies to tackle the problems that they found have been obstacles for them to implement SHASSIC. The company's readiness been

measured by identifying their current Safety and Health Management System in top management, at site and also surrounding.

The questionnaire given were in form of likert scale, therefore the data will be analyzed using frequency analysis and average indices to rate and rank the result according to level of implementation and level of agreement. After the compilation of survey data generated from questionnaire, data analysis are carried out in hand of various computer software such as Microsoft Excel 2013 and also Google Form generated by Google. The data then is visualized using the average index analysis, percentage score and also chart diagram like bar chart and radar plot.

Table 1: Average Index Classification

Rating Scale	Average Index, a	Category	Category
1	$1.00 \leq a < 1.50$	Least Implemented	Strongly Disagree
2	$1.50 \leq a < 2.50$	Poorly Implemented	Disagree
3	$2.50 \leq a < 3.50$	Moderately Implemented	Neutral
4	$3.50 \leq a < 4.50$	Implemented	Agree
5	$4.50 \leq a \leq 5.00$	Well Implemented	Strongly Agree

RESULTS AND DISCUSSION

The results shown below were based on each objective of the study. All of the objectives were achieved by the result from the survey questionnaire. The questionnaire generated using google form have been distributed among project stakeholders and construction workers randomly around Malaysia. From there, a total of final 30 respondent have been selected to present the findings for the study.

Objective 1 – Knowledge about SHASSIC

This objective have been set in order to identify construction people's knowledge of Safety and Health Assessment System in Construction (SHASSIC). Table 2 shows the number of respondent that knew or ever heard about SHASSIC whereby 43.3% of the respondent (13) agreed that they knew about SHASSIC. The rest were not sure and have not heard about it. While table 3 gave a picture of current SHASSIC application in the respondent's company. It clearly shows that the percentage of construction company implementing SHASSIC is very low with only 6.7%. Table 4 is presented to show the detail on companies implementing SHASSIC whereby there are four companies that have already implement and in progress of implementing SHASSIC.

Table 2: Knowledge about SHASSIC

SHASSIC Awareness	n	%
Yes	13	43.3
No	15	50
Maybe	2	6.7

Table 3: SHASSIC application in company

SHASSIC Application	n	%
Yes	2	6.7
No	26	86.7
In Progress	2	6.7

Table 4: Detail on Company Implementing SHASSIC

Company	Type of company	No. of project implement SHASSIC	Year start practice	Average score	Component of highest score	SHASSIC improves project's performance	SHASSIC implementation in future
AZRB	Contractor (G7)	15	2012	86%	Site Inspection	Yes	Yes
YMK	Contractor (G5)	10	2015	50%	Document Check	Yes	Yes
Intel Light Resources	Contractor (G7)	1	2017	Not Available	Site Inspection	Yes	Yes
Pembinaan tln Sdn Bhd	Contractor (G7)	In Progress	2017	Not Available	Not Available	Not Sure	Not Sure

Objective 2 – Readiness to implement SHASSIC if it is going to be mandatory in 2020

Objective 2 is to determine the aspects implemented in the project as steps of readiness in implementing SHASSIC. The aspects asked have been divided into five section which is top management commitment, document management, record and audit, training and also safety precaution at construction site. From the result, the average index of each element asked have been presented in Table 5. For overall, they have implemented to three of the section asked which are top management commitment, training and safety precaution at construction site. Meanwhile, for section of document management and also record and audit, the result shows that they have moderately implemented. Figure 1 is a

chart presenting the mean for every section asked which indicates that safety precaution at construction site have the highest mean (4.02) compared to others.

Table 5: Average index for each element in readiness aspect

Elements	Frequency Analysis					Average Index	Classification
	1	2	3	4	5		
Top Management Commitment							
Regular evaluation of subcontractors	0	3	7	11	9	3.87	Implemented
Using computer software to manage data and information regarding safety and health matter	1	1	6	16	6	3.83	Implemented
Strengthen Site Safety Management	2	0	7	14	7	3.80	Implemented
Improve Working Environment	2	0	5	18	5	3.80	Implemented
Uplift Safety Awareness	1	1	7	15	6	3.80	Implemented
Implementation of safety and health system such as OHSAS 18000	1	1	10	9	9	3.80	Implemented
Enhance the current Construction Safety Course for Project Managers with greater emphasis on risk management and soft skills such as communication and supervisory skills.	0	3	7	12	8	3.80	Implemented
Conduct regular management reviews to ensure effectiveness of the OSH management system	1	2	9	9	9	3.77	Implemented
Have a structured approach to manage OSH	0	2	10	12	6	3.73	Implemented
Good internal communication channel within the organization	1	2	9	10	8	3.73	Implemented
Always review systems, policies, procedures and processes	1	2	12	7	8	3.63	Implemented
Document Management							
Hazard Identification, Risk Assessment and Risk Control (HIRARC)	1	3	10	11	5	3.53	Implemented
Document stating results achieved or providing evidence of activities performed.	2	1	11	12	4	3.50	Implemented
Machinery management	2	1	11	13	3	3.47	Moderately Implemented
Emergency response plan	2	1	13	11	3	3.40	Moderately Implemented
OSH management system documented according to OHSAS 18001	2	1	16	7	4	3.33	Moderately Implemented
Workers health records are updated	3	3	14	5	5	3.20	Moderately Implemented
Record and Audit							
Learning from past incidents such as accidents or near misses is indispensable in improving OSH	1	2	8	13	6	3.70	Implemented
Establish and maintain an internal audit program and procedures	2	1	9	12	6	3.63	Implemented
Minutes of meeting have been recorded and managed	1	2	11	10	6	3.60	Implemented
Effective in meeting organization's policy and objectives	2	1	13	11	3	3.40	Moderately Implemented
Regular audits should be conducted to help companies understand the strengths and weaknesses of their systems and improve upon them.	1	3	12	12	2	3.37	Moderately Implemented
OSH records been stored and readily retrievable and protected against damage, deterioration or loss	2	1	14	11	2	3.33	Moderately Implemented
Training							
Strengthened the certification process and provided greater flexibility to recognise experienced workers	0	2	10	11	7	3.77	Implemented
Training to establish an audit program	1	1	10	11	7	3.73	Implemented
Provide training for hazard identification	1	1	9	13	6	3.73	Implemented
Workers trained to be fully aware of the consequences of non-adherence to safety procedures and requirements and how to mitigate the risks	2	1	8	13	6	3.67	Implemented
Enhanced the Construction Safety Orientation Course (CSOC) to ensure that new workers are equipped with basic safety knowledge as soon as possible	1	3	8	14	4	3.67	Implemented
Develop and retain a core pool of construction workers who can guide new workers and ensure that the safety culture continues to permeate through the sector	1	2	9	13	5	3.63	Implemented
Training for equipment and machinery handling	2	1	10	12	5	3.57	Implemented
Provides training to employees on safety topics required by the OSHA	2	2	11	8	7	3.53	Implemented
Perform emergency response drills	3	0	8	16	3	3.53	Implemented
Review the recruitment criteria for construction workers to ensure suitable level of competency	1	2	13	13	1	3.37	Moderately Implemented
Safety Precautions at Construction Site							
Prevention of Falling Objects	1	1	4	12	12	4.10	Implemented

Workers equipped with suitable PPE	1	1	4	12	12	4.10	Implemented
Fire Protection	1	1	5	11	12	4.07	Implemented
Hazardous areas surrounded by caution tape	1	1	7	8	13	4.03	Implemented
Monitored by safety officer regularly	1	1	7	9	12	4.00	Implemented
OSH Policy	2	0	6	10	12	4.00	Implemented
Emergency Preparedness	2	1	7	7	12	3.93	Implemented
Equipped as stated in site rules and regulations	2	0	5	15	8	3.90	Implemented

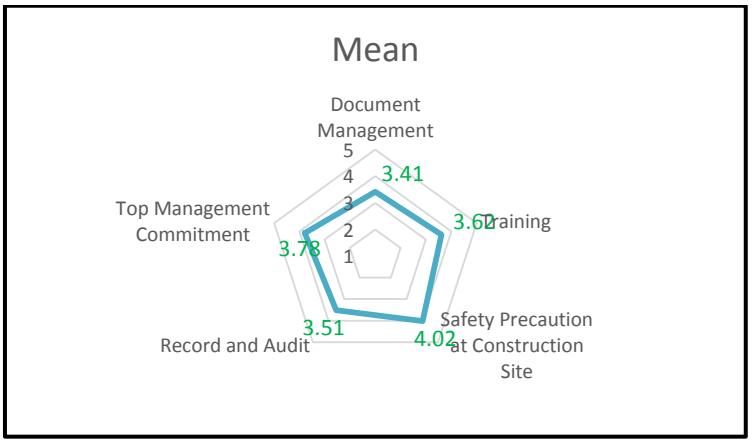


Figure 1: Mean for average index for readiness elements

Objective 3 – Strategies to increase the readiness of project stakeholders in SHASSIC implementation.
Objective 3 is developed to identify the suitable strategies in order to increase the readiness of project stakeholders to implement SHASSIC by 2020. These strategies includes the involvement of the construction company, government and also CIDB. The data obtained for this section have been represented in its average index as shown in Table 6. It clearly shown that all of the respondents were agreed to all of the strategies proposed in order to increase the readiness of project stakeholders in implementing SHASSIC.

Table 6: Average index for each element

Elements	Frequency Analysis					Average Index	Category
	1	2	3	4	5		
Construction Company							
Awareness of management and employees in term of safety and health assessment system	0	0	2	15	13	4.37	Agreed
Implementation of safety and health management system	0	0	2	17	11	4.30	Agreed
Continuous safety trainings are required during construction activities	0	0	2	18	10	4.27	Agreed
Promote widespread adoption of SHASSIC by influencing developers to factor in SHASSIC results in their selection of contractors	0	0	5	15	10	4.17	Agreed
Strong commitment and enthusiasm from the top management	0	0	3	19	8	4.17	Agreed
Appoint an experienced auditor for audit program	0	0	3	19	8	4.17	Agreed
Encourage incorporating safety requirements into contractual agreements / tenders for construction projects by larger developers and service buyers setting examples	0	0	3	19	8	4.17	Agreed
Enhance Assessment	0	0	5	16	9	4.13	Agreed
Regular audits should be conducted to help companies understand the strengths and weaknesses of their systems and improve upon them	0	0	5	17	8	4.10	Agreed
Benchmarking with other companies that implementing SHASSIC	0	0	7	13	10	4.10	Agreed
Government							
Allocating budget to finance the SHASSIC implementation	0	0	11	9	10	3.97	Agreed
Provide adequate budget to constantly organize training for safety and health officer (SHO)	0	0	11	9	10	3.97	Agreed
Provide incentive such as tax rebate for those who implement SHASSIC	0	0	9	15	6	3.90	Agreed
Issuing a circular requiring all government construction projects undergo SHASSIC with minimum score of 70 percent (4-star)	0	0	12	12	6	3.80	Agreed
Impose fines on projects that do not implement SHASSIC	0	1	13	9	7	3.73	Agreed
CIDB							
Providing awards to the excellent construction projects in term of its safety and quality aspect	0	1	5	13	11	4.13	Agreed
Increase the awareness towards the importance of SHASSIC	1	0	5	13	11	4.10	Agreed

implementation							
Industry Excellence Award	0	1	6	12	11	4.10	Agreed
International Recognition	0	0	8	12	10	4.07	Agreed
Develop practical assistance programmes to raise the quality of the risk assessment conducted	0	1	4	18	7	4.03	Agreed
Continue to work with the relevant stakeholders on the development, publication and promotion of case studies and best practices to illustrate the application and benefits of SHASSIC	0	0	9	12	9	4.00	Agreed
Organizing more SHASSIC campaign or roadshow to enhance the knowledge about SHASSIC	1	0	7	13	9	3.97	Agreed
Giving incentive for those contractors or developers that successfully trained their workers in achieving good SHASSIC score	0	0	10	11	9	3.97	Agreed
Increase the promotion through mass media to aware people about the importance of SHASSIC	1	0	5	17	7	3.97	Agreed
Leverage on media to promote a business case for integrating SHASSIC into business	0	0	9	14	7	3.93	Agreed
Review SHASSIC promotion and implementation approach	0	1	6	17	6	3.93	Agreed
To monitor and gradually raise the quality of audits conducted	1	0	6	14	9	3.90	Agreed
Appoint more assessor for SHASSIC assessment	0	0	11	11	8	3.90	Agreed
Creating Industry Champion (Smart Partnership)	0	1	7	16	6	3.90	Agreed

CONCLUSION

The conclusions that can be drawn from this study are as follows:

1. The first objective was to study the knowledge of involved construction party towards SHASSIC by the questionnaire given. From the analysis, it shows that only 43.3 percent of the respondent knew or ever heard about SHASSIC which can be classified as moderate. From that number, there are only four companies that implement SHASSIC on their project.
2. The second objective was to identify the readiness of project stakeholders to implement SHASSIC if it is being made mandatory in 2020. These have been found through the respond from questionnaire given whereby they have been asked about the current safety and implementation in their project based on five sections. From there, it can be conclude that they have implement the elements in four out of five sections asked. They are top management commitment, record and audit, training, and also safety precautions at construction site. Meanwhile, they have moderately implemented the elements in record and audit section. Among those elements, the three top scores obtained are from 'Safety precautions at construction site' section which are prevention of falling objects, workers equipped with suitable PPE, and also fire protection. In conclusion, project stakeholders are ready to implement SHASSIC based on the elements they have already implemented on their project.
3. The final objective was to propose strategies in increasing the implementation of SHASSIC among project stakeholders in the construction industry in Malaysia. Through the questionnaire distributed, the respondent have agreed to all of the elements proposed as ways to increase the number of SHASSIC implementation whereby the highest mean comes from construction company section. Top three highest score obtained were, awareness of management and employees in term of safety and health assessment system, implementation of safety and health management system, and also continuous safety trainings are required during construction activities. In a nutshell, these results shows that the strategies proposed were agreed by the respondents to increase the number of project implementing SHASSIC.

REFERENCES

[1] Construction Industry Development Board (2015). *Safety and Health Management in Construction Industry*. Annual Report CIDB 2015, 99-101.

[2] Everett, J. G., & Jr, P. B. F. (1996). Costs of accidents and injuries to the construction industry. *Journal of Construction Engineering and Management, 122*(2), 158-164.

[3] Strategic Thrust 3 (2009). *Striving for the Highest Standard of Quality, Occupational Safety and Health and Environmental Practices*. Annual Report CIDB 2009, 90-101.

[4] Singh, A., Hinze, J. and Coble, R.J. eds. (1999). *Implementation of Safety and Health on Construction Sites*. Brookfield: A.A. Balkema.

[5] Hamid, A. R. A., Majid, M. Z. A., & Singh, B. (2008). An overview of construction accidents in Malaysia. *Issues in Construction Industry*, 110-123.

[6] David, L. G. (2003). *Construction Safety and Health*. New Jersey Columbus, Ohio: Prentice Hall.

[7] Construction Industry Development Board Malaysia (2015). *Construction Industry Transformation Programme 2016-2020*, Kuala Lumpur: CIDB.

[8] Construction Industry Development Board Malaysia (2008). *Manual on Occupational Safety and Health for the Construction Industry,* Kuala Lumpur: CIDB.
[9] R Affandi, (2009). The Effectiveness of Safety and Health Assessment System in Construction System in Construction (SHASSIC).
[10] M Ramuseren (2009). Safety and Health Assessment System in Construction. *The Ingenieur*, *Vol.43*, 18-20.
[11] Misnan, M. S., Mohamad, S. F., Yusof, Z. M., & Bakri, A. (2010). Improving Construction Industry Safety Standard through Audit: SHASSIC Assessment Tools for Safety.
[12] Yakubua, D. M., Bakria, I. M., Normalaa, H., & Cheb, M. ASSESSMENT OF SAFETY AND HEALTH MEASURES (SHASSIC METHOD) IN CONSTRUCTION SITES.
[13] Mangold, W. G., and Faulds, D. J. (2009). Social media: The new hybrid element of the promotion mix. *Business horizons*, *52*(4), 357-365.
[14] Holsti, O. R. (1969). Content analysis for the social sciences and humanities.

Adoption of Augmented Reality–Building Information Modeling (AR-BIM) in Malaysia

Lim Chong Shien, Aminah Md. Yusof, Chai Chang Sa'ar

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

cslim23@live.utm.my

Keywords: Building Information Modeling; Augmented Reality; AR-BIM; Acceptance Level; Factor Analysis.

ABSTRACT. Building Information Modeling (BIM) is one of the most popular technology contributed in information handling. However, the technology's contribution in fieldwork is very limited due to the limited interaction between real and virtual world. Integrating Augmented Reality (AR) with BIM is believed to highly increase BIM's applicability in fieldworks. The aim of this study is to determine the feasibility of adopting AR-BIM system in Malaysia AEC industry. Meanwhile, the industry's opinion on importance and barriers of BIM adoption, together with the perceived value of AR during construction were determined too. Responds collected from questionnaire were analyzed using factor analysis. Results show the local AEC industry seeing reduce greenhouse gaseous emission is the key value of BIM, financial issues is the greatest challenge in BIM adoption and poitioning as the most potential application of AR in Malaysia during construction. Although the industry do aware of the benefits of AR-BIMs, they only willing to use just one type of these AR-BIMs due to certain reasons. In conclude, this study had reveal the importance and challenges for BIM adoption in Malaysia, together with the perceived value of AR during construction and the acceptance level of the local AEC industry on different type of AR-BIMs. These findings could serve as a reference to the local authority when setting BIM and AR-BIM relevant rules.

INTRODUCTION

Advancement in computing technology since past few deacades allow the construction of complex structure to be happenened. However, as design gets complex, information had became too much to be handle. In order to handle these information, varieties of technology had been introduced while BIM is one of the outstanding one. However, as BIM do not interact the real world with virtual world, its application in fieldworks is limited [1]. Numbers of modification had been proposed to improve the applicability of BIM in fieldworks while integrating AR with BIM should be one of the solution [2].

Problem Statement

Construction Industry Development Board (CIDB) had targeted Stage 2 BIM implementation by 2020 in Construction Industry Transformation Programme (CITP) 2016-2020 [3]. However, as reported by CIDB in the same paper, only ten percent of the local AEC industry had adopted Level 1 BIM. Initiatives should be taken to promote the adoption rate so that the board's target could be achieved. Integrating AR with BIM is expected to boost the adoption rate of BIM significantly by increasing its applicability in fieldworks [2]. However, the acceptance level of local AEC industry on AR-BIM is unknown as there is no relevant research conducted.

Objectives

As this study aimed to determine the feasibility of adopting integrated Augmented Reality-Builiding Information Modeling (AR-BIM) System in Malaysia Architecture, Enfineering and Construction (AEC) industry, few objectives are formulated as followed:

1. To identify the importance and barriers in adopting BIM in Malaysian AEC Industry.
2. To identify the perceived value of AR during construction in Malaysian AEC Industry.
3. To determine the acceptance level of integrated AR-BIM System in Malaysian AEC Industry.

Scope of Study

Due to certain limitation, the study is scope as followed:

1. Minimum 30 copies of questionnaire will be distributed to professions in Malaysian AEC Industry.
2. The samples of this research only focus on professions of different managerial level in Malaysian AEC Industry.

LITERATURE REVIEW

Building Informaiton Modelling (BIM) is the modeling technology which is capable to generate, communicate and also analyze a building model [4]. The technology is important as such it not just allow the cross-disciplinary exchange of information to be happened, but also allows the users to facilitate the interoperability of the whole project, detecting the conflict within [5]. Surveys and studies had been conducted to determine on the importances and challenges of adopting

BIM [6][7][8][9][10][11][12][13][14][15][16]. The importance and challenges of BIM adoption mentioned in these surveys and studies were tabulated and shown in Table 1.

Table 1: Benefits and Challenges of BIM Adoption as Mentioned in Previous Surveys and Studies

Benefits of BIM	Description	References
(i) Provide better understanding on design intent	3D visualization allowed design to be understand more easily and hence produce more integrated design and construction.	[7][9][10]
(ii) Promise better communication	Accurate 3D visualization reduce time of communication and prevent miscommunication to be happened.	[9][11][12]
(iii) Promise better project quality	3D model reduce number of conflicts and reworking, better option for structural analysis and possible for more complex design.	[7][9][10] [11][12]
(iv) Reduce conflicts during construction	3D integrated model allowed inter-professional and cross-professional clashes to be identified easily.	[7][10][12] [15]
(v) Reduce number of Variation Order (VO)	Issue of VO should be reduced if conflicts were detected earlier and miscommunications were prevented.	[6][11]
(vi) Reduce construction period	Construction period are shorten as communication are improved and unnecessary reworking were prevented.	[7][8][10] [12]
(vii) Promise better cost estimation	Real time cost estimating function provide instant feedbacks on all the changes made.	[8][12][14]
(viii) Reduce greenhouse gaseous emission	Greehouse gaseous released are reduced as a result of more efficient and shorter construction period.	[8]
Challenges of BIM Adoption	**Description**	**References**
(i) Insufficient training resources	Limited BIM experts available in market, insufficient budget to allocate for training.	[6][11][13]
(ii) Insufficient training time	Time as a factor when required to train all the professional staffs on BIM.	[12][13]
(iii) High software cost	Financial support required to purchase and maintain BIM software.	[6][12][13]
(iv) Extra cost to upgrade hardware	Additional financial support to upgrade hardware to fulfill the need for BIM software.	[6][12][13]
(v) Staff buy-in	Staff (especially senior staff) refuse to adopt new technology.	[6][12]
(vi) Lack of external incentives	None of the client request for the use of BIM.	[6]
(vii) Risk of losing intellectual properties	Professionals worried of their design might be unsurped by other project members.	[6][16]

Augmented Reality (AR) is the computing technology which overlaying an additional computer generated virtual world on top of the physical world to form a mixed world [17][18]. Current AR technology is a two-steps operation, where the users first register markers into the system with information attached, the systems will then tracks the preset markers and displays the preregistered contents when the users mounting the devices on top of these preset markers [18]. Previous researchers had mentioned few potential application of AR during construction and these mentioned potential applications were tabulated and shown in Table 2 [1][19][20][21][22][23][24].

Table 2: Potential Application of AR during Construction as Mentioned in Previous Studies

Potential Application	Description	References
(i) Setting Out	Reference points could be showed using AR at a time by referencing to just one point.	[19][20]
(ii) Excavation	Desired depth of the excavation is showed using AR, replaced the original stakes method.	[19][21]
(iii) Positioning	Precise location of the construction elements are showed using AR.	[19][22]
(iv) Inspection	Difference between as-built condition and as-planned model are provided during inspection.	[19][23]
(v) Communication	Visualization provided to prevent miscommunication, especially during commenting, coordination and strategizing.	[1][24]

One of the concern of BIM is about its low applicability in fieldworks. As BIM involve zero interaction between real and virtual world, the technology just served as a visualizing tool at construction site [1]. Still the users required to zoom into a particular component manually before comparing the model and the actual situation. Such concept of using BIM had increase the information extracting time and making BIM to be less useful. Combining AR with BIM could be a good option to increase the applicability of BIM in fieldworks. Several ideas of AR-BIM had been proposed, these AR-BIM are (a) Table-top AR-BIM, (b) Portable AR-BIM and (c) Remote Monitoring AR-BIM. Table-top BIM had been achieved by SmartReality in 2013 [25] [26]. Table-top AR-BIM display the BIM model with correct scale and

orientation when the user mount the devices on top of flat engineering drawings, example of Table-top AR-BIM is shown in Figure 1. Portable AR-BIM will display the specified corner of BIM model when the user looking at that corner of the structure. Daqri Smart Helmet had conducted a demo of Portable AR-BIM associated with Autodesk and Mortenson [27]. Example view of Portable AR-BIM is shown in Figure 1. Remote Monitoring AR-BIM are those type of AR-BIM which combine the BIM model with the video recorded using drone and display the combine structure in the user computer. This type of AR-BIM allow the user to compare the as-planned and as-built condition while sitting in the office. Bentley had done a demo on this type of AR-BIM but only achieved it partially with some delay in the as-built situation [28][29]. Result of the demo is shown in Figure 1.

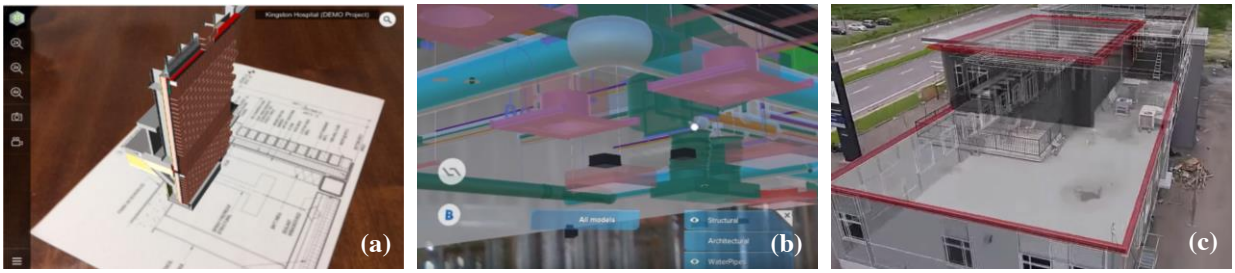


Figure 1: (a) Table-top AR-BIM (b) Portable AR-BIM (c) Remote Monitoring AR-BIM.

In conclude, BIM is one of the technology which potentially improve the entire AEC industry's performance. Research overseas show that most of the users had enjoyed plenty of benefits and experienced positive Return of Investment (ROI) by adopting BIM into their business. However, there are also some challenges to be overcame before the AEC Industry could enjoyed all these benefits. Other than BIM, AR is another fast-growing technology which also potentially improve the industry performance. Researchers had proposed several concept of integrating AR and BIM. Nevertheless, the acceptance level of the local AEC industry on these interface of AR-BIM is remained unknown.

METHODOLOGY

Questionnaire had been distributed to respondents of different professions and managerial level. Results of the questionnaire were analyzed using few statistical analysis. These statistical analysis are KMO Test, Bartlett's Test of Sphericity, Reliability Test and Primary Component Analysis.

KMO Test, Bartlett's Test of Sphericity and Reliability Test

Kaiser-Meyer-Olkin (KMO) is type of quantitative data analyzing tool which measure the adequacy of the sampling from 0 to 1, where 1 indicate the sampling are having a compacted correlations' patterns and 0 is the vice versa. Samples with factor 0.5 and above are considered to be acceptable, average for 0.5 to 0.7, great for 0.8 to 0.9 and superb if more than 0.9 [30]. Data collected in this study is considered average with KMO score between 0.5 and 0.7. Bartlett's Test of Sphericity is another analyzing test to validate the sample adequacy. Bartlett's Test was conducted to determine the adequacy of the data to be analyze using factor analysis by measuring the significance of the data. Data with significant value less than 0.05 is considered significant and adequate to be analyzed using factor analysis. Data collected in this study is considered adequate with significant value of 0.000. The consistency and reliability of the data set were analyzed using Reliability Test measuring the ratio of true score variance to observed score variance was measured in this test. In this study, Cronbach Alpha (α) was used to represent the consistency and reliability of the data. Cronbach Generally, data set with higher Cronbach Alpha is considered to be much reliable and Cronbach Alpha of 0.7 and above is considered acceptable [31]. Result of the three tests were tabulated in Table 3.

Table 3: Results of (a) KMO Test (b) Bartlett's Test (c) Reliability Test by Section

Section	A Importance and Challenges when Adopting BIM	B Potential Application of AR during Construction	C Acceptance Level on Different AR-BIM Interface
(a) KMO Adequacy Measure	.627	.545	.542
(b) Sig. in Bartlett's Test	.000	.000	.000
(c) Cronbach's Alpha	.801	.738	.943

Primary Component Analysis

Primary Component Analysis is a type of factor analysis compact large numbers of variables into a lesser number of factors with minimum losses in the information. The concept of factor analysis is about examining the potential relationship between the variables of the data set and summarizing them under a common factors [32]. In this study, the

data set were rotated using Varimax method and only factor with loading 0.700 and above considered as important factor.

RESULTS AND DISCUSSION

Few key results of respondent's background were summarized and tabulated in Table 4. All of the architect and quantity surveyor had heard of BIM. However, there are still certain percentage of engineers, contractors and developers never heard of BIM before. Mechanical and Electrical engineer is the profession who most seldom heard of BIM as there is only 40% of them had heard of BIM before. Meanwhile, only some civil and structural engineers, developers and quantity surveyor had experience using AR related software before. There are certain percentage of respondents from each professions had never heard of AR before. Contractor is the profession who most seldom heard of AR as 53.8% of them never heard of AR before.

Table 4: Cross Tabulation on Respondent's Background

	Have you aware of Building Information Modeling (BIM) before?			**Have you aware of Augmented Reality (AR) before?**		
	Yes and using.	Yes, but never used.	No, never heard of it.	Yes and using.	Yes, but never used.	No, never heard of it.
Architecture	50.0%	50.0%	0.0%	0.0%	62.5%	37.5%
C & S Engineer	38.9%	50.0%	11.1%	22.2%	55.6%	22.2%
Contractor	23.1%	53.8%	23.1%	.0%	46.2%	53.8%
Developer	11.1%	77.8%	11.1%	11.1%	77.8%	11.1%
M & E Engineer	20.0%	20.0%	60.0%	.0%	60.0%	40.0%
Quantity Surveyor	30.0%	70.0%	0.0%	30.0%	40.0%	30.0%

Results of Primary Components Analysis on importance and challenges of BIM adoption were tabulated in Table 5(a) and Table 5(b). As shown in Table 5(a), local AEC industry disagree on BIM's contribution in reducing the number of conflicts during construction and providing better cost estimation. Meanwhile, local AEC industry believed the most significant contribution of BIM should be its ability to reduce greenhouse gaseous emission. As Construction Industry Development Board (CIDB) had introduced and manadated the use of Malaysian Carbon Reduction and Environmental Sustainability Tools (MyCREST) in 2016 [33][34], the local industry should now having high awareness on greenhouse gaseous issues. Under such circumtances, they might had choosen reduce greenhouse gaseous emission as the most important contribution of BIM adoption. While looking at the challenges for BIM adoption, the local AEC industry seems to disagree that lack of external incentives and training issues had hurdled them for the adoption. Their main concern is on financial issues. While Small and Medium Enterprise (SME) might have limited turnover for software and hardware improvement, those from well-established company might also feels challenging to request additional budget from financial department, who had limited knowledge and awareness on BIM.

Table 5: Result of Primary Component Analysis on (a) Importance of BIM Adoption (b) Challenges of BIM Adoption (c) Potential Application of AR during Construction

(a) Importance of BIM adoption	**Factor Loading**
Allow better understanding on the design intent.	.799
Promise better communication.	.755
Reduce number of Variation Order (VO).	.735
Promise better project quality.	.718
Reduce number of conflicts during construction.	
Promise better cost estimation.	
Reduce project duration.	.757
Reduce greenhouse gaseous release.	.901

(b) Challenges of BIM adoption	**Factor Loading**
Lack of external incentives.	
Staff buy-in.	.859
High software cost.	.864
Additional cost for hardware upgrade.	.882
Insufficient training time.	
Insufficient training resources.	
Risk of losing intellectual properties.	.861

(c) Potential Application of AR during Construction	**Factor Loading**
Setting Out, show all desired references points virtually.	.831
Excavation, show the desired excavating depth virtually.	
Positioning, show all the precise location virtually.	.952

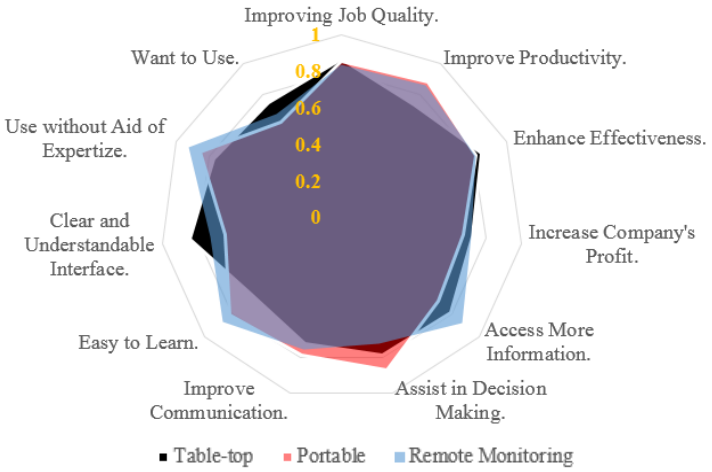
Inspection, show the difference between as-planned and as-built condition.	
Communication, as it synchronize mental models.	.906

Results of Primary Component Analysis on potential application of AR during construction were tabulated in Table 5(c). Significantly, the local AEC industry is very confident in using AR for positioning purpose, but doubt on the applicability of AR for excavation and inspection. Current practice using bare eyes to identify the location for positioning. However, such practice might cause deviation between as-built and as-planned situation, especially when precise positioning is required. Utilizing AR for precise positioning could significantly increase the accuracy and efficiency [18]. Besides, the industry seems to have sufficient trust in the application of AR for on-site communication and setting out, as both of these factors are having factor loading higher than 0.700.

Results of Primary Component Analysis on Malaysian AEC industry acceptance level on different type of AR-BIM were summarized and tabulated in Table 6. Meanwhile, the comparison between the results were shown in Figure 2.
As shown in Table 6, respondents seems to have less confident when mentioned about the learning easeness of Table-top AR-BIM and the Portable AR-BIM's ability of increasing company's profit. Besides, the respondents also think the interface of Portable AR-BIM is not clear and understandable. Supprisingly, although the respondents do have confident on the usefulness of these AR-BIMs, they just willing to use Table-top AR-BIM for some reason. However, as the reasons of decline were not included in the questionnaire, their reason of refusing to use Portable AR-BIM and Remote Monitoring AR-BIM were remained unknown and should be further investigated. While looking at Figure 2, respondents seems to have more trust in Table-top AR-BIM when mentioned about improving job quality, enhance effectiveness, increase company's profit and having clear and understandable interface. Meanwhile, the respondents seems to believe Portable AR-BIM should be outstanding in improving productivity, assisting in decision making and improving communication. While Remote Monitoring AR-BIM seems to have highest score when mentioned about ability to access more information and the ease of learning and using.

Table 6: Results of Primary Component Analysis on Malaysian AEC Industry Acceptance Level on (a) Table-top AR-BIM (b) Portable AR-BIM (c) Remote Monitoring AR-BIM

Elements Defining Acceptance Level	(a) Table-top	(b) Portable	(c) Remote Monitoring
This can improve my job quality.	.865	.853	.838
This can improve my productivity.	.733	.878	.855
This can enhance my effectiveness.	.844	.812	.808
This can increase my company's profit.	.725		.723
This help me to access more information.	.792	.701	.880
This help me in decision making.	.785	.872	.716
This can improve communication among the project team.	.719	.787	.751
This is easy to learn.		.818	.869
This is having a clear and understandable interface.	.847		.732
This can be used without the aid from expert.	.774	.859	.927
I want to use this type of AR-BIM.	.744		



*Factor with factor loading less than 0.700 is included for comparison. However, still these factors are considered as unimportant factors.

Figure 2: Comparison between the Results of Primary Component Analysis on Malaysian AEC Industry Acceptance Level on Different Type of AR-BIM

CONCLUSION

This paper had identified the importance and barriers of BIM adoption in Malaysia AEC Industry. Local AEC industry seeing reduce greenhouse gaseous emission as the most important benefit of BIM adoption and financial issues as the greatest challenges for the adoption. When identifying the perceived value of AR during construction, local AEC industry are having highest confident on the applicability of AR during positioning. Meanwhile, Malaysia AEC industry do agree on most of the usefulness and ease of use of all three type of AR-BIMs. However, they just willing to use Table-top AR-BIM due to certain reasons. Based on these findings, all three types of AR-BIM is said to be feasible to be adopt in Malaysia, only the hurdles affecting the industry willingness of using Portable AR-BIM and Remote Monitoring AR-BIM should be identified prior to the adoption. Future works could focus on the risks and limitations of AR-BIM, barriers of AR-BIM adoption and potential application of different type of AR-BIM.

Significant of Study

This study had alerted the members of Malaysia AEC industry on BIM, AR and AR-BIM. Although CIDB had mandate for BIM adoption for public project worth RM 100 million and above [35] and targeted for Level 2 BIM implementation in 2020 [3], still there are quite a numbers of industry players had never learnt of BIM. Through this study, the industry members should now have a better understanding of the beneifts and barriers of BIM adoption and these findings could serve as a guideline to them before adopting BIM. Meanwhile, as Malaysia had liberalize architectural, engineering and quantity surveying servies in 2012 [36], the AEC industry is expected to be impacted as the result of liberization. Adoption of new technology such as AR and BIM is one of the key to secure local industry's competitiveness in the market. With sufficient understanding on AR and BIM, the industry memebers should have a direction for their future development to secure or even improve their competitiveness in local and global markets. Besides, the acceptance level on AR-BIMs revealed in this study should serve as a guideline for the local authority when establishing any AR-BIM related policies in the future.

REFERENCES

[1] Wang, X., Truijens, M., Hou, L., Wang, Y., Zhou, Y. (2014). Integrating Augmented Reality with Building Information Modeling: Onsite construction process controlling for liquefied natural gas industry. *Automation in Construction*, 40 (2014), 96-105. Elsevier.

[2] JBKnowledge. (2014). *Five Ways the Construction Industry will Benefit from Augmented Reality*. Retrieved from official website of JBKnowledge: http://jbknowledge.com/five-ways-construction-industry-will-benefit-augmented-reality.

[3] CIDB Malaysia. (2015). *Construction Industry Transformation Programme 2016-2020*. Kuala Lumpur, Kuala Lumpur: Construction Industry Development Board (CIDB) Malaysia.

[4] Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2008). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. (1st ed.). Hoboken, N.J.: John Wiley & Sons Inc.

[5] Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. (2nd ed.). Hoboken, N.J.: John Wiley & Sons Inc.

[6] McGraw-Hill Construction. (2008). *Building Information Modeling (BIM): Transforming Design and Construction to Achieve Greater Industry Productivity*. New York: McGraw-Hill Construction.

[7] McGraw-Hill Construction. (2011). *The Business Value of BIM in Europe*. New York: McGraw-Hill Construction.

[8] NBS. (2016). *National BIM Report 2016*. Newcastle upon Tyne, NE11RH: RIBA Enterprises Ltd.

[9] Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering*. 11(3), 241-252. American Society of Civil Engineers (ASCE).

[10] Australian Institute of Architects, Consult Australia, Autodesk. (2010). BIM in Australia. *Report on BIM/IPD Forums Held in October/November 2010*. October-November. Perth, Melbourne, Brisbane and Sydney: Australian Institute of Architects, 1-14.

[11] Co-operative Research Centre (CRC) for Construction Innovation. (2007). *Final Report: Business Driver for BIM*. Brisbane: 2007 Icon.Net Pty Ltd.

[12] Migilinskas, D., Popov, V., Juocevicious, V., Ustinovichius, L. (2013). The Benefits, Obstacles and Problems of Practical Bim Implementation. *Procedia Engineering*, 57(2013), 767 – 774. Elsevier.

[13] InfoComm International. (n.d.). *Building Information Modeling*. [Brochure]. FairFax, VA: InfoComm International.
[14] Cheng, J.C.P. and Ma, L.Y.H. (2013). A BIM-based System for Demolition and Renovation Waste Estimation and Planning. *Waste Management*, 33(2013), 1539-1551. Elsevier.
[15] Kassem, M., Dawood, N., Chavada, R. (2015). Construction Workspace Management within an Industry Foundation Class-Compliant 4D Tool. *Automation in Construction,* 52(2015), 42-58. Elsevier.
[16] Solihin, W. and Eastman, C. (2015). Classification of rules for automated BIM rule checking development. *Automation in Construction,* 53(2015), 69-82. Elsevier.
[17] Jiao, Y., Zhang, S., Li, Y., Wang, Y. Yang, B. (2013). Towards Cloud Augmented Reality for Construction Application by BIM and SNS Integration. *Automation in Construction*, 33(2013), 37-47. Elsevier.
[18] Chi, H., Kang, S., Wang, X. (2013). Research Trends and Opportunities of Augmented Reality Applications in Architecture, Engineering, and Construction. *Automation in Construction*, 33(2013), 116-122. Elsevier.
[19] Shin, D.H., Dunston, P.S. (2008). Identification of Application Areas for Augmented Reality in Industrial Construction Based on Technology Suitability. *Automation in Construction*, 17(2008), 882-894. Elsevier
[20] Siu, M.F. and Lu, M. (2010). Bored Pile Construction Visualization by Enhanced Production-Line Chart and Augmented-Reality Photos. *Proceedings of the 10th International Conference on Construction Applications of Virtual Reality*. 4-5 November. Sendai, Japan: CONVR, 165-174.
[21] Bentley. (2012). *Augmented reality for subsurface utilities: further improving perception*. Retrieved from https://communities.bentley.com/other/old_site_member_blogs/bentley_employees/b/stephanecotes_blog/archive/2012/06/18/augmented-reality-for-subsurface-utilities-further-improving-perception.
[22] Roberts, G.W., Evans, A., Dodson, A.H., Densby, B., Cooper, S., Hollands, R. (2002). The Use of Augmented Reality, GPS and INS for Subsurface Data Visualisation. *XXII FIG International Congress*. 19-26 April. Washington, D.C.: International Federation of Surveyors.
[23] Hammad, A., Garrett Jr., J.H., Karimi, H.A. (2002). Potential of Mobile Augmented Reality for Infrastructure Field Tasks. *Applications of Advanced Technologies in Transportation*. 5-7 August. Boston, Massachusetts: American Society of Civil Engineers (ASCE), 425-432.
[24] Lee, S., Shin, D.H., Woo, S. (2010). Functional Requirement of an AR System for Supervision, Commenting and Strategizing in Construction. *Proceedings of the 10th International Conference on Construction Applications of Virtual Reality*. 4-5 November. Sendai, Japan: CONVR, 159-164.
[25] Prweb. (2013, August 22). New Augmented Reality App for Construction Introduced at AGC IT Forum. *Prweb*, retrieved April 24, 2017, from http://www.prweb.com/releases/2013/8/prweb11046756.htm.
[26] JBKnowledge. (2014). *The 2014 Construction Technology Report Reveals New Trends and Concerns in Construction Technology*. Retrieved from http://jbknowledge.com/2014-construction-technology-report-reveals-new-trends-concerns-construction-technology.
[27] Daqri. (2016). *Building the Worksite of the Future*. Retrieved from https://medium.com/@DAQRI_Media/building-the-worksite-of-the-future-8326b0233006.
[28] Bentley. (2016). *Augmenting Drone Videos could Facilitate Construction Monitoring*. Retrieved from https://communities.bentley.com/other/old_site_member_blogs/bentley_employees/b/stephanecotes_blog/archive/2016/02/22/augmenting-drone-videos-could-facilitate-construction-monitoring.
[29] Vrfocus. (2016, September 17). Building Site Monitoring Company Bentley Systems Uses AR Drones to Help Development. *Vrfocus*, retrived April 23, 2017 from https://www.vrfocus.com/2016/09/building-site-monitoring-company-bentley-systems-uses-ar-drones-to-help-development/.
[30] Field, A. (2005). Factor analysis using SPSS. Retrieved from http://www.sussex.ac.uk/Users/a-ndyf/factor.pdf.
[31] Nunnally, J.C. (1978). *Psychometric theory* (2nd ed.). New York: McGraw-Hill.
[32] Hair, J.F. (1992). *Multivariate data analysis* (3rd ed.). New York: Macmillan.
[33] The Star Online. (2016, February 20). Board calls for stronger infrastructure to cope with impact of natural disasters. *The Star Online*, retrieved April 30, 2017 from http://www.thestar.com.my/metro/smebiz/news/2-016/02/20/towards-a-more-resilient-standing-board-calls-for-stronger-infrastructure-to-cope-with-impact-of-nat/#Lr1dgguwOdmVpRo5.99
[34] Borneo Post Online. (2016, May 13). MyCREST rating system mandatory for public projects worth RM50 mln and above. *Borneo Post Online*, retrieved April 30, 2017 from http://www.theborneopost.com/2016/05-/13/mycrest-rating-system-mandatory-for-public-projects-worth-rm50-mln-and-above/
[35] The Star Online. (2016, November 17). Developers to be required to use BIM on govt projects of RM100mil and up. *The Star Online*, retrieved April 24, 2017 from http://www.thestar.com.my/business/business-news/2016/11/17/developers-to-be-required-to-use-bim-on-govt-projects-of-rm100mil-and-up/#ohleqjQAKVtIeaRV.99
[36] Malaysia Investment Development Authority. (2017). *Liberalisation of the Services Sector*. Retrieved from http://www.mida.gov.my/home/liberalisation-of-the-services-sector/posts/

Contract Management In Construction Project

Nur Naimah Suhaime, Aziruddin Ressang

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

aziruddin@utm.my

Keywords*:* Contract; Contract Management; Average Index and Risk Making

ABSTRACT: This research is to study problems in contract management. Factors affecting contract management were compiled from journals and interview those involved with managing construction contract such project manager and quantity surveyor. Questionnaires were distributed to project managers, site engineer and quantity surveyors. The data collected were analysed using Average Index and Risk Matrix. The results showed that construction material changing prices due to price fluctuated (Risk = 14.1, categorised as High Risk), declining in the country economic situation (Risk = 14.1, categorised as High Risk), low profit due to competition between contractors (Risk = 14.1, categorised as High Risk), and delaying payments by the owner are the common problems that occurred in contract management (Risk = 14.1, categorised as High Risk).

INTRODUCTION

In the construction project, there are many activities involved. Every activity during the construction works should refer to the contract of the project that already agreed by all the parties involved which are client, consultant and contractor. Contract Management is important aspect in construction project to make sure the construction works are going smoothly according to the specifications stated in the contract.

Problem Statement

For every construction project, the problems in contract management cannot be avoided and classified as the critical aspect in the project management. So that, the types of the contractual problems need to identify by all the parties involved. The effects that can occur due to the contractual problems are cost overrun, delay in project duration, and lack of quality. In the other hand, each contracting parties need to understand the content and concept on the risks in contract clauses. The owner and contractor often have disagreements over contract management responsibility due to the different understandings of contract clauses [9]. So that, it may cause mismanage a problem whereby the contracting parties assuming that the problem are not under their responsibility.

The mismanaged contractual problems may possibly make contract relationship adversarial and cause the inefficient project. As the result, it will directly causes the critical problems such as increasing on the project cost, delays in project duration and decrease the product quality.

Aim and Objective

The aim of this study is to identify the problems in contract management in construction project. The objectives of this study are:

1. To study the contractual problem in construction project
2. To study the method used in contract management of the project
3. To propose method to improve contract management in construction project

Scope of Study

This study is focusing more on the types of contractual problems and the methods to improve contract management in construction project. The target respondents where the questionnaires will be distributed are client, contractor and consultant. The study will be implemented in Johor Bahru only. Other area is not involved in this study scope.

LITERATURE REVIEW

Contract

Contract can be define as a voluntary agreement between two or more parties that a court will enforce. The rights and obligations created by a contract apply only to the parties to the contract (i.e., those who agreed to them) and not to anyone else [2].

Contract Management

Contract management is the process that enables both parties to a contract to meet their obligations in order to deliver the objectives required from the contract. It also involves building a good working relationship between customer and provider. It continues throughout the life of a contract and involves managing proactively to anticipate future needs as well as reacting to situations that arise [6].

The central aim of contract management is to obtain the services as agreed in the contract and achieve value for money. This means optimising the efficiency, effectiveness and economy of the service or relationship described by the contract, balancing costs against risks and actively managing the customer–provider relationship. Contract management may also involve aiming for continuous improvement in performance over the life of the contract.

Table 1: Types of Contractual Problems

Types Of Contractual Problems	Cause	Effects Of Contractual Problems
Project with low profit	Competition between contractors	Financial problem to complete the project
Policy adoption of awarding the bid to the lowest prices compare to the accurate price	Minimum budget from the client	Low quality output due to the low quality material used
Delaying payments by the owner	Financial arrangement for the project	Delay in completion
The changing value of currency exchange	Global issues	Cost overrun
Slow decision by the owner	Not properly time decision	Delay in work progress
The size of project is small in relation to the number of contractors	Too many of contractors in one project	Problems in payments
Price changes of construction material	Price fluctuated in the market	Exchange in material price (Variation Order)
Declining in the country economic situation	Global issues	Effect the completion time
Differences of construction items and its price	Some contractors provide the price item that belonging to other item.	Material cost overrun
Conflicts between tender documents	Unclear understanding between involved parties	Miscommunication between all involved parties
Poor quality of construction works	Low productivity level of work	Low quality product
Ineffective planning and scheduling of the project	Inexperienced management and supervision	Construction work did not follow the sequence

METHODOLOGY

In this study, the following methodology has been implemented in order to achieve the objective of the study which consists of five stages.

1. In the first stage, problem statements were identified by looking at latest global demand and trend. Based on the problem statement, formation of objective, title selection and scope of the study then were determined.
2. The second stage is the conduction of detail data and information collection. Consist of two data. Primary data is where questionnaire using Likert scale method on five (5) ordinal options was design. To achieve the objective of this study, the questionnaire is divided into four (4) sections. Sections A- Respondent's Detail, Sections B –Types of Contractual Problems, Sections C – Method Used in Contract Management, Section D – Suggestion Method to Improve Contract Management. Questionnaire had been distributed among construction companies in Johor Bahru as discuss in scope of study. Secondary data collection based on readings from articles, journals, research paper, published books and websites.
3. In the third stage, data analysis of primary data collected from the respondent answered questionnaires using Microsoft Excel software. The percentage frequency distribution, average index formula and scale rating in Table 2, risk formula from HIRARC in Table 3 are used.

   The percentage frequency distribution formula:

$$\text{Percentage Frequency (\%)} = \frac{Number\ of\ respondent}{Total\ number\ of\ respondent} \times 100$$

The average index formula (Abd Majid and Mc Caffer, 1997):

$$\text{Average Index} = \frac{\sum ai.xi}{\sum N}$$

Where:
ai = constant expressing the weight given to each response (1 to 5)
xi = the frequency of response
N = number of respondents

Table 2: Classification of Rating Scale

Rating	Average Index	Response in Section C
1	1.00 ≤ Average Index ≤ 1.50	Not affected at all
2	1.50 ≤ Average Index ≤ 2.50	Slightly affected
3	2.50 ≤ Average Index ≤ 3.50	Moderately affected
4	3.50 ≤ Average Index ≤ 4.50	Affected
5	4.50 ≤ Average Index ≤ 5.00	Extremely affected

The risk formula (DOSH, 2008):

Risk = Likelihood x Severity

Table 3: Risk Matrix Table

	Severity (S)				
Likelihood (L)	**1**	**2**	**3**	**4**	**5**
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

RISK	DESCRIPTION
15 – 25	HIGH
5 – 12	MEDIUM
1 – 4	LOW

4. In the fourth stage, data analyses were interpreted and discussed according to sequence of objectives with suitable figure and table.
5. In the fifth stage, conclusion and recommendation of the study will be discussed.

RESULT AND DISCUSSION

This study was to investigate the Contract Management in Construction Project. Questionnaires sets were distributed to 30 respondents but only 20 responded completely. The results from the questionnaire obtained are discussed below based on the objectives of the study which the result is divided into three parts.

Finding 1: Contractual Problems in Construction Project

Objective one is to study the types of contractual problems in construction project. The result for this objective is obtained by analysing the contractual problems based on severity and frequency of construction project that exposed to the risk factor. By using the risk formula and risk matrix table, the primary contractual problems have been identified.

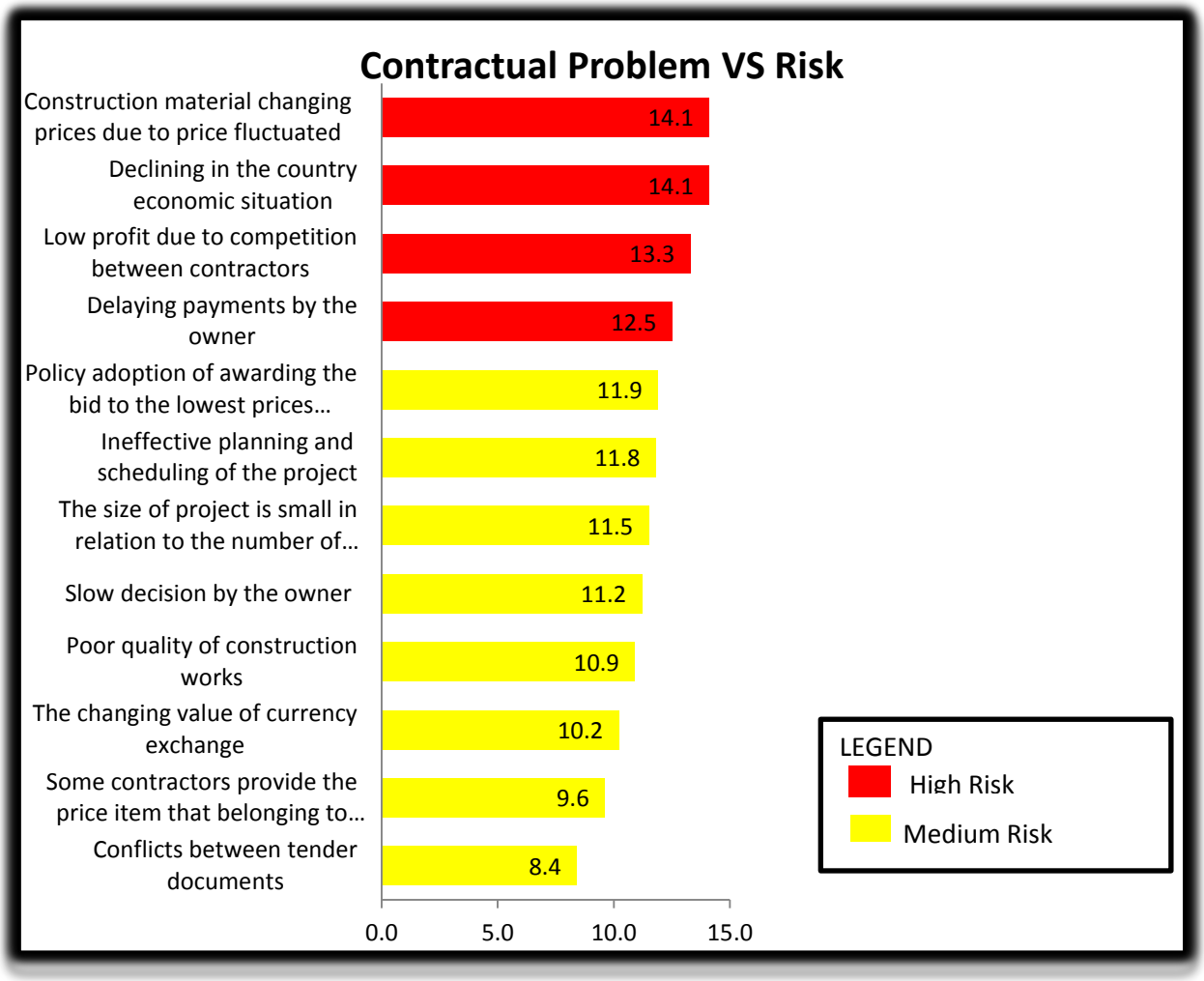


Figure 1: Contractual Problem VS Risk

Finding 2: Method Used In Contract Management of the Project

The second analysis was conducted to study method used in contract management of the project. These factors were analyses using average index and classification on each method is tabulated in Table 4. In this study, the method of contract management belongs to only two classes that is *moderately affected* and *affected*.

Table 4: Methods used in Contract Management and its Classification

Method of Contract Management	Average Index	Classification
Price estimation before tendering	4.4	AFFECTED
Ensure budget is available before tendering	4.4	AFFECTED
Awarding tender to the combination of best technically and lowest prices	4.3	AFFECTED
Standardize Bill of Quantities (BQ) Rate for each project	4.3	AFFECTED
Price monitoring and documenting department	4.3	AFFECTED
Specifying time period for owner to respond	4.2	AFFECTED
Price offer already include the technical aspect	4.1	AFFECTED
Following price indicates in pricing	4.0	AFFECTED
Tender must conformed to the requirement	4.0	AFFECTED
Rejecting offers less than the certain percentage of the estimated	3.9	AFFECTED
Price moderation of the lowest price	3.4	MODERATELY AFFECTED
Price moderation of the lowest price	2.9	MODERATELY AFFECTED

Finding 3: Method to Improve the Contract Management in Construction Project
Based on the questionnaires, the suggestion method to improve contract management that are chosen by the respondents are as stated in Table 5 below:

Table 5: Suggestion Method to Improve Contract Management

No	Suggestion Method To Improve Contract Management
1	Checking of price estimating for the project
2	Provide the amount of required budget before tendering
3	Discussion with all parties involved about the tender and responding to requirements
4	Prioritise to the offers with combination of best technically
5	Provide the department of price monitoring and documenting
6	Always refer to the following price indicates in pricing
7	Prepare the scheduling and recording of specifying time period for owner reply
8	Standardise the convert rate for each project
9	Avoid offers less than the certain percentage of the estimated price
10	Prioritise to the offers with lowest price

CONCLUSION

Objective 1: To Study the Contractual Problem in Construction Project
The first objective of this study has been achieved through literature review from journals, books and websites. As the result, several types of contractual problems in construction project were identified and the most related were taken in this study. From the result obtained, the problems in contract management that have the high risk are:

1. Construction material changing prices due to price fluctuated
2. Declining in the country economic situation
3. Low profit due to competition between contractors
4. Delaying payments by the owner

Objective 2: To Study the Method Used in Contract Management of the Project
The second objective of the study has been achieved through literature review and questionnaire survey by analyses the method used in contract management of the project. From the literature review, a list of methods has been attained and from the survey, the list of methods is analyses using average index. The impacts are categories in two classes that are MODERATELY AFFECTED and AFFECTED. This result clearly shown the methods that usually used in contract management are:

1. Price estimation before tendering
2. Ensure budget is available before tendering
3. Awarding tender to the combination of best technically and lowest prices
4. Standardize Bill of Quantities (BQ) Rate for each project
5. Price monitoring and documenting department
6. Specifying time period for owner to respond
7. Price offer already include the technical aspect
8. Following price indicates in pricing
9. Tender must conformed to the requirement
10. Rejecting offers less than the certain percentage of the estimated

Objective 3: To Propose Method to Improve Contract Management in Construction Project
The third objective of this study has been achieved through the questionnaire survey from the scale given from respondents based on the given suggestions. . From the questionnaire form, it can be concluding that the methods to improve contract management in construction project are:

1. Price estimating for the project should be checked
2. The amount of required budget should be provided before tendering
3. All parties involved need to do discussion about the tender and responding to requirements
4. To the offers with combination of best technically should be prioritised
5. The department of price monitoring and documenting need to be provided
6. The following price indicates in pricing should always be referred
7. The scheduling and recording of specifying time period for owner reply must be provided

8. The convert rate for each project should be standardised
9. Offers less than the certain percentage of the estimated price need to be avoided

REFERENCES

[1] Bhzad Sidaw (2012). *Management Problems of Remote Construction Projects and Potential It Solutions: The Case of Kingdom Of Saudi Arabia*. Journal of Information Technology in Construction - ISSN 1874-4753

[2] Bill Davison (2009). *An Analysis of the Consequences of Contract Administration Problems for Contract Types*. Journal of Management Research, ISSN 1941-899X

[3] DOSH (2008). *Guidelines for Hazard Identification, Risk Assessment, and Risk Control*. Department of Occupational Safety and Health. JKKP DP 127/789/4-47

[4] D.G. Proverbs, G. D. Holt and H. Y. Cheok. *Construction Industry Problems: The Views Of Uk Construction Directors*. Built Environment Research Unit, School of Engineering and the Built Environment, University of Wolverhampton, West Midlands, UK, WV1 1SB, UK

[5] Frank D.K. Fugar and Adwoa B. Agyakwah-Baah. *Delays in Building Construction Projects in Ghana*.Department of Building Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Australasian Journal of Construction Economics and Building, 10 (1/2) 103-116

[6] Gurjeet S Tuteja. *Contract Management – Implementation Challenges and Strategy*

[7] M. Haseeb, Xinhai-Lu, Aneesa Bibi, Maloof-ud-Dyian, Wahab Rabbani (2011). *Problems of projects and effects of delays in the construction Industry in Pakistan*. Australian Journal of Business and Management Research, Vol.1 No.5 [41-50]

[8] Nerija Banaitiene* and Audrius Banaitis. Risk Management in Construction Projects, Chapter 19 *Department of Construction Economics and Property Management, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Vilnius, Lithuania*

[9] Subhash Chandra Pandey. The Challenges of Contract/ Project Implementation, Vol 4. No 1. January 2010

Impulsivity of Noise due to Single Lightweight Vehicles Transit on Rumble Strips

Muhammad Habab Abd Halil, Zaiton Haron, Khairulzan Yahya

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

zaitonharon@utm.com

Keywords: Rumble strips; impulsive noise; noise annoyance; traffic noise; transvers rumble strips.

ABSTRACT. Rumble Strips (RS) or Transverse Rumble Strips (TRS) acts as a safety precaution or measures that alert inattentive drivers from potential dangers such as crashing to the side of the road or head on collision with vehicle at the opposite lane. However, there are some report suggested that the noise produced from TRS are being annoyance to surrounding residence. This study investigates the characteristics impulsivity of noise produced from single lightweight vehicle passing on the TRS. Impulsivity can be measured from noise indices such as L_{Aeq}, L_{AFmax}, L_{AIeqT} and L_{AImax}. The TRS measured were typical TRS profile usually used by local authorities in Malaysia, specifically in Johor state. Results shows that TRS increase the sound level produce by lightweight vehicles by at most 6dBA. Furthermore, TRS produce impulsive sound behavior to all lightweight vehicles tested on every speed. These results proved that TRS produce significant impact in sound annoyance heard by nearby residence and can be classified as traffic noise pollution.

INTRODUCTION

Rumble Strips (RS) or Transverse Rumble Strips (TRS) acts as a safety precaution or measures that alert inattentive drivers from potential dangers such as crashing to the side of the road or head on collision with vehicle at the opposite lane. Many factors contribute to drivers leaving the roadway or straying from their lane. These include driver fatigue and drowsiness; distracted driving; poor traction between vehicles and road surfaces and poor visibility in adverse weather conditions. TRS produce sound to the drivers to notify them that they are very close to the edge of the road and need to quickly adjust their vehicle. These noises produce via vibration of the vehicle's tire with the TRS. This vibration is audibled enough to awake sleepy drivers or alerting inattentive drivers. TRS is a very effective measure for decreasing car accident [1]. A case study was conducted on the noise produce by TRS on rural roadways. They used the sound level meter and concluded that the noise level produced have a major impact on the nearby resident by having 74 dBA [2]. In addition, a study was done on the external noise level produce by different configuration of TRS in Illinois roadways. It was resulted that the TRS having a significant increase of noise level by 7 dBA at a distance of 50 feet.

Problem Statement

Problem arises when the TRS is built near housing area where the sound produce can be annoyance to the residence. The noise level produced by the TRS has a major impact on the nearby resident [2]. There was some report received to the local authorities stating that since the installation of TRS, the neighborhood are having a hard time to sleep due to the noise [3]. It is believe that the external noise produced from the rumble strips is a trade-off from the safety it provide [4]. The noise produce is enough to be notice by a normal human at a distance of up to 150 ft from the rumble strips [5].

Furthermore, in Malaysia, the TRS design method does not have a centralized and effective guideline. The design of TRS varies from one district to another. The district engineers use their judgement and provided design template received from the supplier to install the TRS. The poor design of the TRS creates many problems. The TRS designed could generate too much vibration on the ground and creating excessive unwanted noise that can be heard by nearby resident. The purpose of TRS is to alert the driver inside of the vehicle only and not the resident. Better design of TRS is a compulsory for the safety of the drivers and the comfort of the resident.

Objectives

This research aim is to evaluate whether sound level produced by TRS when it hits by lightweight vehicles create annoyance to nearby residence. To fulfill the aim of this study, several objectives has been determined;

1. To determine the increase of sound level produced by lightweight vehicles for two types of typical TRS at different speed
2. To evaluate the impulsivity of sound produced by lightweight vehicles when driven through TRS.

Scope of Study

This research focusing on the noise level produced by lightweight vehicles when driven through two types of TRS namely Multilayer Overlapped (MLO) and Middle Overlapped (MO). This study only focusses on the noise level produced by three types of lightweight vehicle which is hatchback, passenger car and Multipurpose Vehicle (MPV).

This study will only use several constant running speeds of 30, 50 and 70 km/h when the vehicle passing through the TRS. Furthermore, this study focuses on Johor state residential area only.

LITERATURE REVIEW

The first RS appeared on New Jersey's Garden State Parkway in 1955 when 40 km of singing shoulders were installed in Middlesex and Monmouth Counties [6]. Rumble strips was introduced as a measurement to reduce crashes caused by distracted or inattentive drivers. Driver inattention comes in many forms, including distraction, daydreaming, fatigue, and under the influence of alcohol. RS alert drivers by transmitting sound and vibration through a vehicle. The warnings provided by RS give notice to drivers to take corrective action before they run off the roadway. However, several complaints were made by nearby residents regarding the noise pollution produced by the rumble strips. Sound level meter is used to measure the noise level, manufactured by Bruel & Kjaer [7].By using the sound level meter, we could determine the sound level or dBA produced by the vehicle. The research of noise level produced by RS is not a new thing nowadays. There are many study and research have been conducted throughout the world. A study was conducted by [4] on external noise produced by Centerline Rumble Strips (CRS) using noise meter with data logger systems. The CRS were installed in federal highway in Manhattan, Kansas. It was determined that the noise level approximately 60 dBA when the distance is 60 meter from the CRS. It is believe that the external noise produced from the rumble strips is a trade-off from the safety it provide [4]. Another study conducted to evaluate the external noise produced by CRS on undivided rural two-lane highways in Kansas [5]. It was concluded that the noise produced is enough to be notice by a normal human at up to 150 feet from the CRS.

TRS is one of the countermeasure for reducing traffic accidents. TRS is usually installed at residential area or urban area. TRS function as an alert system to the driver, telling him to slow down or prepare to stop as there are obstacles ahead such as junction or speed hump or pedestrian crosswalk. It was determined that TRS benefits in reducing accidents at pedestrian crosswalks [8]. There are many types of TRS available in Malaysia. The types of TRS available is according to the district own design and application. Because of the inconsistent of each district TRS design, there are too many types of TRS to be study and therefore, this study has divide the types of TRS into two main types namely Multilayer Overlapped (MLO) and Middle Overlapped (MO). Figure 2 shows the difference of these types of TRS.

A report was publish by the National Academy of Sciences stating that head-on collision frequency and rate decreased after the installation of RS [9]. A research was conducted in USA to estimate the effectiveness of reducing speed in vehicles with TRS and identify the effectiveness of TRS. In general, the installation of TRS produced small speed reduction but shows statistically significant reduction which is 1.6 km/h [10]. A technical advisory regarding the shoulder and edge line RS stated that RS have a significant reduction is seen in single vehicle run off road injury crashes (Federal Highway Administarion, 2011). Furthermore, head on and opposite direction sideswipe collisions are statistically reduced since the installation of RS.

A research conducted by [11] concludes that there is a slight decrease in the annual frequency of crash. In addition, there were no fatal crashes on several routes since the installation of RS [11]. [8] find that accidents and vehicles speed is reduced at pedestrian crosswalks on roads in China after the installation of TRS. [10] investigate the effectiveness of TRS by reducing speed of vehicles. He found that the installed TRS slowing down cars in small value but proven a statistically significant reduction

[3] investigate the classification of TRS profiles and assessing the noise level produced by the TRS. He used a single lightweight vehicle and Pass-By method to collect his data. In addition, he also conducted the experiment inside of the test vehicle. Local residents suggest that the impulsive character of TRS noise make it more annoying than normal traffic noise. It was concluded that TRS in good profile generated high noise level, as well as higher traffic volume. His study also found that RR profile has a tendency of noise increment at higher frequency while MLO tends to have significant noise increase at low frequency [3].

In 2016, Haron *et al*. conducted a study on the impulsive and tonality character of the TRS. The study used single lightweight vehicle as the test vehicle, and Sound Level Meter (SLM) as the instrument. It was concluded the TRS have significant increase of sound by maximum 5 dBA when the running speed is 70 km/h. Furthermore, TRS have a significant impulsive and tonality character based on the result collected [12].

A technical report on rumble strip noise was published by the Minnesota Department of Transportation. The study includes measurements of controlled vehicle pass-by to record of RS noise levels in a controlled environment and to characterize the centreline rumble strips in terms of overall noise level and frequency. It was found that the sound level is diminished with increasing distance from the roadway [13].

METHODOLOGY

a. **Detection of sound level by single lightweight vehicles.** To measure the noise level of the selected sites, several apparatuses is needed such as Sound Level Meter (SLM), tripod, microphone, sound calibrator, anemometer, and test vehicles. The sound level meter is a tool for measuring the intensity of sound and the impulsivity of the sound. A typical SLM set up consist of microphone to picking up the sound wave and convert it into electric signal for the SLM to process and producing result of the needed parameters. The sound level usually uses unit of decibels to describe the level of sound collected. Field test layout is prepared as

Figure 1. A single lightweight vehicle will be driven at pre-set constant speed for three times to get the average reading to reduce error. This step will be repeated for each vehicle, each speed and each type of TRS. For each TRS, this study has measured and recorded its profile measurement as well as its condition.

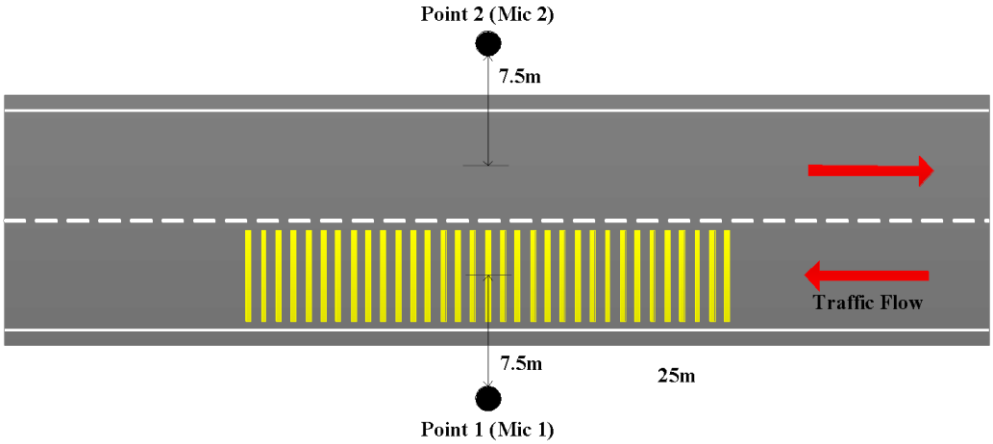
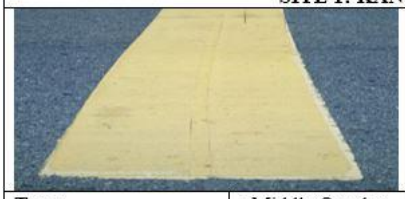
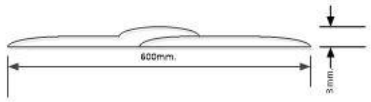


Figure 1: Field test layout

SITE 1: KANGKAR PULAI			
			
Type	: Middle Overlap (MO)	**Spacing**	: 2.35 m
Thickness	: 3 mm	**No. of Strip**	: 33
Width	: 600 mm	**Length**	: 3.35 m

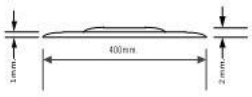
SITE 2: SRI SKUDAI			
			
Type	: Middle Layer Overlap (MLO)	**Spacing**	: 2.45 m
Thickness	: 3 mm	**No. of Strip**	: 30
Width	: 400 mm	**Length**	: 2.80 m

Figure 2: TRS profile measurement

b. Impulsive due to Single Light Weight Vehicle. This study will only focus on the A-weighted sound level because it is the most commonly used for measurement of sound pressure level. According to [12] there are several ways to determine whether the TRS installed is having an impulsive characteristic or not. The first is to compare the equivalent continuous sound level (L_{Aeq}) and maximum fast response A-weighted sound level (L_{AFmax}). If the difference is 10 dB or more, it's indicate an impulsive characteristic. Next is comparing the difference between A-weighted sound level that is averaged of the same time interval with time-weighting characteristics I (L_{AIeqT}). When the difference is more than 2 dB, impulsive characteristics is identified. The third is when the difference is greater than 2 dB between L_{AFmax} and A-weighted maximum Impulse response (L_{AImax}), impulsive characteristics would be indicated [12].

RESULT AND DISCUSSION

a. Sound Level Produced When Single Lightweight Vehicles Passing Through TRS. All three vehicles are driven through both types of TRS at three different speed. When a vehicle passed through the TRS, the sound level was recorded by the SLM (mic 1). For example, figure 3 below shows sound pressure level versus time history when driven through MLO measured with L_{Aeq} parameter using MPV (Alza) at three different speed. The sound level L_{Aeq} are compared with road without TRS as a baseline. The peak noise shows at 6th second means that the vehicle is directly in front of Mic 1. The L_{Aeq} produced is shown when the vehicle driven through road that have TRS (solid line) and without TRS (dotted line). The increase of sound level can be

observed at the 6th second with average increase of 6.3dBA. This increase of 6dBA is significantly high enough to be classify as an annoyed sound. However, when vehicles with lower engine power is used such as hatchback (Axia), the sound level increase is very low which is below 3dBA thus does not have any significant impact on the annoyance of the sound produced. Figure 5 shows an average increase of SPL when compared to the vehicles speeds except for Hatchback vehicle. It is noted that the SPL on MLO is higher than MO on every vehicle at every speed although the SPL increased on both TRS is below 3dBA except for, MPV vehicle on MLO at speed 30, 50 and 70km/h and Passenger Car Unit (Saga) on MLO at speed 70km/h. This result shows that the overall increase on SPL on every vehicle does not give significant impact on the noise annoyance when measured with L_{Aeq} only.

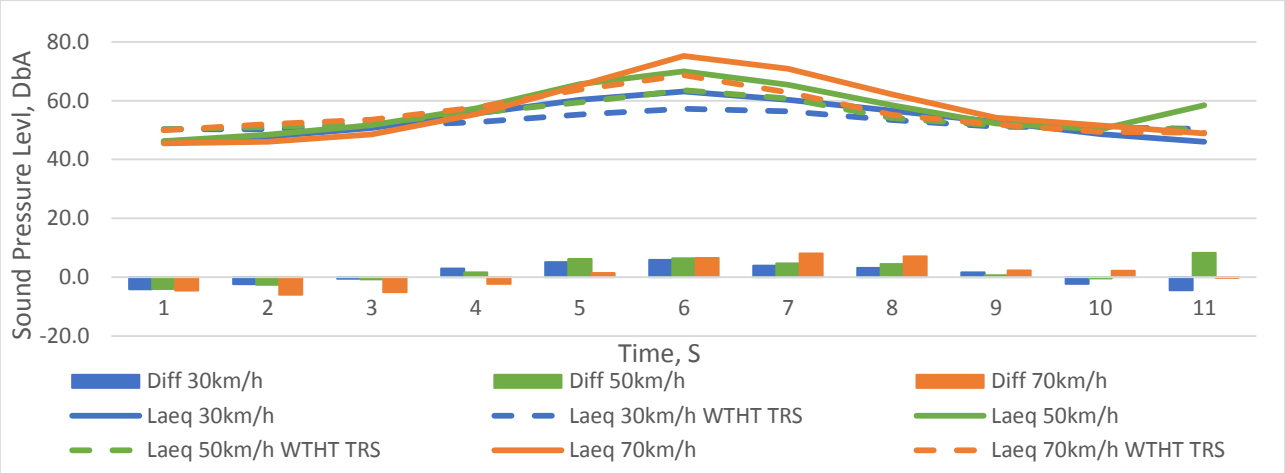


Figure 3: Sound Pressure Level versus Time using MPV vehicle at MLO

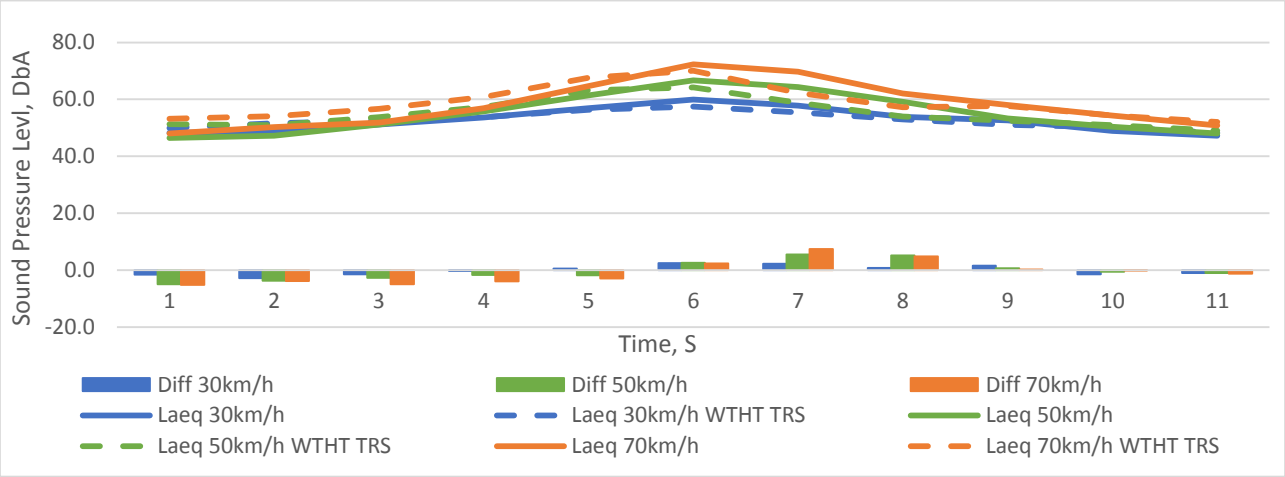


Figure 4: Sound Pressure Level versus Time using Hatchback vehicle at MLO

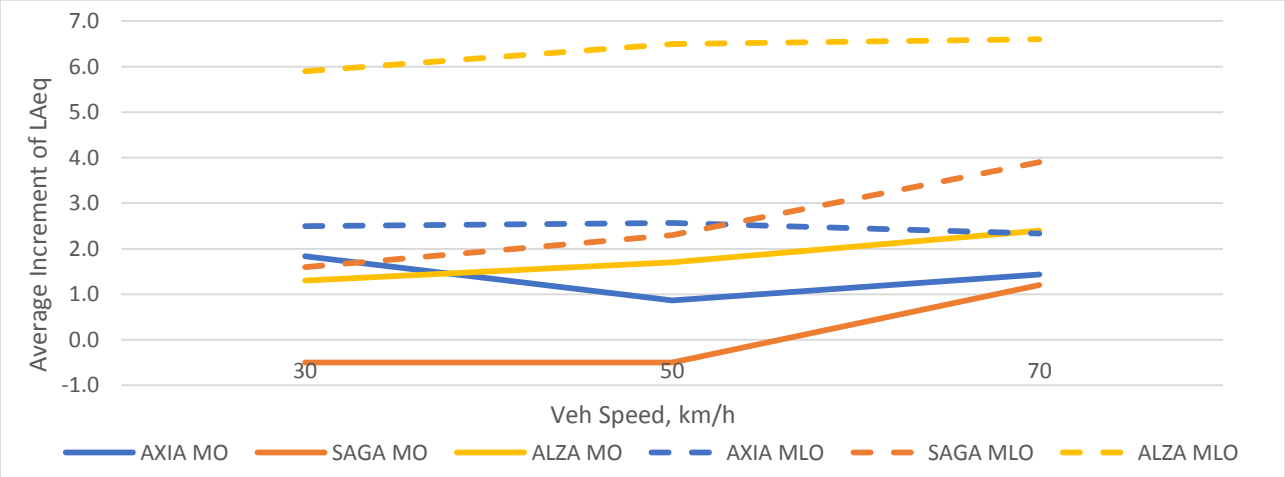


Figure 5: Average Increment of L_{Aeq} versus Speed

However, sound parameter does not contain only L_{Aeq}. So this study cannot make a conclusion based on increases of L_{Aeq}. Thus, this study further it's research by analyse others sounds parameters such as L_{AFmax}, L_{AImax}, LAIeq and L_{ASmax}. These parameters are compared with the baseline values which is, road without TRS denoted with symbol w (L_{Aeqw}, L_{AFmaxw}, L_{AImaxw}, L_{AIeqw} and L_{ASmaxw}). Table 1 shows average increase of L_{AIeq} across all vehicles with maximum increase of 7.2dBA. However, at speed 30km/h, the sound parameters are reduced when compared to baseline for all vehicles. This can be assumed that the TRS act as a sound damper when vehicles are moving at low speed

Table 1: Average increase of L_{AIeq} across all vehicles

Vehicle	Type of profile	Speed (km/h)	L_{Aeq}	L_{AFmax}	L_{AImax}	L_{AIeq}	L_{ASmax}	L_{Aeq} - L_{Aeqw}	L_{AFmax} - L_{AFmaxw}	L_{AImax} - L_{AImaxw}	L_{AIeq} - L_{AIeqw}	L_{ASmax} - L_{ASmaxw}
AXIA	MLO	30	59.9	81.8	84.2	61.4	74.6	2.5	-2.9	-1	3.2	-7.8
	MO		61	73.6	77.4	61.8	68.7	1.8	-3.7	-3.5	1.9	-6.1
	MLO	50	66.7	83.5	85.2	68.6	79.4	2.5	0.9	2	3.2	1.3
	MO		68.1	86	87.3	69.1	83.9	0.9	7.3	6.4	1.2	9.6
	MLO	70	72.3	80.2	81.8	74.2	75.1	2.3	4.9	5.3	3.1	2.8
	MO		73.9	75.3	77.5	75.6	73.1	1.5	-9.3	-9.4	2.6	-5.1
SAGA	MLO	30	60.3	81.8	84.2	61.1	74.6	1.6	-3.8	-2.5	1.9	-7.8
	MO		60.6	74.7	78.6	61.4	69	-0.5	-11.6	-9	-0.7	-14.3
	MLO	50	67.6	83.6	85.2	69.3	80.6	2.3	1	2	3.5	2.5
	MO		66.6	86	87.3	67.5	83.9	-0.5	7.3	6.4	-1.1	9.6
	MLO	70	73.1	82.3	85.5	75.6	75.3	3.9	4.3	6.2	5.9	0.7
	MO		72.7	75.4	77.5	73.8	73.3	1.2	-9.2	-9.4	-0.3	-4.9
ALZA	MLO	30	63.1	77.1	79.7	64.3	71.8	5.9	-2.8	-0.9	6.6	-5.4
	MO		64.5	83.6	84.4	65.3	81.4	1.3	14.3	13.5	1.5	14.4
	MLO	50	70	77.7	81.3	71.5	69.7	6.5	1.1	3.1	7.5	-2.2
	MO		71.5	78.6	80.3	72.6	76.3	1.7	5.1	6.2	2.1	4.5
	MLO	70	75.2	76.9	78.6	76.6	74	6.5	-2.2	-2.1	7.2	0.5
	MO		77	88.4	90.1	78.6	84.8	2.4	-8.1	-7.2	2.6	-8

b. Impulsivity due to Single Lightweight Vehicle. To determine the impulsivity of a sound source, this study have to identify four guidelines that determine whether the sound produce an impulsive behaviour. These guidelines were discussed in the methodology of this study. Referring to Table 2, determination of impulsive characteristics can be observed by the four guidelines mentioned earlier. For simplicity, this study has marked an impulsive behaviour of the sound produce. It is shown that almost every vehicle on every TRS at every speed produce impulsive behaviour. This finding shows that lightweight vehicles produce impulsive sound when driven through TRS which is annoyance to nearby residence.

Table 2: Guidelines

Vehicle	Type of profile	Speed (km/h)	L_{AImax} - L_{AFmax}	L_{AFmax} - L_{Aeq}	L_{AIeqT} - L_{Aeq}	L_{AImax} - L_{ASmax}
AXIA	MLO	30	2.4	21.9	1.5	9.6
	MO		3.8	12.6	0.8	8.7
	MLO	50	1.7	16.8	1.9	5.8
	MO		1.3	17.9	1	3.4
	MLO	70	1.6	7.9	1.9	6.7
	MO		2.2	1.4	1.7	4.4
SAGA	MLO	30	2.4	21.5	0.8	9.6
	MO		3.9	14.1	0.8	9.6
	MLO	50	1.6	16	1.7	4.6
	MO		1.3	19.4	0.9	3.4
	MLO	70	3.2	9.2	2.5	10.2
	MO		2.1	2.7	1.1	4.2
ALZA	MLO	30	2.6	14	1.2	7.9
	MO		0.8	19.1	0.8	3
	MLO	50	3.6	7.7	1.5	11.6
	MO		1.7	7.1	1.1	4
	MLO	70	1.7	1.7	1.4	4.6
	MO		1.7	11.4	1.6	5.3

CONCLUSION

Transverse Rumble Strips (TRS) are proven to be countermeasures to alerting inattentive drivers from accidents. This study investigates the sound level and impulsivity of the sound produced when lightweight vehicles are driven through the TRS. For this study, three types of lightweight vehicles were chosen namely hatchback, passenger car unit and multipurpose vehicle. These types of lightweight vehicles are the most common used by Malaysian citizens. For the TRS, we chosen two typical types of TRS that are common in Johor residential area which is Multi-Layer Overlapped (MLO) and Middle Overlapped (MO).

This study has obtained several conclusions;

1. TRS increase sound level produced by lightweight vehicle significantly to be classify as noise annoyance.
2. For lower engine power vehicle, the LAeq increase is small thus no significant impact on the noise annoyance.
3. All types of vehicles produced impulsive sound behaviour when driven through both types of TRS. Thus this study proved that TRS produce significant impact on the noise annoyance heard by local residence.

REFERENCE

[1] Persaud, B. N., Retting, R. A., & Lyon, C. A. (2004). Crash reduction following installation of centerline rumble strips on rural two-lane roads. Accident Analysis and Prevention, 36(6), 1073–1079.

[2] Haron, Z., Othman, M. H., Yahya, K., Yaacob, H., Hainin, M. R., Badruddin, M., & Yusof, M. (2012). Noise Produced By Transverse Rumble Strips : A Case Study on Rural Roadways. Journal of Mechanical and Civil Engineering, 1(5), 12–16.

[3] Othman, M. H. (2016). Performance and Modelling of Transverse Rumble Strips on Noise and Vibration Stimuli. Universiti Teknologi Malaysia.

[4] Karkle, D. E., Rys, M. J., Russell, E. R., & Asce, F. (2011). Centerline Rumble Strips: Study of External Noise. Journal of Transportation Engineering, 137(5), 311–318.

[5] Makarla, R. (2009). Evaluation of External Noise Produced By Vehicls Crossing Over Centerline Rumble Strips on Undivided Highways in Kansas. ITE Journal. Kansas State University.

[6] Carlson, P. J., & Miles, J. D. (2003). EFFECTIVENESS OF RUMBLE STRIPS ON TEXAS HIGHWAYS : FIRST YEAR REPORT (Vol. 7).

[7] Mato, R. R. A. M., & Mufuruki, T. S. (1999). Noise pollution associated with the operation of the Dar es Salaam International Airport. Transportation Research Part D: Transport and Environment, 4(2), 81–89.

[8] Liu, P., Huang, J., Wang, W., & Xu, C. (2011). Effects of transverse rumble strips on safety of pedestrian crosswalks on rural roads in China. Accident Analysis and Prevention, 43(6), 1947–1954.

[9] D. J. Torbic, Hutton, J. M., Bokenkroger, C. D., Bauer, K. M., Harwood, D. W., Gilmore, D. K., … Lyon, C. (2009). NCHRP Report 641 – Guidance for the Design and Application of Shoulder and Centerline Rumble Strips.

[10] Thompson, T. D. (2004). Evaluation of Rumble Strips at Rural Stop-Controlled Intersection in Texas. Texas A&M University

[11] Noyce, D. A., & Elango, V. V. (2004). Safety Evaluation of Centerline Rumble Strips : A Crash And Driver Behavior Analysis. In Annual meeting of the Transportation Research Board. Washington, D.C.

[12] Haron, Z., Yahya, K., Darus, N., Othman, M. H., & Sanik, E. (2016). IMPULSIVITY AND TONALITY OF NOISE DUE TO RUMBLE STRIPS INSTALLATION.

[13] Inc, H. E. (2014). Rumble Strip Noise Study. Minneapolis.

Effect of Cool Paint Application to the Indoor Temperature of Student Hostel Room in UTM Residential College

Nur Adleen Fitriyana Azman, Rozana Zakaria

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

rozana@utm.my

Keywords: cool paint; temperature; relative humidity.

ABSTRACT. Indoor thermal comfort has a great influence on the productivity and satisfaction of residential college occupants. The exposure to excessive heat to the occupants may cause discomfort and contributed to the uncomfortness among students living inside the residential college. As UTM is an old establishment typical existing residential buildings in it college might not been able to cope with the rising temperatures thus increasing the building cost to provide thermal comfort for its occupant. This study aims to investigate the effect of cool paint application to the indoor temperature of student room in existing residential college in UTM. The Dulux Weathershield paint are said to have several properties that can keep a building cool, thus the paint is selected as the material to paint the room. Readings taken are captured using TES-1370 CO_2 which record ambient temperature and relative humidity for 16 hours for 2 days in the month of April and in May. The surface temperatures data are captured using Digital Infrared Thermometer Fluke 62 and all data captured are recorded and compared with the data before the application of cool paint and after the application of cool paint. The results of the research indicates that, after the application of cool paint the ambient temperature and the surface temperature of the room is slightly lower than the temperature before the application and its relative humidity is higher.

INTRODUCTION

Malaysia is a developing country in which the rate of development has increased tremendously to counterbalance the population growth and industrialization. As the cities grow, the natural landscape had been replaced with concrete jungle and it has been one of the reasons of the rise in temperature of the Earth. Throughout the year, the frequency and intensity of heat have increased steadily and the values are expected to be more severe in the future [1]. These events have a negative impact not only to the human but also the Earth and its population. As the number of building increased to cope with the growing population, the heat produced also increased and it has contributed in decreasing the indoor thermal comfort in buildings thus increasing the energy consumption [2].

Problem Statement

Building is provided with specific properties to provide thermal comfort to its occupant. Heat island effect is a condition in which the temperatures in the city centers are higher compared to surrounding suburban areas. The phenomenon is mainly related to the high density of buildings and urban structures that absorb solar radiation, use of highly absorbing materials, lack of green spaces and the production of anthropogenic heat [3]. The rising temperature has the effect of increasing the cooling demand in commercial or residential building thus increasing the cost of providing comfort to the user.

In a study done before, cool paint has been proven to reduce cooling demand in homes and buildings. The application of materials to the surface of building envelope have been said to affect the thermal performance [1]. This study pay serious interest on the indoor temperature of student room in residential college in UTM with the application of cool paint.

Objectives

The objectives of this study are:

1. To determine parameter of comfort in an indoor environment of room in a building.
2. To determine existing indoor temperature of student hostel room in residential college in UTM.
3. To investigate the effect of cool paint application to the indoor temperature of the student hostel room in residential college.

Scope of Study

The research is carried out in student hostel room in UTM residential college, at block L12 KTHO. Several parameters are set and recorded such as ambient temperature, surface temperature, relative humidity and also the room U-value. The student hostel room will be painted with cool paint to determine its effect on reducing the indoor

temperature thus reducing the cost of cooling demand. The results will be compared between the parameters taken before the room is painted and after the room is painted.

LITERATURE REVIEW

Many researches had been carried out to study the effectiveness of material with high reflective surfaces to reduce temperature of the building. A study had been conducted with DOE simulation to investigate the effect of surface reflectance on building cooling and energy consumption [2]. The results of the study show that solar reflectance effect depends on the outdoor climatic conditions, insulation level and also surface's orientation. Its result also show that extensive use of surfaces with high solar reflectance could lower urban air temperature, thus reducing building cooling demand.

Meanwhile, Bansal et al., (1992), have conducted a scale model measurements to study the effect of envelope colour on thermal performance of buildings. The results demonstrated that envelope colour has appreciable effect on the thermal behaviour of buildings. According to results of the studies, a white painted test cell which have a high solar reflectance was 7°C cooler than the corresponding black painted cell whose have low solar reflectance when the painted cell was both exposed to strong solar radiation without the provision for any ventilation. This study shows how the envelope colour of a building can affect its thermal performance.

In another study done by Cheng et al., (2004), he concluded that cooling load in buildings with black envelope can be more than twice of that value with white envelope. Additionally, the effect of light coloured surfaces is most appreciable in light mass envelope. According to the authors, in Hong Kong when temperate climate year-round most residential buildings are enveloped in thin concrete walls only, in which make them the ideal candidates for envelope colour applications. As a conclusion, it is widely recognized that a reflective roof surface in place of a dark one can be of great benefit in hot and sunny climates, increasing human comfort and reducing the cooling load.

According to Bretz et al., (1997), walls are typically repainted every ten years or so, and every time they are repainted, a white paint may be selected in place of a darker colour for no additional cost. Similarly, high-albedo alternatives to conventional roofing materials are usually available, usually at a little or no additional cost at all. In this study, it is proven that choosing a solar-reflective surfacing at the time of installation should not add to the cost of the roof and will provide the building resident with benefits from energy savings and increased comfort for the user.

METHODOLOGY

The experiment is carried out in a student room in L12 KTHO, and the room selected are the standard room for student in residential college available in UTM. Parameters involved are recorded and observed in the room before the application of cool paint, the experiment are carried out for 16 hours from 7.00am to 11.00pm per day for 2 days before the application of cool paint and after the application of cool paint. Throughout the process of data collection, the room condition and activity are like any normal day.

Ambient Temperature and Relative Humidity. The basic experimental parameter of this experiment is temperature. The TES-1370 CO2 are the equipment used in the experiment and the device is supported with probe sensor. The function of the probe is to detect temperature and relative humidity. The data are recorded for 16 hours with 5 minutes interval.

Surface Temperature. Surface temperatures of room were also taken by using Digital *In*frared Thermometer Fluke 62. These handheld tools are ideal for measuring surface temperatures of rotating, hard to reach, electricity lives or dangerously hot targets like electrical motors and panel. The data are collected before and after the application of cool paint so comparison can be made.

After the desired data are collected and recorded, data comparison is made. The results of both data collection are compared and findings are made.

RESULTS AND DISCUSSION

The parameter of comfort in an indoor environment of a room in a building are obtained and can be identified as temperature, humidity, clothing insulation, work rate and design of building. The result of the experiment shows the difference in temperature of the student room before and after the application of cool paint.

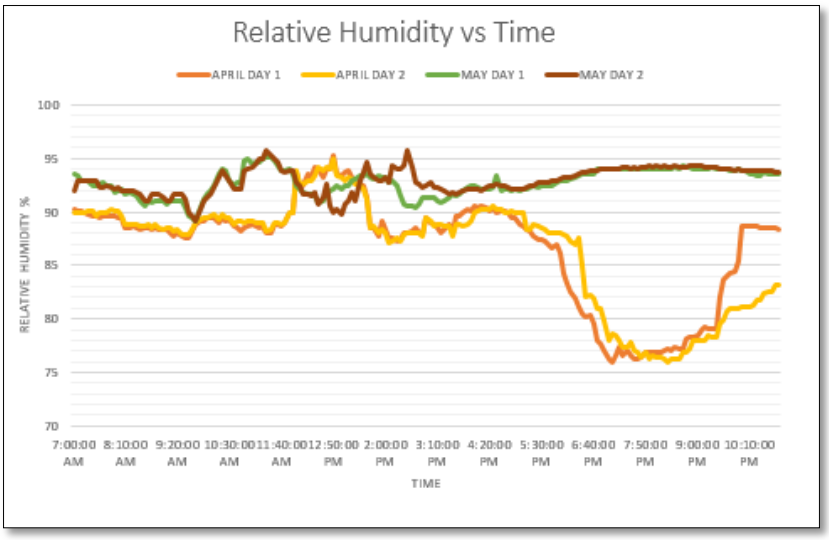


Figure 1: Graph of Temperature versus Time between April and May

Figure 1 above shows the reading of indoor temperature obtained during the experiment between April 2017 and May 2017. The data collected are captured every 5 minutes for 16 hour each day for 2 days in April and in May. The temperature and climate is slightly different but the average temperature for both month still the average temperature of tropical climate. Data obtained in April 2017 are the data recorded on the room before the application of cool paint meanwhile data in May are after the application of cool paint. The graph show that the temperature taken in April 2017 is slightly higher than data captured in May 2017 for both days. In April, during day 1 the temperature gradually increased from morning to afternoon and the highest temperature recorded is 32.4°C at 7.55pm, meanwhile the highest temperature on day 2 is 31.9°C at 7.15pm. In contrast with that, during data collection in May which is after the application of cool paint, the temperature also gradually increased from morning to afternoon for both day the data is tested but the temperature taken is lower than temperature taken in April. The highest temperature taken for May is 31°C at 2.40 pm or day 1, and at 10.00am for day 2.

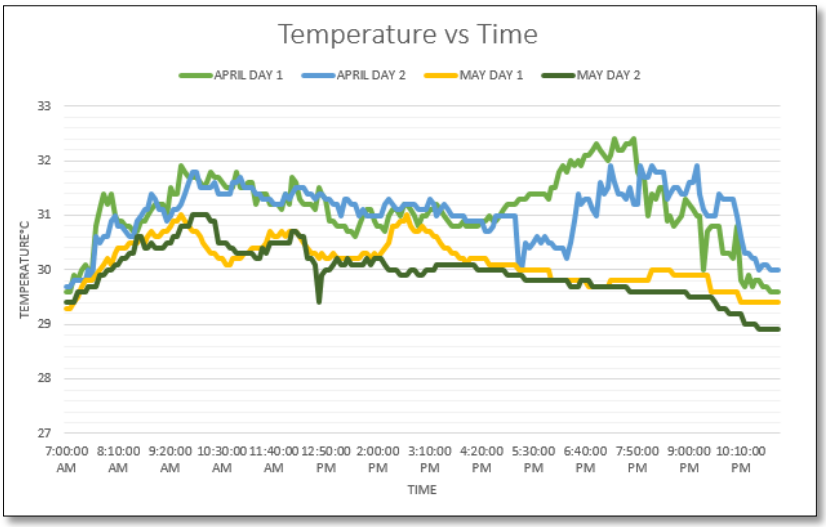


Figure 2: Relative Humidity versus Time between April and May

Figure 2 above shows the differential of relative humidity of the student room between before and after application of cool paint in April and May for 2 days in each month. From the graph, we can see that the difference in value of relative humidity percentage in the room before and after the application of cool paint. In April, we can see the humidity for the room is 95.3% and the lowest humidity is 75.9% for day 1 but for day 2 the highest humidity is 94.9% and the lowest is 73%. Meanwhile for the month of May, in day 1 the highest humidity is 95.2% and the lowest is 89.2% but for day 2 the highest humidity is 95.7% and lowest is 89.1%. the percentage of humidity in which the periods of before the application of cool paint is lower than the percentage obtained after the application of cool paint.

Apart from the ambient temperature, the surface temperatures of selected wall in the room is also collected and the data is compared in Table1.

Table 1: Comparisons of Surface temperatures of wall in the student room in residential college

CONDITION SURFACES OF THE WALL	BEFORE WALL BEEN PAINTED (°C)	AFTER WALL IS PAINTED (°C)
Surface 1 (4.2mx3.0m)	30.6	30.4
Surface 2(1.1mx3.0m)	31.2	30.3
Surface 3(1.4mx3.0m)	30.8	30.2

Based on the table above, we can see that the surface temperature of the wall selected before the application of cool paint is slightly higher than the reading of surface temperature after the application of cool paint. The data are captured using Digital Infrared Thermometer Fluke 62 on the second day of data collection in both April and May at 12.30pm. For surface 1, the difference in temperatures is about 0.02°C and it's the same for surface 3. Meanwhile for surface 3, the difference in temperature is quite higher which is 0.9°C as the surface selected is a window panel therefore outdoor weather might affect the indoor temperature performance of the surface.

CONCLUSIONS

This research focus on the effect of cool paint application to the indoor temperature of student room in residential college in UTM. Based on the findings obtained, its proven that the ambient temperature of the student room in residential college is slightly lower after the application of cool paint. The type of paint we used which is Dulux Weathershield Keep Cool, is an exterior paint which can reflect suns up to 85 percent more compared to normal paint. The paint reflects more infrared light to reduce heat absorption and reduce energy consumption in which lower the temperature of the room. [5]

The findings obtained also shows that after the application of cool paint, the percentage of relative humidity of the room is higher than its percentage before the application of cool paint. The most important findings are that when the temperature of the room lower, the relative humidity is quite high. In comparison to the standard guideline of Indoor Air Quality (IAQ), the acceptable relative humidity is in range between 40 – 70%. In our findings, the relative humidity exceeds the range provided by the standard.

The research also compares the value of surface temperatures of several walls in the room to before and after the application of cool paint. The findings show that, the surface temperatures of the wall after the application of cool paint is lower than before the application. Based on the product of the paint used, it is said that the cool paint can lower the surface temperature up to 5°C, thus the findings match the properties of the cool paint product.

REFERENCES

[1] Ikmalzatul Abdullah. (2013). Effects Of Envelope Color And Heat Insulation On Building Thermal Performance.

[2] Synnefa A, Santamouris M, Akbari H. (2007). Estimating the effect of using cool coatings on energy loads and thermal comfort in residential buildings in various climatic conditions. Energy and Buildings,39:1167–74.

[3] Voogt, J.A., Oke, T.R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment* 86: 370-384.

[4] Taha, H., Akbari, H., Rosenfel, A., Huang, J. (1988). Residential cooling loads and the urban heat island

[5] Bansal, N.K., Garg, S.N., Kothari, S. (1992). Effect of Exterior Surface Color on the Thermal Performance of Buildings. *Buildings and Environment* 27:31-37

[6] Bretz, S., Akbari, H., and Rosenfeld, A. (1997). Practical Issues for Using Solar Reflective Materials to Mitigate Urban Heat Islands. *Atmosphere Environment* 32: 95-101.

[7] Cheng, V., Ng, E. and Givoni, B. (2004). Effect of envelope color and thermal mass on indoor temperatures in hot humid climate. *Solar Energy* 78: 528-534.

[8] [AkzoNobel.(2014). AkzoNobel Report, from http://report.akzonobel.com/2014/ar/case-*studies/sustainable-business/paint-that-keeps-you-cool.html*

Impulsivity and Tonality of Noise due to Commercial Vehicles Transit on Rumble Strips

Wan Mohammad Asyraf Norudin, Zaiton Haron, Khairulzan Yahya

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

rozana@utm.my

Keywords: Transverse rumble strips (TRS), Sound, Impulsivity, Tonality, Annoyance

ABSTRACT. Transverse rumble strips (TRS) is usually being installed at dangerous area as traffic safety equipment on the road. This study is to investigate of impulsivity and tonality from two types of TRS which is Multilayer Overlapped (MLO) and Middle Overlapped (MO). The commercial vehicles used is Toyota Hilux represents 4wheel drive (4WD), Van Hiace represent van, 40 seated bus represents bus and one-ton lorry represent lorry. The impulsivity were derived from sound parameters such as L_{Aeq}, L_{AFmax}, L_{AImax}, L_{AIeq} and L_{ASmax} while the tonality are from A-weighted 1/3 octave band frequency. The study are carried out using pass by method. From the research, all commercial vehicles do not have significance increment of sound level (<3dB). There are impulsivity when 4WD and van driven through TRS while bus and lorry does not create impulsivity. 4WD and van do not create tonal while bus and lorry already have tonal when driven through TRS and without TRS to create annoyance to surroundings.

INTRODUCTION

Rumble Strips can be defined as raised or grooved patterns installed on a roadway to provide a warning to the road user by giving the rumbling sound and a physical vibration[1]. TRS is one of the types rumble strips which installed perpendicularly to the vehicles flow and across the road on top of the pavement[2]. TRS may be used as standard regulatory to attract road user's attention that there were changing roadway environment which needs the to be more cautious. TRS are often installed on the approach to an intersection and used to attract road users' attention the presence of an intersection ahead[1]. TRS are one of the alternatives to reduce the rate of accidents on road by giving them the warning to slow down the speed.

There are three common TRS profile that can be found in Malaysia: Multilayer Overlapped (MLO), Raised Rumbler (RR) and Middle Overlapped (MO) [4].The installation of TRS based on the local authorities. The local engineer who works with the authority responsible for designing the installation of TRS[5]. The TRS type MLO usually being used by Majlis Perbandaran Johor Bahru Tengah, where the thickness of TRS according to the number of layers. While authorities from Johor Bahru, Kulai and Pasir Gudang used MO profile as TRS at the areas.

Impulsive noise is characterized by a strong acoustic disturbance that occurs over a very short period of time[18]. While tonality of sound can be defined as the number of pure tones in the noise spectrum. Human ear is very sensible to pure harmonic sounds. Noise produced by TRS may have significance impulsivity and tonality to create annoyance to local residents and surroundings.

Problem Statement

The critical spots usually having the road accidents are at an intersection, roundabout, plaza toll and pedestrian crossing. The accidents may cause a loss in the property even lives. In order to reduce the rate of accidents, TRS are being installed just before the critical spots. TRS alert road users by giving them vibration and sound. However, the noise level could give bad effect to adjacent residents' health problem in long term.

The design process of TRS should consider some important aspects in order to reduce the disturbance of noise to the adjacent residents. One of the important aspects is the types of TRS which has different profiles give different level of noise. Types of TRS is contributing to the level of noise when vehicles hit TRS. The thickness, shape and spacing of TRS give different level of sound. So, local authority need to design which types of TRS profile suitable to be installed on the road to reduce noise pollution.

Objectives

The objectives of this study are:

1. To determine the increase of sound level produced by commercial vehicles when driven through two types of typical TRS
2. To assess the impulsivity of sound produced by commercial vehicles transit on two types of typical TRS
3. To evaluate the tonality of sound produced by commercial vehicles transit on two types of typical TRS

Scope of Study

The study focused on the impulsivity and tonality produced due to the installation of transverse rumble strips. The type of vehicles used is commercial vehicles which is 4wheel drive, van, lorry and bus. This study involved two types of TRS which is Multilayer Overlapped (MLO) and Middle Overlapped (MO). The noise level is measured using pass-by method using a single vehicles. The running speed of the vehicles in this study is 30 and 50 km/h.

LITERATURE REVIEW

Traveling speed of vehicles on the road will affect the noise level when the vehicles run across TRS. The vehicle speeds changed, the pavement surface noise was clearly different[6]. The research found that the exterior traffic noise increase when the speed of a single vehicle was driven across TRS increase. In the range 50km/h to 100km/h, as the speed vehicles increase, the exterior noise level due to TRS increase.

The type of vehicles travel on the road will give effect to the noise produced to the surroundings. The type of vehicle is link closely to the weight of the vehicles. The sound level produced by sedan car shows slightly wider range between speed. Vice versa, the sound level produced by truck shows narrow range between speed conducted[6].

The installation of transverse rumble strips gives noise pollution to the local residents. External noise is measured by a sound level meter, which is an instrument which response to sound in approximately the same way as the human ear and which gives reproducible measurements of sound level[10]. The noise from transverse rumble strips is usually more annoying since it is an impulse of pulsating noise compared to continuous noise[4]. The shape of the transverse rumble strips also give the effects on the intensity of the noise[9]. The studied also found that the heavier the vehicles, the higher the level of noise produced during contacting with transverse rumble strips.

METHODOLOGY

a. Sound level produced by single commercial vehicles. The device that was used for measurement of noise level is Pulsar Type 1 sound level meter. The sound level meter was used to determine the level of external noise due to TRS. This sound level meter provides the L_{Aeq} , L_{AFmax}, L_{ASmax}, L_{AImax} and L_{AIeq} values. The L_{Aeq} is defined as the constant noise level that expends the same amount of energy as a fluctuating level over the same time period[12]. The procedure for the measurement followed 11819-1:2001. Acoustics - Measurement of the influence of road surfaces on traffic noise - Part 1: Statistical Pass-By method (ISO, 1997a). The sound level meter was placed on top of tripod about 1.5 meters above the ground during the measurement was conducted. This sound level meter was placed off from the road which is 7.5 meter from the center of the road. The level of noise is measured when single commercial vehicle travel on the road with TRS and without TRS[5]. Point 1 represents the location of the sound level meter when single commercial vehicle across with TRS while Point 2 is the location of the sound level meter when a single commercial vehicle is driven on the road without TRS. The repetition of every activity is 3 times. The noise data is accepted as the wind speed is below 5m/s and 5^0 c to 40^0 c for air temperature[13].

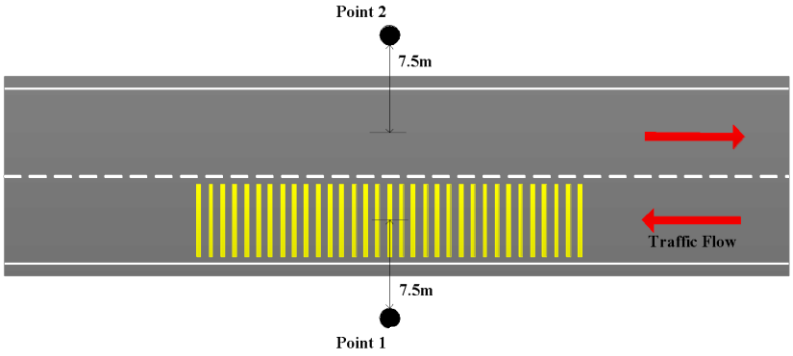


Figure 1: Field test layout

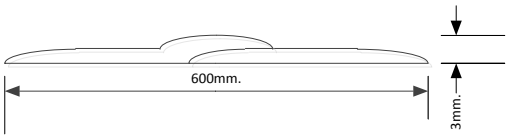
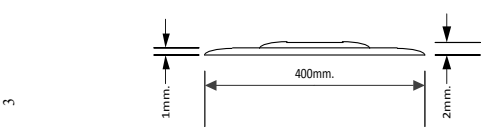
SITE 1: KANGKAR PULAI		SITE 2: SRI SKUDAI	
			
Type	Middle Overlap	**Type**	Middle Layer Overlap
Thickness	3 mm	**Thickness**	2 mm
Width	600 mm	**Width**	400 mm
Spacing	2.35 m	**Spacing**	2.45 m
No. of Strip	33	**No. of Strip**	30

Figure 2: TRS profile measurement

b. ***Impulsivity of sound produced*** The significance of impulsivity can be determined using four methods. The different in A-weighted maximum noise levels between Fast response (L_{AFmax}) and Impulse response (L_{AImax}) is greater than 2dB, so the noise impulsivity is significant[14]. The second method is noise impulsivity is categorize as significant if the

different between Fast response maximum (L_{AFmax}) with the equivalent A-weighted sound pressure level (L_{Aeq}) is greater than 10dB[15]. The third method is the difference between the A-weighted impulse sound pressure levels, determined with time-weighting characteristic I (L_{AIeqT}), averaged over the same time interval, and L_{Aeq} greater or equal to 2dB is consider as impulsivity of noise[15]. Last but not least, the noise impulsivity is significant when the difference between the A-weighted impulse sound pressure levels, determined with time-weighting characteristic I maximum (L_{AImax}) and Slow response maximum (L_{ASmax}) is greater than 6dB[16].

c. ***Tonality of sound produced*** The tonality can be known whether the noise produced when commercial vehicles driven through TRS by using sound level 1/3 octave band frequency spectra. The significance of tonality can be concluded when the A-weighted 1/3 octave band exceeds the neighbouring bands by 5dB[17].

RESULTS AND DISCUSSION

Sound level. The peak noise level shows L_{Aeq} produced by every single commercial vehicles is not greater than which means the difference between vehicles driven through TRS and without TRS is acceptable. The highest difference of L_{Aeq} with TRS and without TRS is when one-ton lorry is driven through MLO at speed of 30km/h. However, the L_{Aeq} values are not represent the overall noise characteristics.

The sound level values related to the peak L_{Aeq} such L_{AFmax}, L_{AImax}, L_{AIeq} and L_{ASmax} with TRS shown in Table 1 with the difference to the baselines L_{Aeq}w such L_{AFmax}w, L_{AImax}w, L_{AIeq}w and L_{ASmax}w without TRS. The difference of the values from the baselines varies. The L_{Aeq} values rise for all commercial vehicles for MLO and MO, for example when hilux is driven through MLO, the L_{Aeq} rise about 5.7dB (8.99%) from speed 30km/h to 50km/h. On the other hand, the values of L_{AIeqT} shows the increment for all commercial vehicles when driven through MLO and MO.

Table 1: Sound parameters values and difference from baseline

Vehicle	Type of profile	Speed (km/h)	L_{Aeq}	L_{Aeq}w	L_{AFmax}	L_{AImax}	L_{AIeq}	L_{Asmax}	L_{Aeq} - L_{Aeq}w
HILUX	MLO	30	63.4	63.8	83.4	85.2	64.3	80.7	-0.4
	MO		65.8	67.2	78.2	78.8	66.3	76.7	-1.4
	MLO	50	69.1	70.6	79.9	81.6	69.6	76.1	-1.5
	MO		69.8	68.5	75	76.8	70.2	72.1	1.3
VAN	MLO	30	60.9	65.8	83.4	85.2	61.5	80.7	-4.9
	MO		63.3	66.6	78.2	78.8	63.9	76.7	-3.3
	MLO	50	69.2	66.8	79.9	81.6	69.6	76.1	2.4
	MO		68.8	67.6	79.7	81.3	69.2	76.1	1.2
BUS	MLO	30	75.6	77.2	84.1	85.5	76	80.2	-1.6
	MO		78.5	75.6	84.4	87	79	79.8	2.9
	MLO	50	83.3	85.8	84.9	86.1	84.1	82	-2.5
	MO		85	82.8	86.3	86.9	85.5	84.2	2.2
LORRY	MLO	30	75.6	72.6	84.1	85.5	76	80.2	3
	MO		75.9	76.4	83.3	86.8	76.3	77.2	-0.5
	MLO	50	77.9	80.4	84.9	86.4	78.8	82	-2.5
	MO		81.4	79.7	84.9	85.5	82.3	82.9	1.7

The L_{AFmax} and L_{ASmax} shows the increment when bus and lorry driven through both TRS from speed 30km/h to 50km/h. However, when hilux and van pass through the MLO, the L_{AFmax}, L_{AImax} and L_{ASmax} shows same decrement from speed 30km/h to 50km/h which -3.5dB (-4.2%), -3.6dB (-4.23%) and -4.6dB (-5.7%) respectively. The L_{AFmax}, L_{AImax} and L_{ASmax} for hilux when driven to MO is also decrease. However, for van, the decrement is only L_{ASmax} value while the L_{AFmax} and L_{AImax} value are increase.

Table 2: Difference of sound parameter according speed increment

Type of profile	Speed	Vehicle	ΔL_{Aeq}	$\%\Delta L_{Aeq}$	ΔL_{AFmax}	$\%\Delta L_{AFmax}$	ΔL_{AImax}	$\%\Delta L_{AImax}$	ΔL_{AIeqT}	$\%\Delta L_{AIeqT}$	ΔL_{ASmax}	$\%\Delta L_{ASmax}$
MLO	50	HILUX	5.70	8.99	-3.50	-4.20	-3.60	-4.23	5.30	8.24	-4.60	-5.70
		VAN	8.30	13.63	-3.50	-4.20	-3.60	-4.23	8.10	13.17	-4.60	-5.70
		BUS	7.70	10.19	0.80	0.95	0.60	0.70	8.10	10.66	1.80	2.24
		LORRY	2.30	3.04	0.80	0.95	0.90	1.05	2.80	3.68	1.80	2.24
MO	50	HILUX	4.00	6.08	-3.20	-4.09	-2.00	-2.54	3.90	5.88	-4.60	-6.00
		VAN	5.50	8.69	1.50	1.92	2.50	3.17	5.30	8.29	-0.60	-0.78
		BUS	6.50	8.28	1.90	2.25	-0.10	-0.11	6.50	8.23	4.40	5.51
		LORRY	5.50	7.25	1.60	1.92	-1.30	-1.50	6.00	7.86	5.70	7.38

Impulsivity. The determination of impulsivity resulting hilux and van for both TRS have the impulsivity except for hilux when driven through MO at speed 50km/h. The impulsivity of both vehicles, hilux and van come out from the difference of LAFmax with LAeq ($L_{AFmax} - L_{Aeq}$ >=10) which create annoyance to the surroundings. However, MLO profile create higher impulsivity compared to MO profile, for example for hilux at speed 30km/h, difference of L_{AFmax} and L_{Aeq} of MLO profile is higher than MO profile.
For bus and lorry which heavier vehicles shows that there are no impulsivity except when lorry driven through MO at speed 30km/h. The lorry driven through MO have an impulsive characterisric and exceeded the limit of difference L_{AFmax} with L_{Aeq} greater than 2 and difference of L_{AImax} and L_{ASmax} greater than 6.

Table 3: Impulsivity of sound parameter

Vehicle	Type of profile	Speed (km/h)	$L_{AImax} - L_{AFmax}$	$L_{AFmax} - L_{Aeq}$	$L_{AIeqT} - L_{Aeq}$	$L_{AImax} - L_{ASmax}$
HILUX	MLO	30	1.8	20	0.9	4.5
	MO		0.6	12.4	0.5	2.1
	MLO	50	1.7	10.8	0.5	5.5
	MO		1.8	5.2	0.4	4.7
VAN	MLO	30	1.8	22.5	0.6	4.5
	MO		0.6	14.9	0.6	2.1
	MLO	50	1.7	10.7	0.4	5.5
	MO		1.6	10.9	0.4	5.2
BUS	MLO	30	1.4	8.5	0.4	5.3
	MO		2.6	5.9	0.5	7.2
	MLO	50	1.2	1.6	0.8	4.1
	MO		0.6	1.3	0.5	2.7
LORRY	MLO	30	1.4	8.5	0.4	5.3
	MO		3.5	7.4	0.4	9.6
	MLO	50	1.5	7	0.9	4.4
	MO		0.6	3.5	0.9	2.6

Tonality TRSs profile also effects the frequency spectrum composition of the noise emitted. The significance of tonality can be determine when the A-weighted 1/3 octave band exceeds the neighbouring bands by 5dB. A change in A-weighted 1/3 octave band are plotted in Figure 3 for hilux and van when driven through MO at speed 50km/h and Figure 4 when lorry and bus transit on MLO at speed 50km/h. From Figure 3, the A-weighted 1/3 octave band of hilux and shows an increment of the frequency. However, there is no evidence of tonality from hilux and van since the -weighted 1/3 octave band not exceeded the neighbouring bands by 5dB.
On the other hand, Figure 4 shows the increment at low frequency only for bus and lorry when driven through MLO. Bus and lorry have significance of tonality at 125 Hz and 80Hz. Bus and lorry already has tonal component on the ordinary road without TRS.

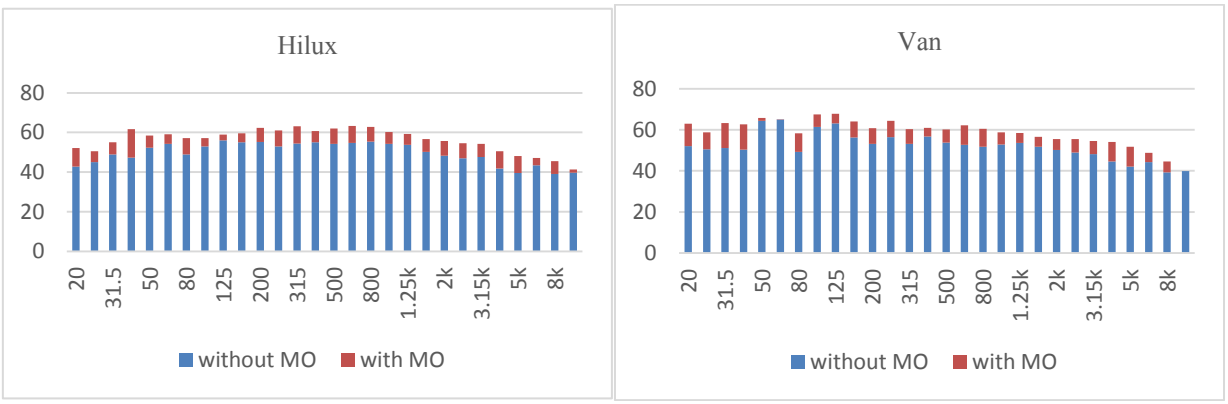


Figure 3: 1/3 octave band frequency content for v=50km/h

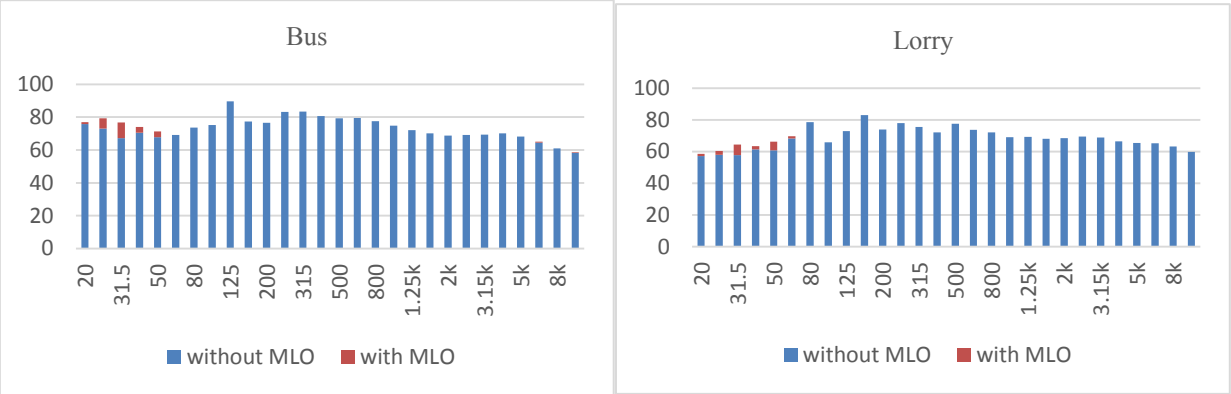


Figure 4: 1/3 octave band frequency content for v=50km/h

CONCLUSION

Transverse rumble strips (TRS) is usually being installed at dangerous area as traffic safety equipment on the road. This study is to investigate of impulsivity and tonality from two types of TRS which is Multilayer Overlapped (MLO) and Middle Overlapped (MO). The commercial vehicles used is Toyota Hilux represents 4wheel drive, Van Hiace represent van, 40 seated bus represents bus and one-ton lorry represent lorry. The outcome of this study is:

1. Both TRS do not produced significant increment of noise level to surroundings
2. Both TRS generated significant impulsivity due to 4wheel drive and van only
3. Both TRS generated significant tonal characteristics due to bus and lorry only

Both TRS generated noise annoyance based on impulsivity and tonality.

REFERENCES

[1] Freeman, J. R., Bansen, J. A., Wemple, B. & Spinks, R. (2008) *Innovative Operational Safety Improvements at Un-Signalized Intersections*. Tallahassee, Florida: Florida Department of Transportation.

[2] Miska, E., & T-01/09, T. C. (2009). Transverse Rumble Strips (TRS), 1-5

[3] Carlson, P., J., Miles, J., D. (2003) Effectiveness of Rumble Strips on Texas Highways: First Year Report. *Texas Transportation Institute The Texas A & M University System College Station , Texas*, 77843-3135

[4] Haron, Z., Yahya, K., Darus, N., Othman, M. H., Sanik, E. (2016) Impulsivity and Tonality of Noise due to Rumble Strips Installation.

[5] Othman, M. H. (2016) Performance and Modelling of Transverse Rumble Strips on Noise and Vibrations Stimuli. Faculty of Civil Engineering Universiti Teknologi Malaysia.

[6] An, D. S., Kwon, S. A., Lee, J., Suh, Y. C. (2016) Investigation of Exterior Noise Generated by Vehicles Traveling over Transverse Rumble Strips. *American Society of Civil Engineers*

[7] Datta, T.K., Gates, T. J., Savolainen, P. T. (2012) Impact of Non-Freeway Rumble Strips Phase 1, *ORBP Reference Number : OR09084A*

[8] Elghamrawy, T., El-Rayes, K., Liu, L., Odeh, I. (2012) Performance of Temporary Rumble Strips at the Edge of Highway Construction Zones. *Journal of Construction Engineering and Management*, 138,923-930

[9] Lee, J., An, D., Lim, J., Kwon, S., Son, H., Eo, M. (2013) Fundamental Study of Traffic Noise Characteristic due to Change Transverse Rumble Strip Shape. *Journal of Advanced Material Research*

[10] Jamrah, A., Al-Omari, A. & Sharabi, R. (2006) Evaluation of Traffic Noise Pollution in Amman, Jordan. *Environmental Monitoring and Assessment*, 120, 499–525.

[11] Banihani, Q., Jadaan, K. (2012) Assessment of Road Traffic Noise Pollution at Selected Sites in Amman, Jordan: Magnitude, Control and Impact on the Community. *Jordan Journal of Civil Engineering*, Volume 6, No. 2.

[12] Davis, M. L. and Masten, S. J. (2004) Principles of Environmental Engineering and Science. McGraw-Hill.

[13] ISO (1997a). ISO 11819-1:2001: Acoustics - Measurement of the influence of road surfaces on traffic noise - Part 1: Statistical Pass-By method . Brussels: European Committee for Standardization.

[14] Department of Envionment and Resource Management (DERM) (2000). Noise Measurement Manual, 3rd Edition, Queensland, Australia.

[15] Environmental Protection Agency, Guidance Note for Noise in Relation to Scheduled Activities, 2nd Edition, Environmental Ireland, 2006

[16] Sabato, A. and Niezrecki C. (2016) Rumble Strips Noise Emission Effects on Urban Road Traffic. INTER-NOISE and NOISE-CON Congress and Conference Proceedings, NoiseCon16, Providence, Rhode Island, pages 1-871, pp. 184-191(8). *Institute of Noise Control Engineering*

[17] ISO 9612: 1997, Acoustics-Guideline for the measurement and assessment of exposure to noise in a working environment.
[18] Strawn, R., Garceau, M., Biswas, R. (1993) Unstructed Adaptive Mesh Computations of Rotorcraft High-Speed Impulsive Noise. Paper No. AIAA-93-4359, *AIAA 15th Aeroacoustics Conference*

Unconfined Compressive Strength and Microstructural Characterisation of Magnesium Chloride Treated Marine Clay

Amalien Aisyah Binti Mohamed, Datin Fauziah Binti Kasim

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

fauziahkasim@utm.my

Keywords: Marine Clay; Unconfined Compressive Strength; Magnesium Chloride; Scanning Electron Microscope.

ABSTRACT. Marine clay is a type of clay that is abundantly found in the coastal and in several offshore areas spread over many parts of the world as well as Malaysia. Marine clay is categorised in the soft soil group that has been characterised by low shear strength and high compressibility. Thus, marine clay requires soil improvement before any construction to be carried out on top of the soil due to its low strength. The study that was carried out had the specific objectives, i.e., to obtain the engineering properties of marine clay from literature review of previous research that used the same marine clay of this study, to investigate the unconfined compressive strength (UCS) of marine clay treated with magnesium chloride ($MgCl_2$), to compare the results between untreated marine clay and treated marine clay with $MgCl_2$ according to the UCS of marine clay, and to analyse the microstructure of the untreated marine clay and the marine clay treated with $MgCl_2$ with Scanning Electron Microscope (SEM). In this study, samples of marine clay soil were prepared under various curing periods (3 days, 7 days, 14 days, and 28 days) and various percentages mixed with $MgCl_2$ (0%, 2%, 4%, 6%, 8%, and 10%). The results from the conducted UCS test showed that 4% $MgCl_2$ gave highest strength of all at 7 days of curing period of 82 kPa compared to the untreated sample that had UCS value of 52 kPa. The microstructural study of SEM was done and had found that $MgCl_2$ additive in the marine clay produced new products that filled the porous structure that occurs in an untreated marine clay.

INTRODUCTION

Marine clay is a type of clay that is abundantly found in the coastal and in several offshore areas spread over many parts of the world as well as Malaysia. Marine clay is categorised in the soft soil group that has been characterised by low shear strength and high compressibility. In addition, marine clay subjected to swelling and shrinkage behaviour according to its moisture content (Marto *et al*., 2015). These characteristics make marine clay a problematic soil. Soft or highly compressible soils are often encountered on many civil engineering project sites, which lack sufficient strength to support the loading either during construction or throughout the service life. Since more and more construction projects are encountering soft clays, there is a need to improve the properties of soft clays. By right, soil stabilisation is a must to improve the physical and engineering properties of problematic soils to some predetermined targets.

Problem Statement

Majority of soft marine clay in Malaysia covers in west and east coasts of Peninsular Malaysia. The main problem is the properties of marine clay which is unable to fulfil the specification requirements for construction activities such as highway construction. The settlement of the marine clay has become the problem for transportation design. This is due to the poor strength of marine clay when subjected to heavy loadings. A method of soil stabilisation is a way to be applied onto marine clay for the improvement of the strength. Nowadays, among the different methods of soil improvement, chemical stabilisation that uses chemical additives in order to increase soil strength parameters is attracting more attention. Magnesium Chloride ($MgCl_2$) as a raw environmental friendly additive has been used by previous researchers to improve laterite, bentonite, and kaolin soil. A research that used $MgCL_2$ as soil stabiliser onto marine clay also was done before, but the percentages of $MgCl_2$ used were in small amounts. Inspired by the successful experiments that has increased the strength characteristic of the soils by using $MgCl_2$, this study was aimed at utilising the $MgCl_2$ stabiliser in treating the marine clay with higher content of the additive, thus improving the strength of the marine clay.

Objectives

The specific objectives of the study were:

4. To obtain the physical and mechanical properties of the pure soft marine clay as the sample to be treated by adding magnesium chloride ($MgCl_2$) via literature review.
5. To determine the unconfined compressive strength (UCS) and optimum percentage magnesium chloride of treated marine clay by using various percentages of magnesium chloride ($MgCl_2$) added to marine clay at different curing periods of 3, 7, 14 and 28 days.
6. To compare the results of untreated marine clay and treated marine clay with $MgCl_2$ with respect to the unconfined compressive strength of marine clay.

7. To analyse the microstructure of untreated marine clay and marine clay treated by $MgCl_2$ with respect to various curing periods using Scanning Electron Microscope (SEM).

Scope of Study

The study focused on the effects of magnesium chloride ($MgCl_2$) on compressive strength of soft marine clay by conducting laboratory tests of unconfined compression test (UCT) and Scanning Electron Microscope (SEM) . Before the laboratory tests were conducted, data on the physical properties of untreated soft marine clay and magnesium $MgCl_2$ were collected from the previous researchs that had been done on the same sample. The sample involved in this study was collected from West-Coast Expressway (WCE) project in Teluk Intan, Perak. The samples were tested by adding various percentages of magnesium chloride ($MgCl_2$) of 2%, 4%, 6%, 8% and 10% by the dry weight of soil at various curing periods of 3, 7, 14, 28 days.

LITERATURE REVIEW

Soft or highly compressible soils, particularly marine clays are often encountered on many civil engineering project sites, which lack sufficient strength to support the loading either during construction or throughout the service life (Zhang *et al*., 2013). When infrastructures such as road embankments and bridge foundations are constructed on these soil deposits, several geotechnical engineering problems are encountered (Latifi *et al*., 2015). According to Kasim *et al*. (2015), majority soft soils in Malaysia cover in west and east of Peninsular Malaysia. This leads to problem towards sustainable construction, in particularly the currently undergoing West Coast Expressway (WCE) project (Marto *et al*., 2015).

Soil stabilisation is the process of improving the physical and engineering properties of problematic soils to some predetermined targets (Latifi *et al*., 2016). Nowadays, among the different methods of soil improvements, the use of chemical additives for soil stabilisation in order to increase soil strength parameters and loading capacity is attracting more attention. This is due to their low cost and convenience, particularly in geotechnical projects that require a high volume of soil (Latifi *et al*., 2016). The stabilisers of soils are categorised into two main groups as traditional and non-traditional stabilisers. Traditional stabilisers are calcium based. They include cement, lime, fly ash and bituminous materials. Meanwhile, non-traditional stabilisers are not calcium based. They consist of various combinations such as enzymes, liquid polymers, resins, acids, silicates, ions and lignin derivatives (Latifi *et al*., 2016).

The use of traditional soil stabilisers such as lime or cement can cause negative environmental impacts including retarded vegetation growth, reduction in groundwater quality and human health problems especially air pollution due to CO_2 emission from the production and process of cement (Latifi *et al*., 2016). Various products of non-traditional soil stabiliser which are not calcium based potentially effective alternative for treating soils. These non-traditional chemical stabilisers are usually sold as concentrated liquids diluted with water at the construction site, then either spread on the soil before compaction or pressure injected to treat deeper soil layers (Latifi *et al*. 2013). Non-traditional stabilisers comprises of a variation combination of chemical agents that interact with the soil such as magnesium chloride ($MgCl_2$) and biomass silica stabilizer.

As the usage of $MgCl_2$ is becoming more common, its potential for the improvement of the geotechnical properties of problematic soils is receiving increasing attention (Latifi *et al*., 2015). Previous researches were already conducted to test the compressive strength of various soft soil when treated with $MgCl_2$. Latifi *et al*. (2016) had stabilised laterite soil using $MgCl_2$ contents of 1%, 3%, 5%, 7%, and 9% at curing periods of 0, 3, 7, 14, and 28 curing days. All of the percentages caused great strengths compared to the untreated laterite. For all percentages, the strength increased as curing days increased. 5% was the optimal amount of $MgCl_2$ for the study.

Meanwhile, soil stabilisation onto bentonite and kaolin using $MgCl_2$ by Latifi *et al*. (2015) also showed positive results. 2%, 4%, 6%, 8%, 10%, and 12% of $MgCl_2$ by dry weight of both types of soils were used for the research. For bentonite, all of the $MgCl_2$ treated soils at all percentages resulted in much higher UCS values at all curing periods (of 0, 3, 7, 14, and 28 days) than the untreated bentonite. 8% $MgCl_2$ gave the highest strength of the treated bentonite of all. For kaolin, it was also had found from UCS results from Latifi *et al*. (2015) that using $MgCl_2$ as additive would increase the strength of the soil. Different than for bentonite, 10% $MgCl_2$ gave the greatest UCS values at all curing periods for kaolin. Sukairi (2016) had done soil stabilisation of marine clay using 0.2%, 0.3%, 0.4%, 0.5%, and 0.6% amounts of $MgCl_2$. From the research, all of the amounts of $MgCl_2$ increased the marine clay strength but with different strength gained pattern.

Another research had performed SEM analysis onto expansive and dispersive soil that was treated using $MgCl_2$. Turkoz *et al*. (2014) had compared the SEM images between an untreated soil and a soil treated with 7% $MgCl_2$ that was the optimal percentage for the research. The images of the samples without the additive depict a higher-density structure. In the sample with a 7% additive content, the structure is aggregated and contains more voids. Increasing the additive content caused the particles to reorganise and the structural integrity to increase. The resultant agglomeration reduces the interactions between the surface areas and water, which in turn changes the geotechnical properties.

METHODOLOGY

The main objective of the research was to study the effect on strength of marine clay treated by magnesium chloride. Unconfined Compressive Test (UCT) and Scanning Electron Microscope (SEM) were conducted to get the data on strength of marine clay treated by magnesium chloride. This research methodology consisted of 4 key activities: collection data on properties of marine clay, preparation of sample, unconfined compressive strength and microstructural characterisation.

Collection Data on Physical Properties of Marine Clay

The soft marine clay was obtained from the West-Coast Expressway (WCE) project in Teluk Intan Perak. The data was collected from the previous research of the same type of sample. The data for index properties are plastic limit, liquid limit, plasticity index, specific gravity, maximum dry density and optimum moisture content. All of the data were taken by Sukairi (2016) after the soil was being tested through several tests such as cone penetration test, field vane shear test, specific gravity test and compaction test.

Preparation of Sample

Various amounts (0, 2, 4, 6, 8, and 10% by dry weight of the soil) of the magnesium chloride ($MgCl_2$) solution were added and mixed into the prepared soil sample. All mixing was performed manually, and special attention was paid to obtaining a homogeneous mixture in each step. The optimum water content and maximum dry density values needed to prepare the samples for use in strength tests for each magnesium chloride additive percentage were determined. In Table 1, mix proportions used in preparing samples are presented in detail. Curing times of 3, 7, 14 and 28 days were used in this study. A minimum of three samples for each curing time were prepared in order to provide adequate data to validate the results.

Table 1: Types of sample prepared for UCS test

Sample	Mixing Percentage
1	Soft Marine Clay + 0% magnesium chloride ($MgCl_2$) + water (OMC)
2	Soft Marine Clay + 2% magnesium chloride ($MgCl_2$) + water (OMC)
3	Soft Marine Clay + 4% magnesium chloride ($MgCl_2$) + water (OMC)
4	Soft Marine Clay + 6% magnesium chloride ($MgCl_2$) + water (OMC)
5	Soft Marine Clay + 8% magnesium chloride ($MgCl_2$) + water (OMC)
6	Soft Marine Clay + 10% magnesium chloride ($MgCl_2$) + water (OMC)

Unconfined Compressive Strength Test. The unconfined compressive strength (UCS) test has been used on all specimens based on British Standard 1377 part 7:1990 with a constant stress rate at 16 mm/min. Each specimen was compressed until peak load was achieved where the applied load was recorded by a data acquisition system. The UCS test is to determine the compressive strength of treated and untreated soil using magnesium chloride ($MgCl_2$) as stabiliser. Triplicate samples were used to get a consistent and accurate result.

Scanning Electron Microscope. Microstudy was done to get extra information that may be useful by conducting some micro-structural tests to discuss the possible mechanisms that developed the stabilisation process. The change in structure of the soil occurred because of the physiochemical processes due to the addition of the additives was studied through the Scanning Electron Microscope (SEM). At least two samples of an untreated marine clay sample and one treated marine clay that had the greatest UCS were brought to be analysed for comparison. Magnifications of 500 times, 1000 time, 2500 times, and 5000 times were used because they were found to produce clear images of the marine clay mincrostuctures.

RESULTS AND DISCUSSION

Physical Properties of Marine Clay

From the previous study by Sukairi (2016), the physical properties had been determined on the same soil obtained from West-Coast Expressway (WCE) project. For this study, the physical properties obtained by Sukairi (2016) have been selected as the baseline for this study. The value of liquid limit, plastic limit, plasticity index and particle density of the sample had been obtained by Sukairi (2016). The value of the physical properties of marine clay obtained shown in Table 2.

Table 2 : Physical properties of marine clay (Sukairi, 2016)

Properties	Marine Clay
Liquid limit (%)	78
Plastic limit (%)	41
Plasticity index (%)	37
Specific gravity	2.68
OMC (%)	38
MDD (Mg/m^3)	1.21

Unconfined Compressive Strength (UCS)

The results from Unconfined Compressive Test (UCT) in Figure 1 shows the untreated marine clay Unconfined Compressive Strength (UCS) is 52 kPa. The results from UCT for the magnesium chloride ($MgCl_2$) content of 2% show increase in strength until 14 days of curing. The strength gained for 2% $MgCl_2$ starts with 52 kPa at 3 days curing period and then increased up to 64 kPa and 75 kPa at curing periods of 7 days and 14 days, respectively. At 28 days curing period, UCS of 2% $MgCl_2$ starts to drop. On the other hand, 4% and 6% $MgCl_2$ also caused increase in strength to marine clay but the peaks are only up to 7 days of curing. After 7 days, UCS starts to decrease for both percentages.

The results from UCT for the $MgCl_2$ content of 8% and 10% shows a decrement in UCS. For 3 days of curing period, 8% and 10 % of $MgCl_2$ stabiliser content strength starts with 24 kPa and 16 kPa, respectively. The early strengths for both percentages are poorer than the UCS for untreated marine clay of 52 kPa. Despite the low initial strength, 8 % $MgCl_2$ gives increment of strength until 28 days curing period but the highest strength at 28 days of curing is only 38 kPa which is still low. 10 % $MgCl_2$ gains strength increment until 14 days curing period. After that, UCS begins to drop down.

Figure 2 shows the relationship between UCS and curing period for various percentage of magnesium chloride $MgCl_2$. In the figure it shows that the strength of marine clay increase when the marine clay treated by using 2%, 4%, and 6% of $MgCl_2$. Normally, the strength increased during curing can be explained through the cementing gel material (hydrates), formed through pozzolonic reactions. The new products formed may fill in voids in marine clay soil structure that makes soil structure denser thus can produce greater strength. When the marine clay treated by using 8% and 10% of $MgCl_2$, the marine clay strengths are far lower than the strength of untreated marine clay. Figure 2 shows that the optimum percentage to treat marine clay is 4% where it has the highest strength. The strength is increase by curing period up to 7 days and its start to decrease the strength when the treated marine clay exceeds 7 days. This indicated that the greatest part of the marine clay treated by $MgCl_2$ reactions happened within 7 days.

For the marine clay treated by $MgCl_2$ more than optimal value of 4%, compressive strength begins to drop. This might be because of precautions that did not take in handling chemical during mixing the marine clay and $MgCl_2$. Both the chemicals and marine clay are sensitive and need special precaution to handle them. The degradation of strength could also have been due to the amount of alkaline stabiliser, which exceeded the requirement for chemical reaction in the samples. During the preparation of samples, it was found that the marine clay soil became 'softer' and squishier as the percentage of $MgCl_2$ increases. The 6% $MgCl_2$-treated marine clay was softer than that of the 4% $MgCl_2$-treated marine clay, and the 8% and 10% $MgCl_2$ was so squishy that it was so hard to prepare a good specimen as they tend to consolidate even after proper compaction was done when preparing them in cylindrical specimens. Based on the Figures 1 and 2, 4% of $MgCl_2$ was depicted as the optimum value for addition to the marine clay.

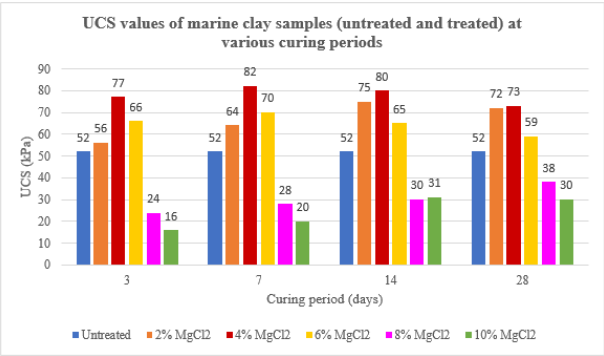


Figure 1: The UCS of marine clay treated by $MgCl_2$

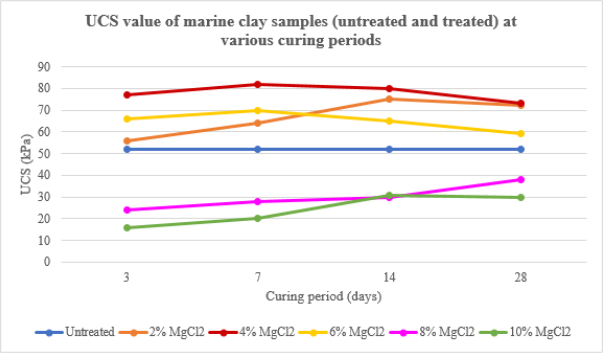


Figure 2: Relationship between UCS and curing period for various percentage of $MgCl_2$

Scanning Electron Microscope (SEM) images

Three samples were chosen to be analysed microstructurally. One 4% magnesium chloride ($MgCl_2$) 7 days curing period sample was chosen because it produced the optimal result. The untreated sample was chosen to be compared with the 4% sample. Meanwhile, one 6% $MgCl_2$ 7 days curing period sample was chosen as an additional data to study what happened to the microstructure that made the UCS value is lower than for 4% $MgCl_2$ samples. Figure 3, Figure 4,

and Figure 5 show the SEM images of untreated sample, 4% $MgCl_2$ treated sample at 7 days curing period, and 6% $MgCl_2$ treated sample at 7 days curing period, all at 2500 times magnifications, respectively. As can be seen in Figure 3, the untreated samples showed a dispersed and obvious discontinuous structure, where the voids and porosity are more visible. Compared to the SEM images of the untreated sample, the sample with this optimal percentage of $MgCl_2$ shows less pores and voids as in Figure 4. There were coarse structures that might be the new products formed from the stabilisation process that filled the pores in soil structure. On the other hand, SEM image of 6% $MgCl_2$ treated sample shows image result similar to the 4% $MgCl_2$ sample, where there are new products formed that filled the voids in soil structure, but at less coarser size. This might due to another advanced reaction because of too much contents of $MgCl_2$ or too high alkalinity that reacted with the soil's chemical compositions. This might be the reason of why the UCS values began to drop lower than the optimal mixture as the chemical content get higher than optimal value of 4%.

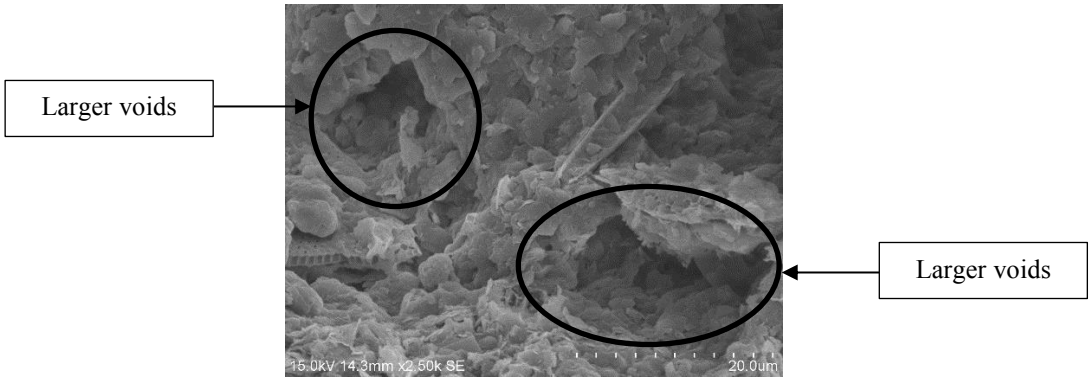


Figure 3: SEM image of the untreated sample at 2500 times magnification

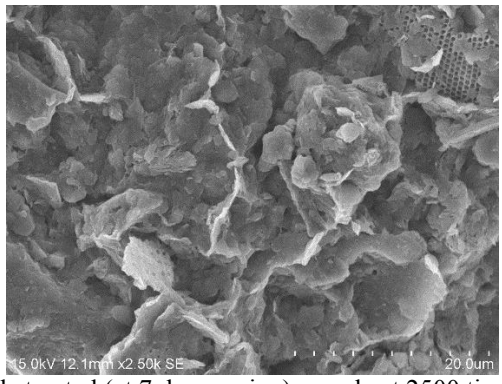


Figure 4: SEM image of the 4% $MgCl_2$-treated (at 7 days curing) sample at 2500 times magnification, denser than that of the untreated sample

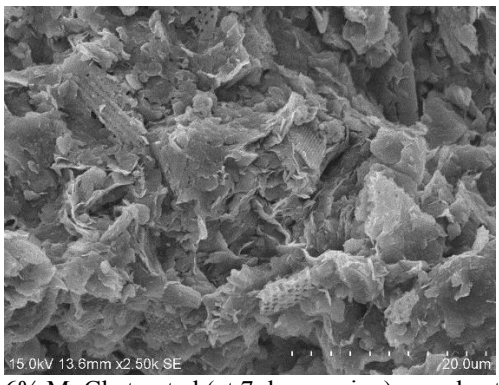


Figure 5: SEM image of the 6% $MgCl_2$-treated (at 7 days curing) sample at 2500 times magnification

CONCLUSIONS

This study was undertaken to investigate the influence of magnesium chloride ($MgCl_2$) percentage and curing time on the unconfined compressive strength (UCS) and microstructural characterisation of treated and untreated marine clay. The conclusions of the study carried out are as follows:

1. The UCS of untreated marine clay is 52 kPa. Marine clay treated with 2%, 4%, and 6% of $MgCl_2$ gives greater UCS results compared to the UCS of untreated marine clay, while marine clay treated with 8% and 10% $MgCl_2$ gives poorer UCS values than the UCS of untreated marine clay.
2. 4% of $MgCl_2$ is the optimal amount of the stabiliser among all five percentages because the UCS results obtained are the greatest. Highest strength of 82 kPa is reached at curing period of 7 days.
3. 2% and 10% $MgCl_2$ contents show similar pattern of UCS gained where the strength increases until 14 days of curing. At 28 days of curing, the strength decreases for both percentages. 4% and 6% $MgCl_2$ contents show same pattern of UCS gained where the strength increases until 7 days of curing. After that, UCS values start to decrease for both percentages. Only strength for 8% $MgCl_2$ content keeps increasing as curing period increases.
4. The Scanning Electron Microscope (SEM) results showed the microstructural behaviour that might be the factor of the UCS results. The untreated marine clay soil structure has many voids. Adding $MgCl_2$ with marine clay produces new products that filled the porous areas within the soil particles that lead to a continuous soil fabric resulting in stronger and denser soil. However, adding too much amount of $MgCl_2$ that is greater than the optimal value of 4% by dry weight of marine clay, produces new products with smaller or finer sizes or too much alkalinity that might be the reason of the decreasing of strength began.

REFERENCES

[1] ASTM International. (2011). Active Standard ASTM D2487 (American Standards): Standard Practice for Classification od Soils for Engineering Purposes (Unified Soil Classification System). Pennsylvania, USA.

[2] Kasim, F., Marto, A., Rahman, N. A. A., and Tan, C. S. (2015). Unconfined Compressive Strength and Microstructure of Clay Soil Stabilised with Biomass Silica. *Jurnal Teknologi*. *77*:11, 9-15.

[3] Latifi, N., Horpibulsuk, S., Meehan, C. L., Majid, M. Z. A., & Rashid, A. S. A. (2016). Xanthan gum biopolymer: an eco-friendly additive for stabilization of tropical organic peat. *Environmental Earth Sciences*, *75*(9), 825.

[4] Latifi, N., Rashid, A. S. A., Ecemis, N., Tahir, M. M., & Marto, A. (2016). Time-dependent physicochemical characteristics of Malaysian residual soil stabilized with magnesium chloride solution. *Arabian Journal of Geosciences*, *9*(1), 58..

[5] Chong, S. Y., & Kassim, K. A. (2015). Effect of lime on compaction, strength and consolidation characteristics of pontian marine clay. *Jurnal Teknologi*, *72*, 41-47.

[6] Latifi, N., Rashid, A. S. A., Siddiqua, S., & Horpibulsuk, S. (2015). Micro-structural analysis of strength development in low-and high swelling clays stabilized with magnesium chloride solution—A green soil stabilizer. *Applied Clay Science*, *118*, 195-206.

[7] Aziz, N. (2015). *Soft Soil Improvement by Using Chemical-rubber Chips Mixture* (Doctoral dissertation, Universiti Teknologi Malaysia).

[8] Sukairi, S. M. (2016). Strength of Marine Clay Stabilized using Geopolymer. Universiti Teknologi Malaysia, Johor Bahru.

[9] Turkoz, M., Savas, H., Acaz, A., & Tosun, H. (2014). The effect of magnesium chloride solution on the engineering properties of clay soil with expansive and dispersive characteristics. *Applied Clay Science*, *101*, 1-9.

[10] Yunus, N. Z. M., Marto, A., Pakir, F., Kasran, K., Azri, M. A., Jamal, S. N. J., & Abdullah, N. (2015). Performance of lime-treated marine clay on strength and compressibility chracteristics. *Int. J. of GEOMATE*, *8*(2), 1232-1238.

Soil Compaction for Natural Laterite Soil.

Amirah Nazihah Binti Amir Husain, Nazri Bin Ali

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

nazriali@utm.my

Keywords: Compaction of laterite soil, Standard Proctor Test, Modified Proctor Test, Comparison of Result.

ABSTRACT. Soil compaction is a cumpolsory in any types of construction such as highrise construction, embankment and road pavement. Generally, soil compaction is a process which is stress is applied to the soils to make the soil particles closely packed, and at the same time eliminate the air voids that lead to increasing of dry density. The key objectives of this research is to investigate relationship of moisture content and dry density of natural laterite soil, in addition to develop compaction curve that can show optimum moisture content and maximum dry density. For this study, two methods of compaction test has been used which are Standard Proctor Test and Modified Proctor Test. Based on the result obtain from test, comparison of result between this method is done. Modified Proctor gave higher value of maximum dry density compared to Standard Proctor even though they are using same range of percentage of moisture content. At the same time, this study also shown that higher compactive effort will produce higher maximum dry density.

INTRODUCTION

Generally, soil compaction is defined as the method of mechanically increasing the density of soil. In construction field, we can say that all construction need soil compaction such as construction of highway embankments, earth dams and other engineering structures because loose soils must be compacted to increase their unit weight. By completing this process will help loose soils obtain satisfactory engineering properties such as strength and bearing capacity. But, if compaction is done improperly, settlement of soil could occur and it will lead to increase the cost because of maintenance or imagine it getting worse, structure failure would happen.

In this study, research is focused on soil compaction for natural laterite soil. Laterite soil produced by intensive and long-lasting weathering of the underlying parents rocks. Laterite that are referred to as a soil types and at the same time a rock types have high content of iron aluminium. Due to high iron oxide content, we can say that most of laterite soil are rusty-red colour. In addition, laterite soils commonly formed in a hot and wet area. So this study is conducted to investigate briefly about soil compaction for natural laterite soils.

Problem Statement

Soil compaction is a compulsory step before start any kind of construction. It is very important to have a proper soil compaction because it necessary flat base which provide crucial support for various construction foundation. By having a proper compaction also help increase resistance and stability. As stated earlier in introduction, compaction is a process to remove air by applying some weights in order to avoid settlement. Soil is divided into two categories which are cohesive soils and non-cohesive soils. Because of that, the process is different depend on types of soils. For this study, research is focused on natural laterite which is commonly referred as soils and rocks at the same time. Failure to remove air between soil particles can lead to unexpected situation such as penetration or absorption of water that can cause cracking of road or lead to settlement which can cause a building falling down. To properly compact natural laterite soils and avoid major problems in the future, this study is conducted.

Objectives

The objectives of this study are:

1. To determine relationship between moisture content and dry density of soil
2. To do soil sampling and to conduct Proctor compaction test based on British Standard- Methods of Test for Soils for Civil Engineering Purposes- Part 4: Compaction Related Test.
3. To develop dry density and moisture content curve in order to obtain optimum moisture content and maximum dry density.
4. To make a comparison between results of Standard Proctor and Modified Proctor.

Scope of Study

Soil compaction is a compulsory to any kind of civil engineering construction that will involve every types of soils. But in this study, research is focused on soil compaction for natural laterite soils only. Laboratory test, which are Standard Proctor and Modified Proctor were conducted in order to determine moisture content of natural laterite soil. Sample were collected at area of Balai Cerap, UTM.

LITERATURE REVIEW

Soil compaction is a part of any civil construction works such as roads and buildings construction in order to increase the maximum dry density of the soil. Compaction of soils also is the mechanical remolding process which were soil particles are forced to pack more closely together to eliminate the air voids [1]. Theories of compaction generally explain about dry density and moisture content relationship which represent by curve obtained in laboratory test or compaction test [2]. Meanwhile, laterite soil is a reddish brown soil which were belongs to ferruginous tropical soils group that are derived from igneous and metamorphic rocks [3]. Most of all laterites are rusty-red coloration because of high iron oxide content. Other than rich in iron and aluminium, laterite also is a soil and rock type which is commonly considered to have formed in hot and wet tropical areas.

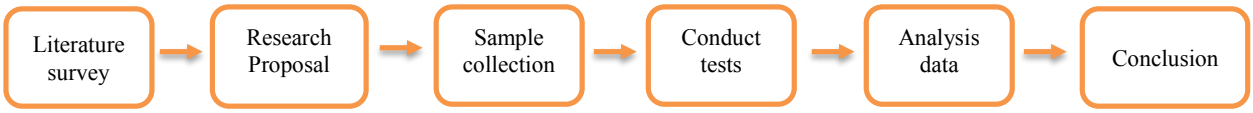
Soil compaction test is conducted to determine the optimum moisture content which can help the soils to achieve its maximum dry density. During the test, void ratio, maximum dry density, permeability, shear strength and critical pressure were measure. Soil is compacted at various energy and the result is discussed based application in its natural state [4]. In addition, other than it is important as a base for construction, soil compaction is an important component of land degradation syndrome which are an issue for soil management around the world [5]. Other than that, soil compaction also one of the causal agent of soil erosion, nutrient depletion and pollution which have been reported by UN and other international organizations [6]. Soil compaction indirectly affect almost all properties of the soil whether physically, chemically or biologically [7].

Soil is compacted in order to reduce settlement and permeability and at the same time to increase shear strength. Soil compaction is a compulsory in geotechnical fields such as railway subgrades and earth retaining structure [8]. Soil compaction by using Proctor Test showed the relationship between water content on dry weight of compacted soil and effect of water to lubrication in the soil. Proctor Test also a method to remove air within the soil by applying controlled mechanical energy in the laboratory [9]. To gain better understanding about properties of compacted laterite soils need characterization of its compositions and structural arrangements. [10] state that nature and magnitude of compaction in fine-grained soil will influenced mechanical behavior.

Meanwhile, [11] found sample of compacted dry-of-optimum stiffer than samples compacted wet-of-optimum at the same relative compaction. [12] Describe the structure as a combination of fabric or structural arrangement and bonding. In addition, Continuous Compaction Control (CCC) is an instrumentation that can enhance assessment of soil properties during compaction by its data is used to adjust operation of compactor in order to optimize the compaction process and achieve uniform compaction. For soil that are compacted by drum rolling, underlying soil become denser as the degree of compaction increase [13]. Meanwhile, in dynamic soil compaction, when applied energy per unit area reached its limit, heaving and loosening of soil around the tamper can occur. [14].

METHODOLOGY

Proctor Compaction Test is conducted to determine the optimum moisture content at which a given soil type will become most dense and achieve its maximum dry density. There are two types of Proctor test which are Standard Proctor Test and Modified Proctor Test. There have been proven that Standard Proctor Test could not reproduce the densities measured in the field and this situation indirectly lead to development of Modified Proctor Test. Therefore this research is conducted to make a comparison between Standard Proctor Test and Modified Proctor Test. After conducting the test, data will be analyze. This research is conducted based on the flow chart below:



Generally, literature survey is when other journals from the other authors which were related to this topic is taken as a reference. This is very important because from the literature survey, an overview about this topic can be done, theoretically or practically. In addition, by doing this survey also really help to spark some ideas which were very useful for this study. Meanwhile, a research proposal is a proposal regarding this study, Soil Compaction for Natural Laterite Soil, which contain all the key elements involved in the research process and included all the information so that readers are able to evaluate the

proposed study very well. In addition, this proposal will explain very well about this study for example why this research is conducted? How this research can give benefits to community? Method to achieve the objectives of this research and the expected finding also have been clarify in this research proposal.

Soil compaction is a compulsory to all types of soils and construction related to Civil Engineering. But, for this research, soil compaction is focused only for natural laterite soil. 20 kg of natural laterite soil is taken around Balai Cerap of UTM Skudai's area at 5 m depth. After digging 5 m depth, soil sample is taken and put into a tray. Then, soil sample is placed in an oven, for at least 24 hours for air-dried process before undergo the test.

There are two types of compaction test can be done to ensure that the objective of this study is achieved. Standard Proctor Compaction Test and Modified Proctor Compaction Test is conducted in order to determine the relationship of moisture content and dry density, indirectly to obtain maximum dry density and optimum moisture content of the soils. The mechanical effort used is normally ramming with 2.5 kg rammer for the light compaction test and 4.5 kg rammer for the heavy compaction test.

For this study, Standard Proctor Compaction Test is done by applying 27 blows per layers, continuously for 3 layers, from the rammer dropped from a height of 300 mm above the soil. Meanwhile, for Modified Proctor Compaction Test, 62 blows is applied per layers and there are 5 layers for this test. Same with Standard test, rammer is dropped, free fall from a height of 300 mm above the soil surface.

Based on the results obtained from the test, dry unit weight and moisture content is calculated. After that, compaction curve is plotted in order to obtain maximum dry density (MDD) and optimum moisture content (OMC) for both Standard Proctor Test and Modified Test. After that, comparison is done between this method in order to shown that which one is much better to use in the field.

RESULTS AND DISCUSSION

To achieve main objective of this study, which is to determine moisture content and dry density relationship, two compaction tests is conducted according to British Standard: Methods of Test for Soils for Engineering Purposes -Part 4: Compaction Related Test (BS 1377-4:1990), which is by using Standard Proctor Compaction Test with 2.5 kg rammer and Modified Proctor Compaction Test, with 4.5 kg rammer. Both of this tests is conducted using same soil type which is natural laterite soil, same moisture content and same particle sizes, which are soils that passing 20 mm sieve. By using same moisture content, which were 25%, 27%, 31%, 33% and 35%, dry density for both of the tests is compared.

Standard Proctor Test

According to BS 1377: Part 4: 1990: 3.3, 'light' compaction test using 2.5 kg rammer method is conducted. This test is suitable for soils particles that are less than 20 mm. The results of the compaction are shown in the Table 1.

Table 1: Result for Standard Proctor Compaction Test

Assumed moisture content	%	25	27	31	33	35
Test No.	Unit	1	2	3	4	5
Mass of empty mould, M1	kg	5.32	5.32	5.32	5.32	5.32
Mass of empty mould + wet soil, M2	kg	6.802	6.864	7.053	6.996	6.991
Mass of wet soil	kg	1.482	1.544	1.733	1.676	1.671
Volume of mould, V	mm^3	993.899	993.899	993.899	993.899	993.899
Bulk density	Mg/m^3	1.491	1.553	1.744	1.686	1.681
Moisture content	%	25.14	27.31	31.85	33.77	35.75
Dry density	Mg/m^3	1.192	1.220	1.322	1.261	1.238

Five different moisture content is used for this test which are 25%, 27%, 31%, 33% and 35%. For every moisture content, 3 representative sample of the soil is taken and was put in moisture container before putting it in oven for 24 hours. Result for the moisture content are shown below.

Table 2: Result for moisture content

PERCENTAGE OF ASSUME MOISTURE CONTENT	25%	27%	31%	33%	35%
AVERAGE OF MOISTURE CONTENT	25.14	27.31	31.85	33.77	35.75

Five (5) samples of soils mixed with different moisture contents are compacted and its dry density is determined. For 25%, 27%, 31%, 33%, and 35% of moisture contents, its' dry density is 1.192 Mg/m³, 1.220 Mg/m³, 1.322 Mg/m³, 1.261 Mg/m³ and 1.238 Mg/m³ respectively. From the analysis, the maximum dry density (MDD) of the soil sample is 1.322 Mg/m³ and the optimum moisture content (OMC) is 31.85 %.

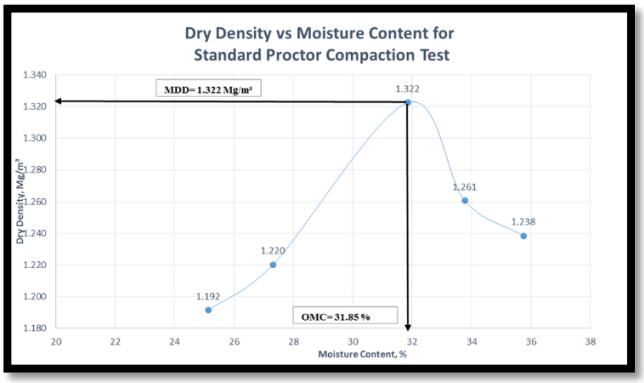


Figure 1: Compaction curve for Standard Proctor

Modified Proctor Test

Based on BS 1377: Part 4: 1990: 3.3, 'heavy' compaction test using 4.5 kg rammer method is conducted using same mould as used in 'light' compaction test. Same as standard proctor test, this test is suitable for soils particles that are less than 20 mm. The results of the compaction are shown in the Table 3.

Table 3: Result for Modified Proctor Compaction Test

Assumed moisture content	%	25	27	31	33	35
Test No.	Unit	1	2	3	4	5
Mass of empty mould, M1	kg	5.59	5.59	5.59	5.59	5.59
Mass of empty mould + wet soil, M2	kg	7.33	7.41	7.64	7.43	7.41
Mass of wet soil	kg	1.74	1.82	2.05	1.84	1.82
Volume of mould, V	mm³	993.899	993.899	993.899	993.899	993.899
Bulk density	Mg/m³	1.751	1.831	2.063	1.851	1.831
Moisture content	%	24.82	26.31	31.63	35.43	38.17
Dry density	Mg/m³	1.403	1.450	1.567	1.367	1.325

Five different moisture content is used for this test which are 25%, 27%, 31%, 33% and 35%. For every moisture content, 3 representative sample of the soil is taken and was put in moisture container before putting it in oven for 24 hours. Result for the moisture content are shown below.

Table 4: Result for moisture content

PERCENTAGE OF ASSUME MOISTURE CONTENT	25%	27%	31%	33%	35%
AVERAGE OF MOISTURE CONTENT	24.82	26.31	31.63	35.43	38.17

Five (5) samples of soils mixed with different moisture contents are compacted and its dry density is determined. For 25%, 27%, 31%, 33%, and 35% of moisture contents, its' dry density is 1.403 Mg/m³, 1.450 Mg/m³, 1.567 Mg/m³, 1.367 Mg/m³ and 1.325 Mg/m³ respectively. From the analysis, the maximum dry density (MDD) of the soil sample is 1.567 Mg/m³ and the optimum moisture content (OMC) is 31.63 %.

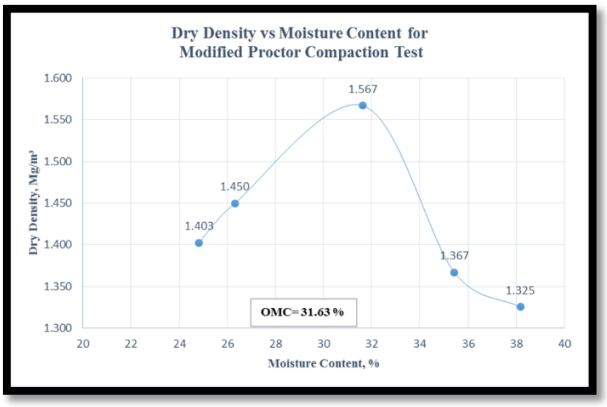


Figure 3: Compaction curve for Modified Proctor

Determine Air Void Line

It is a compulsory for compaction curve to have air void lines. An air voids line is a curved line that show relationship of dry density and moisture content for soil containing a constant percentage of air voids. By removing all air voids, total voids between solid particles are filled with water so that the soil reaches fully saturated condition. For this laterite soil, specific gravity, Gs= 2.765. Table 5 below show value of dry density for respective air void content.

For determination of air void line, moisture content is assumed in the range of 20% until 40% because for both Standard Proctor and Modified Proctor, moisture content is within that range.

Table 5: Dry Density for Respective Air Void Content

AIR VOID CONTENT Va= 0% Gs= 2.765		AIR VOID CONTENT Va= 5% Gs= 2.765		AIR VOID CONTENT Va= 10% Gs= 2.765	
MOISTURE CONTENT	DRY DENSITY (Mg/m^3)	MOISTURE CONTENT	DRY DENSITY (Mg/m^3)	MOISTURE CONTENT	DRY DENSITY (Mg/m^3)
20	1.780	20	1.691	20	1.602
25	1.635	25	1.553	25	1.471
30	1.511	30	1.436	30	1.360
35	1.405	35	1.335	35	1.265
40	1.313	40	1.247	40	1.182

CONCLUSION

Based on test that has been conduct, objective of this study is achieved.

1. We can conclude that dry density is increasing when moisture content is increase, but when we achieved optimum moisture content, dry density of the soil start decrease gradually.
2. Soil sampling and compaction test which are Standard Proctor test and Modified Proctor test is done properly according to BS 1377-4:1990.
3. Based on result of the compaction test, calculation has been done to determine moisture content and dry density of the soil. Result of 5 samples of soil producing compaction curve and indirectly optimum moisture content and maximum dry density of the soil can be obtained.
4. Comparison of result between Standard Proctor and Modified Proctor has been done and result of comparison is shown below.

Table 6: Result of Standard Proctor and Modified Proctor

STANDARD PROCTOR		MODIFIED PROCTOR	
MOISTURE CONTENT (%)	DRY DENSITY (Mg/m³)	MOISTURE CONTENT (%)	DRY DENSITY (Mg/m³)
25.14	1.192	24.82	1.403
27.31	1.22	26.31	1.45
31.85	1.322	31.63	1.567
33.77	1.261	35.43	1.367
35.75	1.238	38.17	1.325

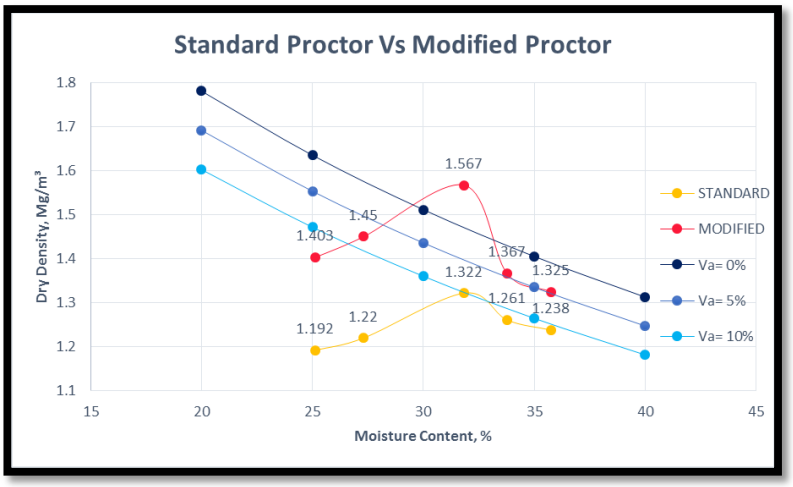


Figure 4: Compaction Curves with Air Void Lines

Based on Figure 4 above, we can say that in the same range of moisture content, which were 25% until 35%, maximum dry density of Modified Proctor test which is 'heavy' compaction test is higher than Proctor Modified test, or known as 'light' compaction test. At the beginning of test, moisture content is assumed 25%, 27%, 31%, 33% and 35% for both test. But result of the test shown that Modified Proctor have higher dry density compared to Standard Proctor. Its' indirectly prove that increasing of compactive effort will increase the maximum dry density.

REFERENCES

[1] C. L. Meehan, D. V. Cacciola, F. S. Tehrani, and W. J. B. (2016). Assessing Soil Compaction using Continuous Compaction Control. Automation in Construction, 14.

[2] M. Hausmann. (2012). Engineering Principles of Ground Modification. McGraw-Hill Publishing Company.

[3] Amadi, A. A., & Eberemu, A. O. (2012). Delineation of compaction criteria for acceptable hydraulic conductivity of lateritic soil-bentonite mixtures designed as landfill liners. Environmental Earth Sciences, 67(4), 999-1006.

[4] Ogunsanwo. (1990). Geoteehnical Properties of Undisturbed and Compacted. lnt Assoc Engng Geol Bull, 67-73.

[5] Batey, T. (2009). Soil compaction and soil management–a review. Soil use and management, 25(4), 335-345.

[6] Hartemink, A. E. (2008). Soils are back on the global agenda. Soil Use and Management, 24(4), 327-330.

[7] Håkansson, I., Voorhees, W. B., & Riley, H. (1988). Vehicle and wheel factors influencing soil compaction and crop response in different traffic regimes. Soil and tillage research, 11(3-4), 239-282.

[8] Horpibulsuk, S., Suddeepong, A., Chamket, P., & Chinkulkijniwat, A. (2013). Compaction behavior of fine-grained soils, lateritic soils and crushed rocks. Soils and Foundations, 53(1), 166-172.

[9] Otálvaro, I. F., Neto, M. P. C., & Caicedo, B. (2015). Compressibility and microstructure of compacted laterites. Transportation Geotechnics, 5, 20-34..
[10] J. Mitchell. (1993). Fundamentals of Soil Behavior (2nd Edition). New York: John Wiley & Sons.
[11] C. W. D. (2000). Compressibility of a Compacted Sand. Journal of Geotechnical and Geoenvironmental Engineering, (Vol. 126), No. 3.
[12] M. JK and S. K. (2005). Fundamentals of Soil Behaviour. New Jersey: John Wiley, Sons.

Strength and Microstructure of Marine Clay Stabilized with Small Percentage of Magnesium Chloride

Hazwan Adib Jahidin, Datin Fauziah Kasim

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

fauziahkasim@utm.my

Keywords: Marine Clay; $MgCl_2$; Unconfined Compressive Strength; Fourier Transform Infrared Spectroscopy.

ABSTRACT. Marine clay contains weak engineering properties. It requires a soil improvement before any construction can be carried out on top of the soil. This study aimed at determining the strength of marine clay stabilized by geopolymer, as one of the chemical stabilizer. The geopolymer used is magnesium chloride ($MgCl_2$). The objectives of the study were to determine the engineering properties of marine clay, the strength of marine clay treated by different percentages of $MgCl_2$ at various curing periods and to analyses microstructure of the treated and untreated marine clay using Fourier Transform Infrared Spectroscopy (FTIR). The highest compressive strength is 82kPa when mixed with 4% $MgCl_2$ at 7 days of curing. The FTIR result shows the new absorption band at 1527 cm^{-1}, attributed to the Mg–OH bond of magnesium chloride solution.

INTRODUCTION

Marine clay is characterised by low permeability and has the capability in attenuation of inorganic contaminants. This sediment is mainly deposited along the coastal areas of Peninsular Malaysia. Marine clay soils present great problems in pavement design due to uncertainty associated with their performance. They are often unstable beneath a pavement and they are the most susceptible to problems due to changes in moisture.

Problem Statement

As a developing country, Malaysia's construction industries continue to advance the country's economy, as well as its social development. New highway is being built along the west coast of Peninsular Malaysia. The West Coast Expressway (WCE) which is scheduled to be completed on 2019 is one of the examples of highway that currently being built. However, the undesirable marine clay properties has become the problem for highway design as it is high compressibility, big water content, low permeability, low shear strength characteristics of compression deformation and shear deformation under the action of additional stress can produce large settlement. Hence, this study was aimed at utilising the $MgCl_2$ in treating the marine clay, thus improving the strength of the clay. This is important as a preparation for the foundation or subgrade of a specific geotechnical engineering project such as for building or road construction

Objectives

The objectives of this study were:

1. To determine the physical properties of marine clay via literature review.
2. To compare the effectiveness of strength between treated and untreated marine clay.
3. To analyse the microstructure of marine clay treated by magnesium chloride.

Scope of Study

This study focused on the strength and microstructure study of marine clay stabilized with $MgCl_2$. The soil selected in this study was marine clay, obtained from the West-Coast Expressway project in Teluk Intan, Perak. The area has up to 30 m depth of soft marine clay. The marine clay had been subjected to various tests to determine its properties in accordance to the British Standard 1377 (1990). The microstructure analyse in this study is Fourier Transform Infrared Spectroscopy (FTIR).

LITERATURE REVIEW

The common classification systems are geological classification, classification by structure, classification based on grain size, unified soil classification system and preliminary classification by soil types. Soil types may be classified on the basis of their geological origin. The origin of a soil may refer to its constituents which is organic soil or inorganic soil or to the agencies responsible for its present status [1]. Marine clay is characterised by low permeability and has the capability in attenuation of inorganic contaminants. This sediment is mainly deposited along the coastal areas of Peninsular Malaysia. It is microcrystalline in nature and consists of clay minerals such as chlorite, montmorillonite, kaolinite and illite [2]. Marine clay soils can present great problems in pavement design due to uncertainty associated with their performance. They are often unstable beneath a pavement and they are the most susceptible to problems due to changes in moisture [3].

Soil stabilization is the process of improving the physical and engineering properties of a soil to obtain some predetermined targets [4]. Stabilization of soils is an effective method for improving soil properties and pavement system performance. For many soils, more than one stabilization agent may be effective and financial considerations or availability may be the determining factor on which to use (Robert *et al*., *2012*). There are two general groups exist for soil stabilizers such as traditional and non-traditional additives [5]

Magnesium chloride ($MgCl_2$) has been used as a green stabilizer in pavement applications. Its potential to improve the geotechnical properties of problematic soils is receiving increasing attention as the usage of $MgCl_2$ is becoming common based [6]. Although it can be used as a solid or in solution, the solution form is more common. The result shows an effective improvement of the dispersive and expansive of clay soil when added with $MgCl_2$ solution. Six different amounts of $MgCl_2$ were used as additive. The amount of $MgCl_2$ used to stabilize clay soil are 3%, 5%, 7%, 9%, 11% and 13% by dry weight of soil. The results showed the liquid limit and plastic limit decreased as the addictive content increased [7]. The decrease of liquid limit and the plastic limit caused by the decreasing in the Double Diffuse Layer (DDL) thickness due to cation exchange by divalent magnesium ions and increased electrolyte concentration, as the MgCl2 is completely soluble in water. Most of the chemical reactions happened at the early stage of curing, indicating the suitability of the $MgCl_2$ stabilization in projects with a tight schedule [6].

In order to assess the functional groups of tested soils before and after stabilization, a molecular characteristic analysis from the FTIR test was performed in this study. The absorption bands at characteristic wave lengths of bonds that vibrate independently of one another were measured in the FTIR process. Figure 2.2 illustrates the common features of the FTIR spectra for unstabilized bentonite and MgCl2 stabilized bentonite at various curing times. The spectra curve of unstabilized bentonite showed montmorillonite as a main clay mineral, with a single sharp band at 3632 cm^{-1} followed by a broad band at 3446 cm^{-1} for OH stretching of structural hydroxyl groups and water, respectively [4].

METHODOLOGY

Laboratory testing is the best way to investigate the soil characteristics before and after treated with chemical stabilization ($MgCl_2$) for fulfilling the specification requirements for construction activities. The laboratory works consist of series of tests on physical and mechanical properties of $MgCl_2$ stabilizer with marine clay as to determine the optimum amount in improving soft soil in terms of strength.

Sampling of Samples

The marine clay samples were taken from Teluk Intan, Perak. The area is one of chainage sections of the west coast highway from Banting, Selangor to Taiping Perak. The soil is very soft and contains a lot of water. A series of laboratory tests has been carefully planned and carried out for the development over soft clay soil in Teluk Intan, Perak, Malaysia

Atterberg Limits

The importance of Atterberg limits is to measure and identify the plasticity range in numerical terms, which is very vital especially for clay because the moisture content in soft soil is known as plastic consistency and this test is determined according to the BS 1377 Part 2: 1990. This test will be conducted on soft soil for the range of particle size finer than 63 micro meter. The fine grained soil can be divided into four conditions, solid, semisolid, plastic and liquids. The plastic limit (PL) stage is the moisture content at the point of transition from semisolid to plastic state. PL is conducted based on BS 1377 Part 2: 1990 Clause 5. A soil is rolled on the glass plate until the soil thread crumbles at the 3mm diameter. The soil is considered to be at its PL when thread crumbles appear and the moisture content is determined. Liquid limit (LL) is defined as the water content at the point of plastic condition to liquid state. LL was conducted according to the BS 1377 Part 2: 1990 4.3 using cone penetration method. The difference between LL and PL is the plasticity index (PI), that is,

PI= LL –PL

Compaction Test

Compaction is a mechanical process of pressing together particles of component to increase the density by expelling air from the void spaces of the particles. Compaction test is conducted based on BS 1377: Part 4: 1990. Standard Proctor test will be used to perform the compaction on soft soil for the determination of the relationship between the moisture content and the dry density of a soil by applying a specified compaction to the soil mass. The soil was compacted using by a 2.5 kg hammer failing a distance of 30 cm into the soil filled mould. The mould will be filled with three equal layers of soil, and each layer is subjected to 25 drops of the hammer blows. The diameter size, height and volume of the mould are 10.2 cm, 12 cm and 981 cm^3, respectively.

Unconfined Compressive Strength (UCS) Test

The main purpose of this test is to obtain the unconfined compressive strength of clay soil sample. The soil sample be put on the Unconfined Compressive machine and axial load was imposed to the soil sample. The stress in the vertical direction on soil sample increased while in the stress in the horizontal direction decreased until the sample had collapsed. The unconfined compression imposed the axial loading without lateral confining pressure that turns this test into simplest laboratory test in determining the soil strength. The samples will be cure for 3, 7, 14 and 28 days in a temperature room before subjected to the UCS test. Data acquisition system would collect real time data and graph between strains versus load is plotted.

Microstructure Study

The soil samples were treated with various percentages of additives. In order to assess the functional groups of tested soils before and after stabilization, a molecular characteristic analysis from the FTIR test was performed in this study. The absorption bands at characteristic wave lengths of bonds that vibrate independently of one another were measured in the FTIR process.

RESULTS AND DISCUSSION

The Properties of Marine Clay

Table 1 show the summary of properties of marine clay in Teluk Intan, Perak from the previous studies. The liquid limit from all the studies gives the similar values which is 78% while the plastic limit gives a different values range from 41% to 47%. Thus, the plasticity index ranges from 31% to 37%. The specific gravity shows almost the similar values ranges from 2.5 to 2.68. However, for USCS classification, all the studies give different classes for this marine clay which is OH, MH, and SM. The results of Standard Proctor compaction test was used to plot the graph MDD against OMC. The MDD was about 1.21 Mg/m^3 and OMC ranges from 38% to 40%.

Table 1: The properties of marine clay in Teluk Intan, Perak

References / Properties	[8]	[9]	[10]
Liquid limit	78%	78%	78%
Plastic limit	46%	47%	41%
Plasticity index	32%	31%	37%
Specific gravity	2.63	2.5	2.68
Loss of ignition	1.2%	-	-
USCS classification	OH	MH	SM
Maximum dry density, MDD (Mg/m3) Optimum moisture content, OMC	- -	1.21 40%	1.21 38%

Unconfined Compressive Strength (UCS)

The effect of various percentages of $MgCl_2$ and curing periods to the compressive strength of marine clay were obtained from the UCS test**.** The results of UCS tests are shown in Table 2, Figure 1 and Figure 2. The compressive strength of the compacted untreated marine clay is 52 kPa. The highest compressive strength is 82 kPa when mixed with 4% $MgCl_2$ at 7 days of curing period.

Table 2: Summary of Unconfined Compressive Strength Results

Sample	Unconfined Compressive strength (kPa) at various curing periods				
	0	**3 days**	**7 days**	**14 days**	**28 days**
Untreated Marine Clay	52	-	-	-	-
Marine Clay + 2% $MgCl_2$	-	56	64	75	72
Marine Clay + 4% $MgCl_2$	-	77	82	80	72.5
Marine Clay + 6% $MgCl_2$	-	66	70	65	59
Marine Clay + 8% $MgCl_2$	-	24	28	30	38
Marine Clay + 10% $MgCl_2$	-	16	20	31	30

Figure 1 shows the relationship between UCS and curing period. The strength of the untreated marine clay increased when the soil was mixed with 2%, 4% and 6% MgCl2 at 3, 7, 14, and 28 days curing periods. However, the strength of marine clay start to decreased when mixed with 8% and 10% at all curing periods. The UCS increased to 56 kPa with increment of 8% when mixed with 2% MgCl2 at 3 days of curing. Then the strength further increased to 64 kPa with increment of 23%, 75 kPa with increment 44% and 72 kPa with increment of 38% on 7, 14 and 28 days of curing, respectively. In general, the results in Figure 1 show that the strength of marine clay was at its peak at 7 to 14 days curing period.

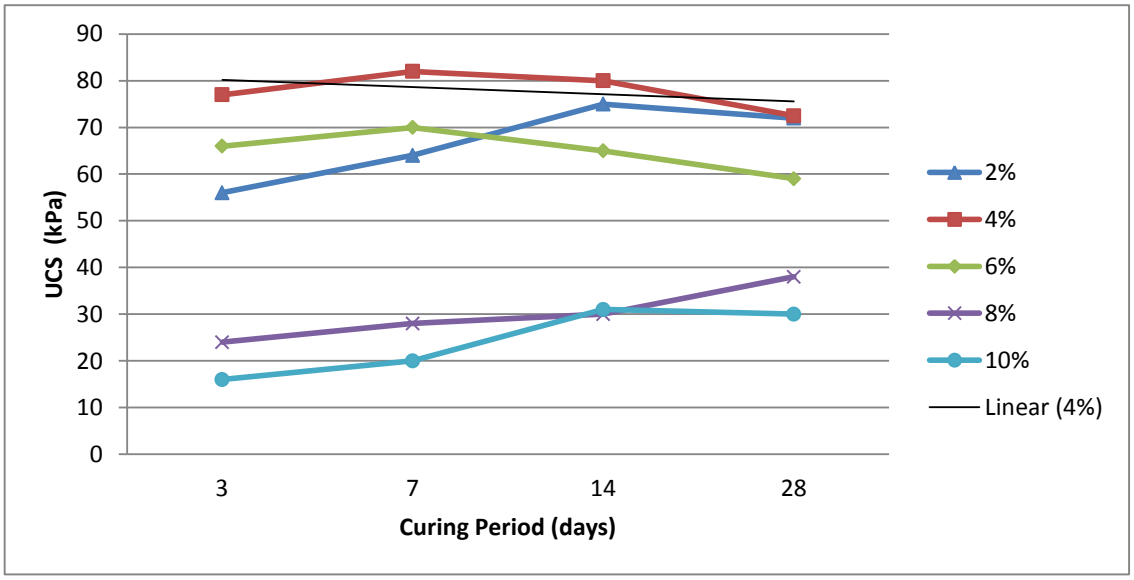


Figure 1: Relationship between UCS and curing period for various percentage of $MgCl_2$

Figure 2 shows the relationship between UCS and percentages of $MgCl_2$. The compressive strength of marine clay start increasing for 2% $MgCl_2$ to 4% $MgCl_2$. Then it start decreasing at 6%, 8, 10% $MgCl_2$. Generally, the results show that marine clay mixed with 4% $MgCl_2$ has the highest strength at any curing periods.

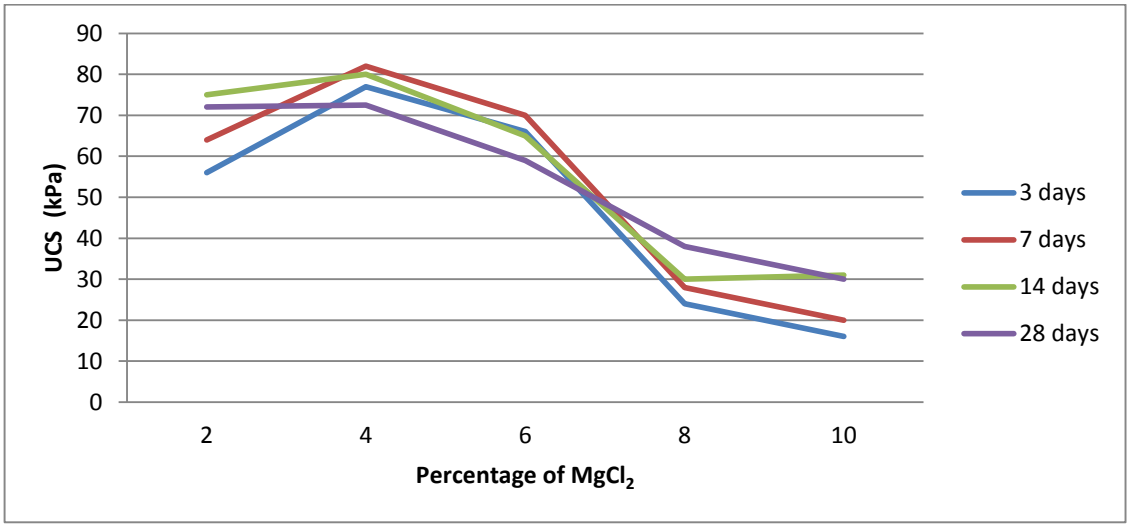


Figure 2: Relationship between UCS and percentage of $MgCl_2$ at various curing periods

Fourier Transform Infrared Spectroscopy (FTIR)

Figure 3 illustrates the features of the FTIR spectra for untreated and treated marine clay mixed with 2% $MgCl_2$. The spectra curve of untreated marine clay showed a main clay mineral with two strong band at 3847 cm^{-1} and 3614 cm^{-1} followed by a broad band at 3400 cm^{-1} for OH stretching of structural hydroxyl groups and water, respectively. In the lower frequency region, main clay mineral was also detected by a strong band at 1031 cm^{-1} for Si–O stretching (in-plane) vibration of layered silicates. While, the spectra curve of treated marine clay with 2% $MgCl_2$ showed a main clay mineral with single strong band at 3841 cm^{-1} followed by a broad band at 3421 cm^{-1} for OH stretching of structural hydroxyl groups and water, respectively. In the lower frequency region, main clay mineral was also detected by a strong band at 1031 cm^{-1} for Si–O stretching (in-plane) vibration of layered silicates. The results of the untreated and the treated marine clay indicated that there were noticeable changes in the FTIR spectra of MgCl2 stabilized samples and, in general, the peaks' intensities reduced with increase of the curing period. This was because of the weathering action of the additive on the clay minerals. The new absorption band at 1527 cm^{-1}, attributed to the Mg–OH bond of magnesium chloride solution, was evident.

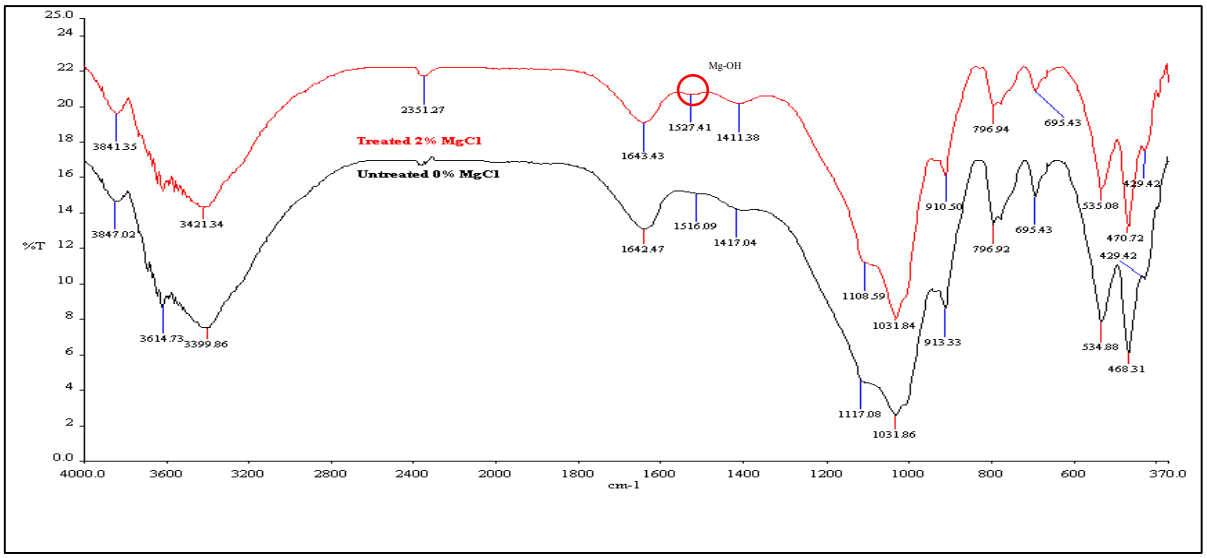


Figure 3: FTIR comparison between untreated and treated marine clay mixed with 2% $MgCl_2$

CONCLUSION

The findings from previous researches and the results of the laboratory tests have drawn the following conclusions:

1. The liquid limit of the marine clay in Teluk Intan, Perak was about 78% while the plastic limit values range from 41% to 47%. Thus, the plasticity index ranges from 31% to 37%. The literature review shows that the specific gravity of the marine clay in Teluk Intan ranges from 2.5 to 2.68. The classification of the marine clay ranges from silty sand (SM) to high plasticity organic (OH) and high plasticity silt (MH)
2. The strength of untreated marine clay increased when the soil was mixed with 2%, 4% and 6% MgCl2 at 3, 7, 14, and 28 days curing periods. However, the strength of marine clay start to decreased when mixed with 8% and 10% at all curing periods. Generally, the strength of marine clay at its peak at 7 and 14 days curing period. Based on the results, it shows that marine clay mixed with 4% $MgCl_2$ has the highest strength at any curing periods. The highest compressive strength is 82kPa when mixed with 4% $MgCl_2$ at 7 days of curing.
3. The spectra curve of untreated marine clay showed a main clay mineral with two strong band at 3847 cm-1 and 3614 cm-1 followed by a broad band at 3400 cm−1 for OH stretching of structural hydroxyl groups and water. While treated marine clay with 2% $MgCl_2$ showed a main clay mineral with single strong band at 3841 cm-1 followed by a broad band at 3421 cm-1 for OH stretching of structural hydroxyl groups and water, respectively. The results of untreated and treated marine clay indicated that there were noticeable changes in the FTIR spectra of MgCl2 stabilized samples and, in general, the peaks' intensities reduced with increase of the curing period. The new absorption band at 1527 cm−1, attributed to the Mg–OH bond of magnesium chloride solution, was evident.

REFERENCES

[1] Venkatramaiah, C. (2006). Geothecnical Engineering: Types of Soil. *New Age International*.

[2] Basack, S. & Purkayastha, R.D. (2009). Engineering Properties of Marine Clays from the Eastern Coast of India. *Journal of Engineering and Technology Research,* 1(6): 109-114.

[3] Yunus N., Marto A., Pakir F., Kasran K., Jamal M. A. A., Jusoh S. N., & Abdullah N. (2015). Performance of Lime-Treated Marine Clay on Strength and Compressibility Characteristics. *Int. Journal of GEOMATE,* (Vol. 8), 16.

[4] Eisazadeh, A., Kassim, K.A., & Nur, H. (2010). Molecular Characteristics of Hosphoric Acid Treated Soils. *World Academy of Science, Engineering and Technology*. 63, 1-3.

[5] Tingle, J S, Newman, J K, Larson, S L, Weiss, C A &Rushing, J F. (2007). Stabilisation Mechanisms of Non-Traditional Additives. *Transportation Research Record: Journal of the Transportation Research Board*.

[6] Latifi, N., A.S.A. Rashid, S. Siddiqua, & S. Horpibulsuk. (2015). Micro-Structural Analysis of Strength Development in Low and High Swelling Clays Stabilized with Magnesium Chloride Solution - A Green Soil Stabilizer. *Applied Clay Science,* 1-18.

[7] Turkoz, M., Savas, H., Acaz, A., & Tosun, H. (2014). The Effect Magnesium Chloride solution on the Engineering Properties of Clay Soil with Expensive and Dispersive Characteristic. *Applied Clay Science*, 1-9.

[8] Kassim, F., Marto A., Abdul Rahman N. A., & Tan C. S. (2015). Unconfined Compressive Strength and Microstructure of Marine Clay Soil Stabilised with Biomass Silica. Universiti Teknologi Malaysia, Johor Bahru.

[9] Aziz, N. (2015). Soft Soil Improvement by using Chemical-Rubber Chips Mixture. Universiti Teknologi Malaysia, Johor Bahru.

[10] Sukairi, S. (2016). Strength of Marine Clay Stabilized Using Geopolymer. Universiti Teknologi Malaysia, Johor Bahru.

Estimating SPT-N value based on Soil Resistivity using Hybrid ANN-PSO Algorithm

Mark Ruben Anak Upom, Mohd Nur Asmawisham Alel

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

alel@utm.my

Keywords: Standard Penetration Resistance; Soil Electrical Resistivity; Artificial Neural Network; Particle Swarm Optimization.

ABSTRACT. Standard Penetration Resistance (N-value) is an industry standard used in many empirical geotechnical engineering formula. Meanwhile, Soil Resistivity Survey is a type of geophysical survey which measures the electrical resistance of soil and excels in covering a much larger volume in the expense of accuracy. Sites possessing existing resistivity data usually have limited amount of borehole data due to cost but an excess of resistivity data. Meanwhile, previous studies have shown that there is correlation between N-value and resistivity value. However, there is currently no reliable method for estimating borehole data using resistivity data. Therefore, the primary objective of this research is to develop a method for estimating N-value using resistivity data. Artificial Neural Network-Particle Swarm Optimization (ANN-PSO) is a hybrid computational model trained using an evolutionary algorithm, Particle Swarm Optimization (PSO), which was used to predict N-value in this research. Utilizing data obtained from a site in Ulu Tiram, Johor consisting of N values from five boreholes complete with their corresponding soil resistivity value, five ANN-PSO models were designed whose performances were tested based on their ability to predict each of these boreholes. The performance metrics used were coefficient of determination, R^2 and mean absolute error, MAE. Four of the ANN-PSO models exhibited good and acceptable performance in terms of R^2 (0.82, 0.77, 0.85, 0.79) and MAE (0.69, 1.08, 0.54, 1.38) meanwhile one model exhibited poor performance with R^2 (0.17) and MAE (4.62) due to unsuitable training set. The results suggest that resistivity value can be used to estimate N-values with acceptable accuracy.

INTRODUCTION

Standard penetration resistance test (SPT) have long been an industry standard for site investigation in the geotechnical field. The purpose of conducting SPT is to obtain the standard penetration resistance, commonly called the N-value, which is the recorded blow count needed to advance through a 150 mm interval of soil. The N-value provides engineers with a rough measure of the density of the soil and is used in many empirical geotechnical engineering formula. However, in recent years, a lot of construction project have started employing geophysical investigation as part of their site investigation process. Geophysical investigation such as electrical resistivity survey have a few advantages over more traditional site investigation methods like SPT such as non-destructive mapping technique, the ability to perform temporal monitoring of a particular site, various scales application, acquirement of detailed measurement over a large area with low cost and large sensitivity of the measurement

Problem Statement

N-value is an important parameter which plays an important role in geotechnical structure design. However, for a project requiring a large coverage of the site, the cost for boring borehole would increase and leads to inefficient use of resources. This is in contrast with Soil Resistivity Survey that excels in covering a much larger volume although in the expense of accuracy. Previous studies show that there is a correlation between SPT-N and soil resistivity [1]. Sites possessing existing resistivity data usually have limited borehole data but an excess of resistivity data. However, there is currently no reliable method for estimating borehole data using resistivity data.

Objectives

The objectives of this study are:

1. To explore the potential application of ANN and PSO in the context of civil engineering.
2. To develop a computer program that can be used to solve an engineering problem.
3. To design a method for estimating SPT-N data and Resistivity data with measurable accuracy.

Scope of Study

This research will focus on designing a hybrid Artificial Neural Network-Particle Swarm Optimization (ANN-PSO) capable of predicting N-values based on existing borehole data (N-values) and their corresponding soil resistivity value. The data that were used during the training and testing of the Artificial Neural Network were obtained from a 2D-Resistivity survey

conducted in Ulu Tiram, Johor up to the depth of 7.5 m. Therefore, the finalized ANN models are only applicable to the site it was trained on. In addition, the site was composed of soil ranging from sand, silt, gravel and clay. The ANN models' performance will be measured based on the coefficient of determination, R^2 and mean absolute error, MAE.

LITERATURE REVIEW

Mahmoud (2013) pointed out that SPT plays a big role in determining properties important to many practices in geotechnical engineering, such as soil description or classification of soil, prediction of the behavior of soil if it will be subjected to extensive settlement or swelling. In short, N-value provides a rough measure of the strength of the soil being investigated. Furthermore, in order to construct a structure, N-value is an important parameter to understand soil condition at different depths.

The advantages of using resistivity method in the context of soil science are due to it being a non-destructive mapping technique, the ability to perform temporal monitoring of a particular site, various scales application, acquirement of detailed measurement over a large area with low cost and large sensitivity of the measurement. These advantages make it a great alternative to destructive method such as auger and borehole. Meanwhile, the evaluation of electrical resistivity in tropical sandy soil was also conducted [5]. Further discussion on the effects of water content on electrical resistivity of loess had also previously studied. The study further noted that influence of porosity changes on resistivity value may be neglected for loess soil type. In addition, Ozcep et al. (2010) found that by using ANN technique, they were able to predict soil water content using resistivity value of soils with comparable performance with other methods. Moreover, Robain et al. (2003) proposed a hypothesis that in the case water of macro voids, conduction is facilitated by the volume whereas in micro void, it is more influenced by surface conduction. Further reading on study (Cosenza et al., 2006) conducted to investigate the relationship between geotechnical data and geo-electrical data was also referred to. The authors successfully obtained a satisfactory quantitative correlation between inverted resistivity values and water content.

In recent years, the field of civil engineering has found a wide range of use for neural networks as tools for research and practical application. Mohamad et al. (2016) utilized a hybrid Genetic Algorithm-ANN to estimate air overpressure in blasting operations. Flood & Kartam (1994) compiled a comprehensive review of potential usage of neural networks in civil engineering up to the year 1994. Meanwhile, in the field of geotechnical engineering, Elarabi & Abdelgalil (2014) used a Backpropagation (BP) based ANN for soil classification purpose in Sudan. The authors further noted that ANN is an effective tool for solving complex, nonlinear and causal problem. Meanwhile, Erzin & Gul (2014) used artificial neural networks for predicting settlement of one-way footings on cohesionless soils based on standard penetration test N value [2]. The training algorithm that was used was of the Levenberg-Marquadt variant. The results suggest potentially useful application of neural networks to replace manual calculation which involves interpretations and use of chart and tables which can be subjective depending on the individual. In addition, Majdi & Rezaei (2013) built an ANN model capable of estimating the unconfined compressive strength of rocks. For further example, Yousif (2012) used an ANN model to predict soil compaction parameter while Chang (2000) combined the use of remote sensing with a neural network model to estimate physical properties of soil. An example of the use of a Genetic Algorithm (GA) type of neural network was demonstrated where the authors predicted air overpressure due to blasting using a hybrid GA-ANN model [4]. The results show improvement over the traditional empirical model typically used in predicting air overpressure, thereby proving the viability of evolutionary algorithm as a useful and practical training algorithm. Meanwhile, Kuok et al. (2010) developed a PSO-NN hybrid to model the daily rainfall-runoff relationship in Sungai Bedup Basin, Sarawak, Malaysia. The PSO-NN model produced encouraging results with a coefficient of correlation, R value of 0.9 and Nash-Sutcliffe coefficient, E^2 of 0.8067.

METHODOLOGY

The research methodology consisted of 5 key activities: Data Pre-Processing, Model and Algorithm Coding, Model Training, Model Selection and Model Testing.

Data Pre-Processing

There are 8 ANN input parameters (D_{main}, Ω_{main}, $N/\Omega_{ref,1}$, $l_{ref,1}$, $\theta_{ref,1}$, $N/\Omega_{ref,2}$, $l_{ref,2}$ and $\theta_{ref,2}$) and 1 ANN output (N_{main}). Data from a total of five boreholes (BH1, BH2, BH3, BH4 and BH5) down to the depth of 7.5 m were used to complete the dataset.

The data have to be standardized before it can be used for the neural network (Shanker, Hu, & Hung, 1995). The equation (Shanker et al., 1995) used to calculate the standardized data is:

$$z_i = (x_i - \bar{x})/\sigma \qquad \textbf{Eq.1}$$

where z_i is the standardized value of x_i, while σ is the standard deviation of the sample and $\bar{x}$ is the mean of sample.

Model and Algorithm Coding

PSO's particle movement is based on 2 main equations; velocity update equation and position update equation. The velocity update equation (Garro & Vázquez, 2015) is given as:

$$\boldsymbol{v_i}(t+1) = \omega \boldsymbol{v_i}(t) + c_1 r_1\big(\boldsymbol{p_i}(t) - \boldsymbol{x_i}(t)\big) + c_2 r_2(\boldsymbol{p}_g(t) - \boldsymbol{x_i}(t)) \quad \textbf{Eq.2}$$

where ω is the inertia weight; c1 and c2 are the acceleration coefficients; r1 and r2 are uniformly distributed random numbers in the domain [0, 1] .

Meanwhile the position update is given as:

$$\boldsymbol{x_i}(t+1) = \boldsymbol{x_i}(t) + \boldsymbol{v_i}(t+1) \quad \textbf{Eq.3}$$

The constants of c_1 and c_2 were set to 1.494 which was inspired by Clerc's constriction factor (Eberhart & Shi, 2001). Meanwhile a random inertia weight (Bansal et al., 2011) was used:

$$\omega = 0.5 + \frac{rand()}{2.0} \quad \textbf{Eq.4}$$

The fitness function, C that was used in this neural network's training is:

$$C = \frac{1}{n}\sum_{n=1}^{n}(d_i - y_i)^2 + \frac{\lambda}{2n}\sum w^2 \quad \textbf{Eq.5}$$

where the first term is the MSE value and the second term is the regularization component. Meanwhile, d_i and y_i refers to the predicted and observed value respectively and n is the number of training sample. λ is called the regularization parameter which needs to be tuned as a hyper-parameter while w refers to the weight in the network.

Model Training, Selection and Testing

The neural network models were trained using the particle swarm optimization method.

After the best models were selected, each model was tested using the testing set. The testing set for each model were divided into 6 set (Test Set A, B, C, D, E and F). They were divided based on the combination of reference borehole used. The performance metric used for the testing stage were coefficient of determination, R^2 and mean absolute error, MAE was calculated using [3]:

$$MAE = mean(|e_t|) \quad \textbf{Eq.6}$$

Lastly, R^2 (Mukaka, 2012) was calculated using:

$$R^2 = \left(\frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{(n\sum x^2 - (\sum x^2)(n\sum y^2 - (\sum y)^2)}}\right)^2 \quad \textbf{Eq.7}$$

RESULT AND DISCUSSION

The performance of the ANN-PSO models in terms of R^2 from best to worst; ANN-PSO III (0.85), ANN-PSO I (0.82), ANN-PSO IV (0.79), ANN-PSO II (0.77) and ANN-PSO V (0.17) meanwhile in terms of MAE from best to worst; ANN-PSO III (0.54), ANN-PSO I (0.69), ANN-PSO IV (1.08), ANN-PSO II (1.38) and ANN-PSO V (4.62). The probable cause of the poor performance of ANN-PSO V would also be discussed in later section. The optimum hyper-parameters are shown in Table 2 while the outputs of each ANN model are shown below with their actual measured value in Table 3.

Table 2: ANN-PSO Optimum Hyper-Parameters

ANN-PSO I			ANN-PSO II			ANN-PSO III			ANN-PSO IV			ANN-PSO V		
N_h	D_r	Λ	N_h	D_r	λ	N_h	D_r	λ	N_h	D_r	λ	N_h	D_r	λ
6	9	12	3	2	7	2	4	3	5	7	13	2	1	4

Table 3: ANN-PSO output and the corresponding actual measured N-value

N-value / Depth (m)	ANN-PSO I		ANN-PSO II		ANN-PSO III		ANN-PSO IV		ANN-PSO V	
	Actual N-value	Predicted N-value	Actual N-value	Predicted N-value	Actual N-value	Predicted N-value	Actual N-value	Predicted -N-value	Actual N-value	Predicted N-value
1.5	10	9	5	6	9	8	9	11	10	6
2.0	10	9	5	6	9	8	9	11	10	7
2.5	10	9	5	6	9	9	9	11	10	7
3.0	9	9	10	8	10	10	14	12	16	8
3.5	9	10	10	8	10	11	14	12	16	8
4.0	9	10	10	9	10	12	14	13	16	9
4.5	12	11	9	8	12	12	14	13	18	9
5.0	12	11	9	8	12	12	14	13	18	10

5.5	12	12	9	8	12	12	14	14	18	12
6.0	13	13	10	9	13	13	16	14	14	13
6.5	13	13	10	10	13	13	16	15	14	13
7.0	13	14	10	11	13	14	16	15	14	14
7.5	15	14	12	11	13	14	16	15	16	14

Coefficient of Determination, R^2

Theoretically, a perfect prediction model would score a R^2 of 1 since the actual value and predicted value are the same. According to Mukaka (2012), R^2 value ranging between 0.7 to 0.9 can be interpreted as high positive correlation while a range of 0.0 to 0.3 can be interpreted as negligible correlation. ANN-PSO I, II, III and IV all registered high positive correlation score with each scoring 0.82, 0.77, 0.85 and 0.75 respectively. Meanwhile, the only model that scored poorly on R^2 value was ANN-PSO V with a R^2 value of 0.17 which is negligible correlation. This poor performance will be discussed in a later section. Graph of measured SPT-N versus predicted SPT-N are shown on the next page.

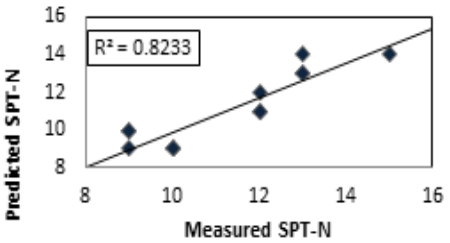


Figure 4: Measured SPT-N vs. Predicted SPT-N for ANN-PSO I

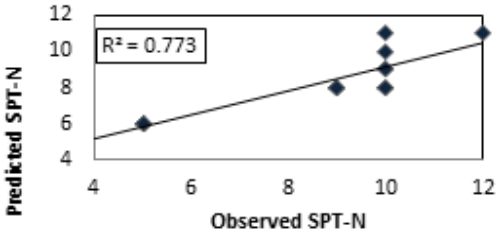


Figure 5: Measured SPT-N vs. Predicted SPT-N for ANN-PSO II

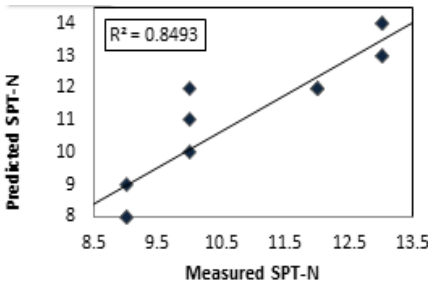


Figure 6: Measured SPT-N vs. Predicted SPT-N for ANN-PSO III

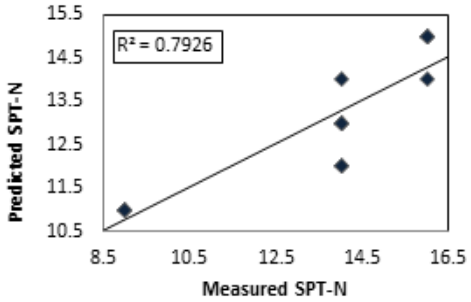


Figure 7: Measured SPT-N vs. Predicted SPT-N for ANN-PSO IV

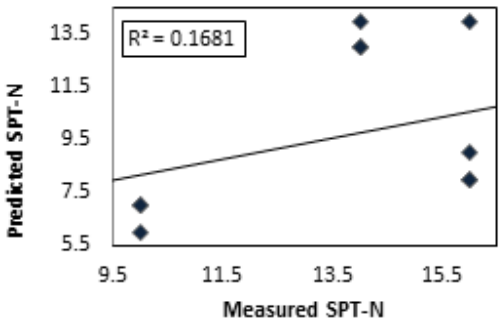


Figure 8: Measured SPT-N vs. Predicted SPT-N for ANN-PSO V

Meanwhile, in terms of MAE, ANN-PSO I, ANN-PSO II, ANN-PSO III, ANN-PSO IV, and ANN-PSO V scored 0.69, 1.08, 0.54, 1.38 and 4.62 respectively. With MAE values below 1 for ANN-PSO I and ANN-PSO III, it can be said that these two models possess good margin of error capable of predicting N-value with good confidence. Since N-values are typically used only as a rough measure of density of soil, ANN-PSO II and ANN-PSO IV are deemed to be within

acceptable margin of error. However, as with the performance of ANN-PSO V on R^2, ANN-PSO V's performance based on MAE is poor and indicates problems with the training sets. A summary of statistical performance of all five ANN-PSO models can be seen in **Table 4**.

Table 4: Statistical Performance of ANN-PSO Models

	ANN-PSO I	ANN-PSO II	ANN-PSO III	ANN-PSO IV	ANN-PSO V
RMSE	0.83	1.18	0.83	1.52	5.53
R^2	0.82	0.77	0.85	0.79	0.17
MAE	0.69	1.08	0.54	1.38	4.62

ANN-PSO V's Performance Analysis

In order to investigate why ANN-PSO V's performance is relatively poor compared to the other models, an analysis of the training set and testing set of all the models were conducted. During the analysis, the difference between the mean of l_{ref} input parameter in the training and the l_{ref} input parameters in the testing set, $\Delta\, \bar{l}_{ref}$, was found to be negatively correlated with the R^2 value and positively correlated with the MAE value. This means that a high $\Delta\, \bar{l}_{ref}$ value, which the case for ANN-PSO V, would imply low R^2 value and higher MAE value, which leads to bad performance. $\Delta\, \bar{l}_{ref}$ was calculated by averaging all the l_{ref} input value in the training set to get $\bar{l}_{ref,Train}$ and the same was done in the testing set to get $\bar{l}_{ref,Test}$. Then $\Delta\, \bar{l}_{ref}$ was calculated by using:

$$\Delta\, \bar{l}_{ref} = \bar{l}_{ref,Test} - \bar{l}_{ref,Train} \qquad \textbf{Eq.8}$$

This was done separately to each model to get the values in Table 4 below.

Table 5: $\Delta\, \bar{l}_{ref}$, R^2 and MAE for each Model

Model	$\Delta\, \bar{l}_{ref}$	R^2	MAE
ANN-PSO I	-5.17	0.82	0.69
ANN-PSO II	-39.33	0.77	1.08
ANN-PSO III	-13.5	0.85	0.54
ANN-PSO IV	-23.08	0.79	1.38
ANN-PSO V	71.08	0.17	4.62

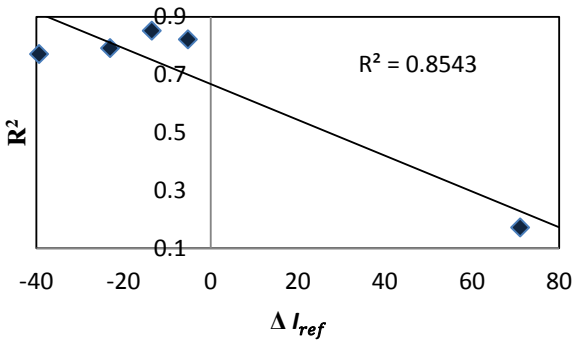


Figure 9: Correlation between $\Delta\, \bar{l}_{ref}$ and R^2 of each Model

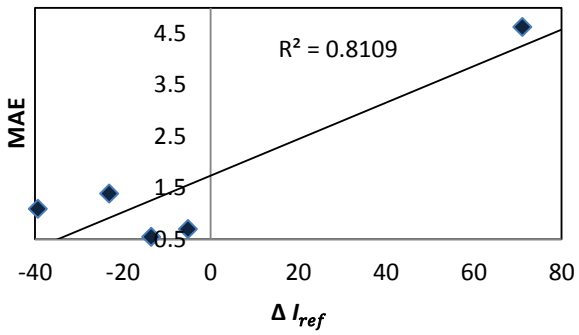


Figure 10: Correlation between $\Delta\, \bar{l}_{ref}$ and MAE of each Model

CONCLUSION

This research proposes a resource efficient method which combines the use of both SPT and Soil Resistivity Survey using ANN-PSO prediction modeling technique.

1. ANN and PSO were found to be particularly useful for solving regression problem. Using an ANN trained by PSO, the ANN was able to estimate N value using resistivity value with acceptable accuracy. In the field of civil engineering, there is no shortage of regression problems for researchers and ANN can be used as an alternative to statistical techniques such as Linear Regression and Ordinary Least Squares Regression. The main advantage ANN have over the statistical technique are that researchers do not need to make assumption (distributional and form) regarding the model whereas ANN is a black box which excels in approximating any type of function.
2. Utilizing Matlab's GUI feature, a program named ANN-PSO was developed. ANN-PSO is an ANN trained using PSO designed to estimate N-value using Resistivity value. The input of the ANN are D_{main}, Ω_{main}, $N/\Omega_{ref,1}$, $l_{ref,1}$, $\theta_{ref,1}$, $N/\Omega_{ref,2}$, $l_{ref,2}$ and $\theta_{ref,2}$ and the ANN output is N_{main}. The program is functional and provides the user with statistical parameters for analysis purposes.
3. Aside from ANN-PSO V's poor performances due to inadequate training set, encouraging result from the four successful ANN-PSO model shows that PSO algorithm is capable of training a Neural Network with exceptional result. The best result comes from ANN-PSO III with an R^2 of 0.85 and MAE of 0.54 which is an exceptional result in terms of accuracy. Meanwhile, it has been shown that by calculating $\Delta\ \bar{l}_{ref}$, we can predict whether ANN-PSO is capable of generating estimated N value with an acceptable accuracy or not.

There are several recently developed improvements which can be further implemented into the PSO algorithm such as modified dynamic neighborhood, multi objective PSO and the use of PSO to also tune the hyper-parameters which can potentially further improve the performance of PSO as a training algorithm. Meanwhile for ANN, other useful applications of ANN are in classification problem and machine vision. When put in the context of civil engineering, ANN could potentially be used to classify soil using geophysical data and identify road or structural defect for quality assurance and building inspection purposes using only visual inputs. This could lead to better use of resources and minimization of human errors.

REFERENCES

[1] Hatta, K. A., & Syed Osman, S. B. A. (2015). Correlation of Electrical Resistivity and SPT-N Value from Standard Penetration Test (SPT) of Sandy Soil. *Applied Mechanics and Materials*, *785*, 702-706.

[2] Erzin, Y., & Gul, T. O. (2014). The use of neural networks for the prediction of the settlement of one-way footings on cohesionless soils based on standard penetration test. *Neural Computing and Applications*, *24*(3-4), 891-900.

[3] Filik, U. B. (2016). A New Hybrid Approach for Wind Speed Prediction using Fast Block Least Mean Square Algorithm and Artificial Neural Network.

[4] Jahed Armaghani, D., Hasanipanah, M., Mahdiyar, A., Abd Majid, M. Z., Bakhshandeh Amnieh, H., & Tahir, M. M. D. (2016). Airblast prediction through a hybrid genetic algorithm-ANN model. *Neural Computing and Applications*.

[5] Peixoto, A. S. P., Yamasaki, M. T., & Lodi, P. C. (2014). Evaluation of Electrical Resistivity in a Tropical Sandy Soil Compacted. *Electronic Journal of Geotechnical Engineering*, *19 C*, 629-644.

Effect of Various Sizes of Recycle Blended Granite (RBG) on Plasticity of Treated Marine Clay

Mastura Bt Mohamed Amin, Nor Zurairahetty Mohd Yunus

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

nzurairahetty@utm.my

Keywords: Marine clay, Recycle Blended Granite, Plasticity Index

ABSTRACT. Recycle Blended Granite (RBG) obtained from demolished title materials acts as stabilizer to increase the strength of marine clay. this technique has been used in various construction purposes notably in highway, railroad and airport construction to improve subgrades and sub bases. It also promotes cheaper and environmental friendly construction work. This study aims to investigate the general properties of marine clay and effect of various sizes of RBG on plasticity of treated marine clay. A laboratory study was undertaken to evaluate the effect of granite dust as a soil stabilizer. Soil sample containing granite dust were prepared and Atterberg limit test were conducted as per relevant BS code of practice to get plasticity result. It is found that the optimum size of RBG is 150μm and the higher the percentage of RBG, the plasticity index become decreases. The plasticity index has been reduced from 28 to 19 from untreated specimen with addition of sizes and percentage of RBG. The conclusion drawn from this experimental work is that marine clay can be stabilized by the RBG to control its high plasticity and increase stability.

INTRODUCTION

In general, marine clay is a soil that has natural water content which is always greater than its liquid limit which means the soil is in liquid state in natural condition. Thus, this make marine clay having a very low shear strength and high compressibility and highly plastic. The deposits of this clay in the most cases need a pre-treatment before giving the external load [1]. Stabilization using Recycle Blended Granite Tiles (RBG) from granite is one of the technique that can be used to improve the properties of marine clay. Utilization of RBG for improvement of soil properties is a sustainable and cost-effective technique. Due to warping, a huge amount of broken granite tile waste is produce every year from manufacturing unites. Problem of the disposal of granite tiles waste can be overcome too by using it for stabilization of marine clay.

There are some research works conducted on clayey soil using admixture such as stabilizing expansive soil mixed with ceramic dust [2]. Another researcher [3] had blended the locally available clayey soil with sand, fly ash, tile waste and jute fibers. The effect of tile waste on clayey soil also have been evaluated [4]. In this study, specific soil is used which is marine clay. There are also research works that specific on of marine clay around the world, but none of them are using RBG from granite as a stabilizer. For an instance, stabilized the marine clay using ferric chloride and quarry dust [1]. A laboratory studies on the properties of stabilized marine clay from India had been done before [6]. Also, a study of mineralogy and geotechnical properties of Singapore marine clay had been conducted [7]. A test results from a study on the efficiency of Rice Husk Ash & Ferric Chloride with marine clay concluded that load carrying capacity of the marine clay foundation soil bed has been improved [8]. In lieu with the government motivation currently which emphasized towards sustainability and promoting green technology, further study on possible used of RBG on unsuitable soil can be considered as cost effective.

Objectives

The aim of the research is to investigate the effect of various sizes of recycle blended granite tiles (RBG) on plasticity characteristics of treated marine clay. The present study had been undertaken with the following objectives:

1. To characterize the untreated soil material.
2. To determine the effect of RBG content at different sizes (4.25mm, and 1.5mm, 0.63mm) on plasticity characteristic of marine clay.
3. To identify the optimum size and percentage of RBG to be treated with Marine Clay

LITERATURE REVIEW

The study of properties of marine clay and recycle blended tile had been done before a test being carry out**.** The measurement and selection of soil parameters for geotechnical design are very crucial. Poorly determined parameters will give significant impact to the safety and economical of project that has poor subsoil condition. An approach in

characterizing and developing fundamental understanding of the properties of soil alluvial clay had been carried out in Klang area, which underwent rapid development in the past few years and until now. In this paper, marine clay in area of Bandar Bukit Raja was taken which is about 10.3 km from Bandar Bukit Tinggi.

Due to their index properties, marine clay can cause many problems when being used for development. According government of Virginia, the main reason is that they contain a type of clay, montmorillonite, which shrinks and swells during natural changes in soil moisture. The clays shrink during dry periods of the year and swell during wet periods. Slight changes in moisture content are sufficient to cause detrimental shrinking and swelling. Problems tend to be more common in some Marine Clay areas than others. The Marine Clays contain a variable mixture of fine-textured soils – clay and silt – with frequent discontinuous sand layers. The most troublesome areas occur on steeper slopes and where the content of clay and silt is much higher than other soil types.

Industrial solid waste means solid waste generated by manufacturing or industrial processes that is not a hazardous waste regulated under Subtitle C of RCRA. Such waste may include, but is not limited to, waste resulting from the following manufacturing processes: electric power generation; fertilizer/agricultural chemicals; food and related products/by-products; inorganic chemicals; iron and steel manufacturing; leather and leather products; nonferrous metals manufacturing/foundries; organic chemicals; plastics and resins manufacturing; pulp and paper industry; rubber and transportation equipment; and water treatment. This term does not include mining waste or oil and gas waste. (40 CFR 258.2)

Table 1 below shows the studies on soil stabilization with use of industrial waste materials to improve the performance of weak soils. They concluded that the characteristics of such soils are improved remarkably. It was found that stabilization of clay by using granite will cause decreasing of plasticity on the soil and thus increase the strength of the soil.

Table 1: Summary of studies on soil stabilization.

Author	Soil (material)	Stabilizing agent	Test / parameter	Findings
Jagmohan Mishra	Black cotton	Granite dust	Compaction, atterberg limit and CBR values	Decrease of plasticity with the addition of granite dust
Kiran B.biradar	Clayey soil	Industrial waste: fly ash,crusher dust, steel slag	index properties, compaction, unconfined compression test, CBR test for soaked and unsoaked condition	With addition of admixture, liquid limit had improved, void ration has decreased (except fly ash)
T. Geeta Rani	Expansive soil	Tile waste	liquid limit, plastic limit	Liquid limit and plastic limit decreasing irrespective of the percentage of addition of tile waste
Ajay Upadhyay	Black cotton	Ceramics waste	Atterberg limit	With the addition of ceramic waste liquid limit, plastic limit and plasticity index of the clayey soil decreases.

METHODOLOGY

Various laboratory methods are available for studying the effects of additives in stabilizing marine clay. Common methods for classification of soil include specific gravity, compaction, Atterberg limits and particle size distribution was used to confirm the soil is marine clay. Atterberg limits test were performed on both the marine clay soils and the recycle blended tiles with different percentage and sizes was used to get the plasticity. Figure 1 shows the flow chart to determine characteristics of marine clay and plasticity of treated marine clay.

A bulk of fresh marine clay samples and an amount of RBG were collected and sent to Geotechnical Laboratory, Faculty of Civil Engineering, Universiti Teknologi Malaysia for analysis. All tests were carried out in accordance with the procedures specified by British Standard Institution. Materials of used for the Atterberg limits test were those of samples sizes passing through 425µm for marine clay and passing 425µm, 150µm and 63µm for RBG. Marine clay sample was both sun-dried and oven-dried, sieved and then tested using liquid limit and plastic limit test by using cone penetration method. This was done with different size and addition of 5%, 10%, 15% of RBG to the marine clay sample.

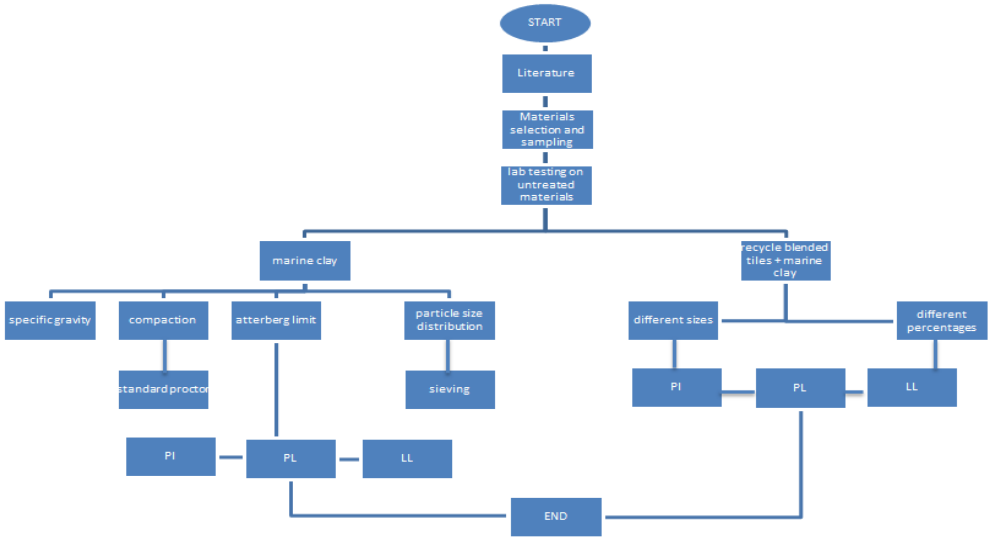


Figure 1 Flow chart of laboratory testing

RESULT AND DICUSSION

This section performed the analysis obtained from the laboratory testing carried out according to British Standard BS 1377:Part 2:1990 for Atterberg limit, specific gravity, particle size distribution and BS 1377 : Part 4 : 1990 for compaction.

General Properties of Untreated Marine Clay

Table 2 shows the general properties of untreated marine clay. Meanwhile Table 3 summaries overall results of index properties at different percentage and sizes of RBG. It is foreseeable that the measured moisture content at LL, PL and PI for all the 9 soil samples shows different value at different percentage and sizes of RBT. Generally, plasticity is the most outstanding characteristics of clayey soil which gives a good overall indication of the soil engineering properties.

Effect on Liquid limit (LL)

Result of LL for all the three soil samples listed in Table 3. The variation of the liquid limit for all the testing is presented in the Figure 2 and Figure 3. As expected, the LL for different percentage of RBG will decrease when percentage of RBG increase at all sizes. The differences of LL value between untreated and additional granite dust at 10% and 15% is about more than 10% of its untreated LL value. Hence, it can be concluded that the use of mix composition at 10% of granite is the optimum percentage because it is already show a small different of graph decreasing compare to 15%.

On the Figure 3, at x-axis granite dust size particles varying from 63µm, 150µm and 425µm has been marked and on y-axis liquid limit value has been plotted. From graph of 5% addition of granite dust it can be seen that on increment of particle size distribution, the liquid limit value decreases. While for additional granite dust at 10% and 15% the graph are almost constants at any particle size of granite with different of less than 2% of LL. In a nut shell, particle size of 425µm have the lowest value of LL for every percentage. Since LL depends on water content in the soil, it can be said that the stabilizer have the ability to reduce the water content in the soil and thus decreasing LL value but it have a limitation up 10 % only for a significant reduce.

Table 2: General properties of marine clay

Moisture content from fresh soil (%)	65.64
Specific gravity, Gs	2.33
Particle size distribution (%)	
Sand	55
Silt + Clay	45
Atterberg limit	
Liquid limit, LL (%)	66.32
Plastic limit, PL (%)	37.63
Plasticity Index, PI (%)	28.69
Compaction	
Maximum dry density (kg/m^3)	1316
Optimum moisture content (%)	35.2

Table 3: Overall result of the Index properties at different particle size and percentage of RBG

Type of marine soil	Percentage of RBG (%)	Liquid Limit	Plastic limit	Plasticity index
Untreated	None	66.323	37.632	28.691
Soil + 63µm RBG	5	63.328	36.261	27.067
	10	53.153	32.281	20.872
	15	51.330	31.390	19.940
Soil + 150µm RBG	5	61.095	34.228	26.867
	10	52.707	32.718	19.989
	15	51.236	32.302	18.934
Soil + 425µm RBG	5	54.052	33.470	20.582
	10	52.658	32.496	20.162
	15	50.573	30.730	19.843

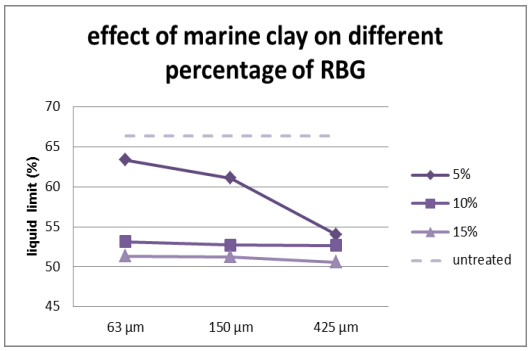


Figure 2: Effect on liquid limit value with different percentage of RBG at same size

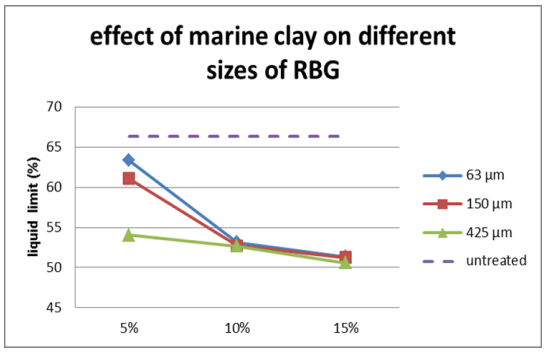


Figure 3: Effect on liquid limit value with different sizes of RBG at same percentage

Effect on Plastic limit (PL)

From the graph of PL below, it can be seen that all sizes of granite dust showing a decreasing value of PL when the percentage of admixture increase. It shows that the RBG has minor effect on plastic limit of marine clay, but the deviation in plastic limit is less than the liquid limit, which is applicable to current study.

Figure 4 and Figure 5 presents the graph showing deviation of plastic limit obtained from the one untreated soil and 9 treated soil with RBG. The changes of plastic limit for all 9 soil sample are less than liquid limit which satisfying with Murthy (2003) remarked that the deviation in plastic limit is less than the liquid limit.

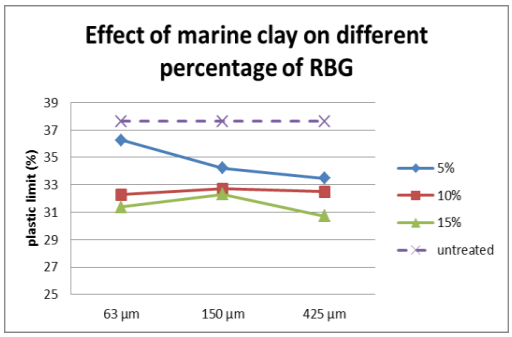


Figure 4: Effect on plastic limit value with different percentage of RBG at same size

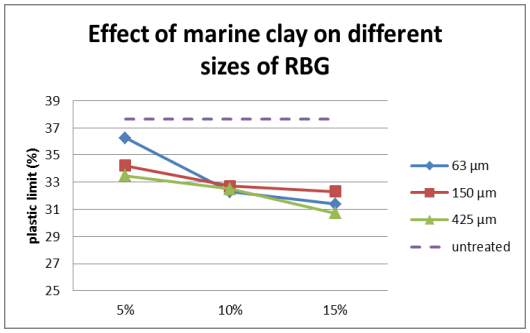


Figure 5: Effect on plastic limit value with different sizes of RBG at same percentage

Effect on Plasticity Index

At last, the plasticity index values which are shown in Table 3 were calculated using equation as stated in British Standard. The plasticity index for Figure 6 and 7 have a wider range for size 63µm and 150µm that are 27% to 19% and 26% to 18% respectively but smaller range for size 425µm that is 20% to 19%. Table 3 shows the variation of plasticity index due to the different percentage and sizes of RBG. It observed that the trend of change in plasticity index is almost

identical to the change observed in liquid limit as both parameters have a strong relationship. From the data analysis and presentation in this study, we could understand the impact of Recycle Blended Granite (RBG) in term of sizes and percentage to the plasticity of marine clay.

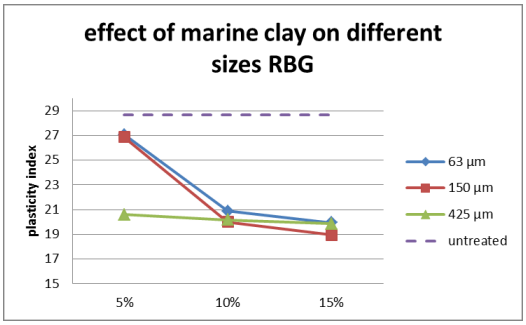


Figure 6: Effect on plasticity index with different sizes of RBG at same percentage

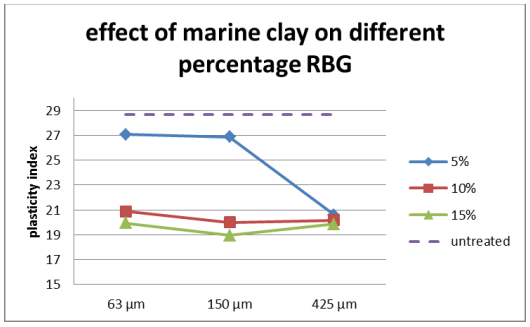


Figure 7: Effect on plasticity index with different percentage of RBG at same size

The relationship between the plasticity index and the liquid limit is used in the British Soil Classification System to establish the sub-group of fine soil. Plasticity shown in Figure 8 is used to classify the three size of RBG with different percentage. Generally, the A-line axis is the plasticity chart provides an arbitrary division between silt and clay, and vertical division of percentage liquid limit to define different degree of plasticity. The result of the classification is shown in Table 3 with reference to plasticity chart in Figure 8.

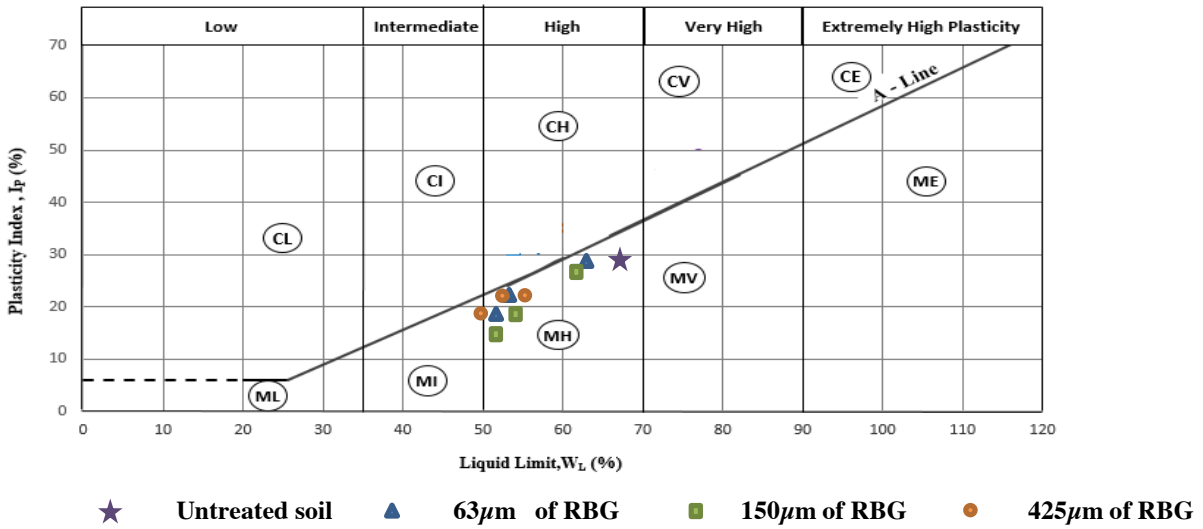


Figure 8: Plasticity chart for Classification (British Standard) of three sizes of RBG

CONCLUSION

From all the findings and discussion, we could conclude that size and percentage of RBG plays important roles to the value of plasticity on marine clay:

1. The untreated soil material can be characterized using a few tests such as Atterberg limit, compaction, particle size distribution and specific gravity.
2. It reveals that particles sizes of the soil also affect the plasticity of the clayey soil. The more sand content, the lower the value on plasticity index was observed except for 15% of RBG at 150µm. For soil size 63µm (range 27% to 19%) is higher than soil size 150µm (range 26% to 18%) and soil 425µm (range 20% to 19%) is lower than 150µm up to 10% of RBG only. This may due to decrease of inter-molecular attraction force in the soil. When the inter-molecular attraction force decrease, it caused the liquid limit decrease and hence the plasticity index depreciates as well.

3. It is found that the optimum size of RBG is 150µm and the higher the percentage of RBG, the plasticity index become decreases. It might be because of the reaction between RBG and soil size 425µm had reach its limit to reduce plasticity effectively hence both of RBG and soil have the same size which is passing 425µm.

REFERENCES

[1] Kiran, B. M. N. (2016). Stabilization of Marine Clay Using Ferric Chloride and Quarry. *International Journal of Latest Trend in Engineering and Technology (IJTET)*, *6*(3), 610–615.

[2] Sabat, A. K. (2015). A Study on Some Geotechnical Properties of Lime Stabilised Expansive Soil – Quarry Dust A Study on Some Geotechnical Properties of Lime Stabilised Expansive Soil – Quarry Dust Mixes. *International Journal of Emerging Trends in Engineering and Development*, *1*(2), 2249–6149.

[3] Singh, B., & Sharma, R. K. (2014). Evaluation of Geotechnical Properties of Local Clayey Soil Blended with Waste Materials. *Jordan Journal of Civil Engineering*, *8*(2), 135-151.

[4] Sabat, A. K., & Pati, S. (2014). A review of literature on stabilization of expansive soil using solid wastes. *Electronic Journal of Geotechnical Engineering*, *19*, 6251-6267.

[6] Rao, D. K., Raju, R. P., Sowjanya, C., & Rao, J. P. (2009). Laboratory studies on the properties of stabilized Marine Clay from Kakinada Sea Coast, India. *International Journal of Engineering Science and Technology*, *3*(1), 422-428.

[7] Bo, M. W., Arulrajah, A., Sukmak, P., & Horpibulsuk, S. (2015). Mineralogy and geotechnical properties of Singapore marine clay at Changi. *Soils and Foundations*, *55*(3), 600-613.

[8] Tan, T. S., Karunaratne, G. P., Choa, V., & Bo, M. W. (2003). Reclamation using waste sediment by sand capping technique. In *Contaminated Sediments: Characterization, Evaluation, Mitigation/Restoration, and Management Strategy Performance*. ASTM International.

Tensile Behavior of Sandstones under Direct and Indirect Tensile Tests

Mohamad Lukman Hakim Mustapha, Rini Asnida Abdullah

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

asnida@utm.my

Keywords: Tensile Strength; Brazilian Test; Direct Tensile Test; Sedimentary rock.

ABSTRACT. The study presents experimental results of tensile strength in sandstone using different testing techniques. A series of Brazilian test were tested under different sample shapes, i.e. using solid and ring disc samples. The validity of these tests was verified using the direct tensile test. It was found that, the Brazilian Tensile Strength (BTS) obtained is generally greater than the Direct Tensile Strength (DTS) and the relationship is rock type dependent. The factor f, in DTS = f BTS, can be considered to be approximately 0.68 for sedimentary rocks based on the experimental data. In addition, the sample shape also effects the tensile strength, with increasing of diameter ratio, r, the tensile strength also increases.

INTRODUCTION

Rock properties are very important in drilling, foundation, tunneling, and reservoir engineers for design. It is very important to know the strength of the rock and the behavior of rock due to structure that will construct above the rock mass. In general, rock mass strength depends on the strength of intact rock and the strength of rock discontinuities. In many rock mechanics problems, the engineering properties of the intact rock are of primary importance. Intact rock refers to the rock material which can be sampled and tested in the laboratory, and which is free of the large-scale structural features such as joints, bedding planes, partings, and shear zones. The whole body of rock, described as a rock system, is broken up by joints into rock elements which are of such a size that they contain no joints or planes of weakness and may be regarded as elastic bodies subject to brittle failure under appropriate conditions. The term joint is used to cover all discontinuities; these might technically be joints, faults, bedding planes or other surfaces of weakness. The properties of the rock system are determined by the properties of the rock elements and of the joints as well as by the geometry of the system. Determination of the tensile strength by direct extension of a cylindrical sample has proved difficult because a satisfactory means has not yet been devised to grip the samples without introducing bending stress. Shaped sample which alleviate the problem the preparation procedure is costly and perhaps too involved for normal used. The most practical method of determining the direct tensile strength for engineering purposes is accomplished by attaching with epoxy resins, metal end caps to cylindrical rock samples which are then pulled in tension by wire cables or roller chains. But the Brazilian tensile test is an easy and common frequently method used for determining the indirect tensile strength of the rock. It is believed that the solid disc sample tested under Brazilian has overestimated the tensile strength, where there is shear failure occurred at the top and bottom of the sample. Therefore, this study presents the Direct Tensile test and Brazilian test under solid and ring disc samples on their relationship with shape in tensile strength.

Problem Statement

Commonly test that used to obtained the tensile strength of rock is using the Brazilian test. It is also believed that shape of the sample used in Brazilian test also effect the tensile strength. The validity of Indirect test result was questioned.

Objectives

The objectives of this study are:

1. To carry out Direct Tensile test and Brazilian test on solid and ring disc shape samples.
2. To study effect of shape in tensile strength of rock.
3. To compare the Direct Tensile Strength (DTS) and Brazilian Tensile Strength (BTS) on solid and ring disc samples.

Scope of Study

This research is carried out to study the Tensile behavior of sandstones under Direct test and Indirect Tensile Test (Brazilian Test). The sandstone sample was taken from Bakong, Mersing Johor and the samples was prepared one sets of samples for Direct Tensile Test and three set for Indirect Tensile Test which consist of one solid disc sample and two ring sample with radius ratio, r = 0.12 and r = 0.16 ($r = \frac{inner\ radius}{outer\ radius}$).

LITERATURE REVIEW

Rock is natural substance from the minerals on the earth crust which a naturally occurring, inorganic, solid, and crystalline substance that will fixed structure chemical composition which either vary within certain limits. The metals and minerals found in rock have been important to human civilization because some of the mineral used for the design in structure or the type of the minerals that is valuable for mankind such as gold, and diamond. Rocks are composed of grains of minerals which is turn to the homogeneous solids formed from a chemical compound that will array in an orderly manner. Knowledge of rock mass strength is important in the design of support system regard to the concept of rock support interaction.

Tensile strength of rock material is usually defined as the maximum tensile stress which can be endured by such a material. Rock material usually has a low tensile strength, which can be determined by direct and indirect methods of which the most famous is the Brazilian test [1]. The direct testing procedure is carried out on the samples which require demanding processing conditions. Due to the complexity of direct methods, particularly in the preparation of samples and applying the load, the Brazilian test, which indirectly determines tensile strength, is more frequently used in engineering practice. The justifiability of this method is based on the experimental fact that most the rocks that are in the state of the biaxial stress break due to the exceeded tensile strength, in the conditions when one principal stress is tensile, and the second compressive, the size of which does not exceed three times the tensile stress.

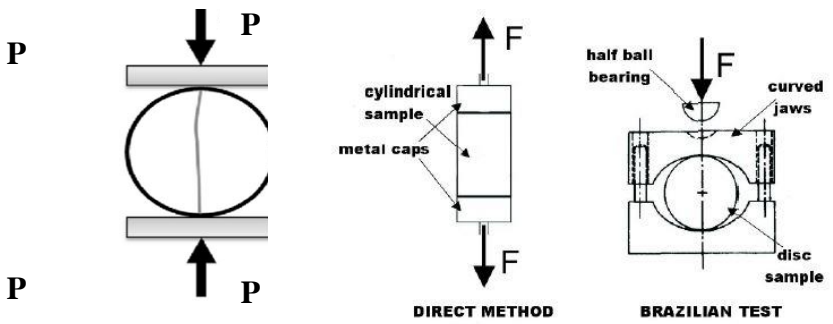
The rock is much weaker in tension compared to the compression or shear [2]. Tensile strength of rock is among the important parameters influencing rock deformability, rock crushing and blasting results [3]. Rock material usually has a low tensile strength, which can be determined by direct and indirect methods which the famous is the Brazilian test. Tensile failure also plays an important role in some engineering activities such as drilling, cutting, and blasting of rock, hydraulic fracturing of a borehole or a tunnel, exploitation of rock slopes, and excavation of horizontally bedded roof strata. The direct tension test is difficult to perform for rock [4]. In other hand, the Brazilian splitting test with rock disc is easy to carry out in laboratory and provides a reasonable estimation for the uniaxial tensile strength (UTS), although there are many issues argued all along.

The important of discontinuities in determining the behaviour and properties of rock masses has continued to grow in improving their problem. In addition, the effects of discontinuities on deformability and strength, it is now appreciated that these features can have a major effect on the tensile strength of rock masses. The mechanical properties of joints, fractures, and faults and those affecting the strength and these discontinuities have become important topics in rock mechanics for theoretical and experimental studies about problems in geology, geophysics, mining engineering, petroleum engineering, hydrogeology, and waste disposal.

The tensile strength is an important aspect of the resistance to failure of a rock or rock mass. Tensile strength is an important controlling property in critical span stability of underground openings [5]. The focus of engineering studies is often on the unconfined compressive strength (UCS) of intact rock samples. Direct tensile strength (DTS) testing is rarely carried out because of the difficulties in preparing the specimens; many poorly-prepared samples fail invalidly (not through the middle of the specimen) and thus must be discarded. Indirect tensile methods, such as the Brazilian Tensile Test, are much easier to prepare although invalid tests (fracture is not through the middle of the specimen or visible platen effects) are also frequent and each sample should be examined after testing to determine its validity [6].

METHODOLOGY

This research is more focused on comparison the tensile strength between solid and ring disc sandstone using Brazilian test with different radius ratio and Direct Tensile Test. So, rock testing in the laboratory are an important part of the engineering discipline of rock mechanics because the information is needed for the design works of rock that obtained from the direct testing, either on laboratory testing or at the field. Due to complex geological conditions and uncertainties, there are many difficulties in determining the actual behavior of rocks in different geotechnical structures, foundation, or substructure that need all data information on behavior of rock before design any structure on the rock.



Direct Tensile Test Preparation

The test samples are prepared with two flat ends and the sample is gripping with araldite glue. The samples needed to secure for 1 days before the testing and make sure the glues is perfectly grip with the samples that will prevent the eccentricity.

$$\sigma_t = \frac{P}{A} \quad \textbf{Eq.1}$$

Where,
σ_t is the tensile strength, (MPa)
P is the load at failure, (kN)
A is the surface area of the test samples, (m^2)

Table 1: Dimension of samples (Direct Tensile Tests)

Sample No	A	B	C
Height (H = 2D), mm	100	100	100
Diameter (D), mm	50	50	50

Indirect Tensile Test (Brazilian Test)

The size and shape effect the rock strength properties due to different scale effect. In this test for solid disc samples, a rock disc of thickness t and diameter D is loaded diametrically with a load P is given by,

$$\sigma_t = 0.636\frac{P}{Dt} \quad \textbf{Eq.2}$$

Where,

σ_t is the tensile strength (MPa)
P is load (kN)
D is the diameter of samples (m)
t is the thickness of samples (m)

For the tests solid disc sample, a thickness-to-diameter ratio (t/D) of 0.5 is taken. This equation was obtained analytically based on the assumption that the rock is isotropic and homogeneous. However, the nature is more complex to described. Therefore, we must consider the anisotropy and heterogeneity effects for better estimation of rock strength.

The formula for the ring test tensile strength is same as solid disc sample but need to add the coefficient which is K as a stress concentration factor and a function of the relative hole radius (r). An approximate value for K as mentioned by Hudson (1969) [7] is $K = 6 + 38r^2$. Since the compression stress is three times the tensile stress at the centre of the Brazilian test specimen, the factor of six in the approximation to K can be interpreted as the stress concentrating effect of a circular hole in an infinite medium, leaving $38r^2$ as the boundary effect.

$$\sigma_t = 0.636K\frac{P}{Dt} \quad \textbf{Eq.3}$$

Table 2: Dimension of samples (Brazilian Tensile Tests)

Sample No	**A1**	**A2**	**A3**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**
Thickness, mm	27	27	27	27	27	27	27	27	27
Diameter (outer), mm	50	50	50	50	50	50	50	50	50
Diameter (inner), mm	-	-	-	6	6	6	8	8	8
Radius ratio, r	-	-	-	0.12	0.12	0.12	0.16	0.16	0.16

RESULTS AND DISCUSSION

Tensile strength of material (sandstones) is defined as the maximum tensile stress which can be endured by such a material. Rock material usually has a low tensile strength, which can be determined by direct and indirect methods of which the most famous is the Brazilian test.

Brazilian Test

The Brazilian test was performed on the 3 types of samples with 2 different size radius ratios and 1 solid samples. In this test, the compressive stress was applied to the samples but they failed in tensile manner. Table 3 shows the data of sandstone samples after the failure.

Table 3: Table of Tensile Strength, Strain at Failure, and Young Modulus.

Type of test	Brazilian Test								
	Solid			Ring (r = 0.12)			Ring (r = 0.16)		
No of Sample	**A1**	**A2**	**A3**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**
Load P, kN	2.2	3.8	4.5	1.3	1.9	1.2	2.1	1.5	1.7
Tensile σ_t, MPa	1.04	1.79	2.12	4.01	5.86	3.70	6.91	4.93	5.59
Vertical Strain at failure ε_f, %	0.80	1.00	1.08	0.56	0.76	0.6	0.66	0.62	0.5
E = $\frac{\sigma}{\varepsilon}$, GPa	14	18	28	75	75	63	116	75	70

Data above shows that the tensile strength of sandstones simultaneously increase as the radius ratio of samples increased. This result is another indicator that the tensile strength demonstrated in such a test is an experimental property rather than a material property. Repeated measurements of tensile strength in the same testing situation usually show a variability far in excess of experimental error. The Brazilian test consists of diametrical compression of a disc, but failure being caused by an induced tensile stress at the centre. To avoid the biaxial stress field in this test, the ring disc sample was developed to compared the tensile strength of the rock. The solid sample A shows the lowest value of average tensile strength is 1.65 MPa compare to the ring disc sample B is 4.52 MPa and sample C is 5.81 MPa. Average Young Modulus (E) for sample A is 20 GPa and sample B is 71 GPa while for the sample C is 87 GPa which is the highest value for Young Modulus.

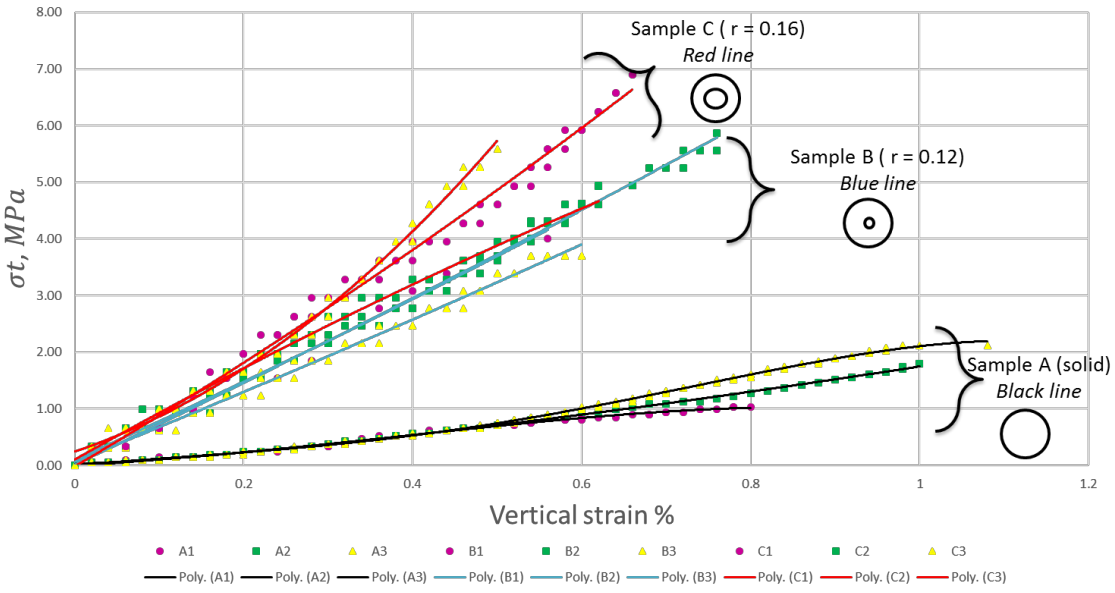


Figure 1: Tensile vs vertical strain graph of (a) Solid samples: A1, A2, A3 and (b) Ring Disc samples (r = 0.12): B1, B2, B3 and (c) Ring Disc samples (r = 0.16): C1, C2, C3

The graph above show that the sample C with radius ratio (r = 0.16) is the highest tensile strength compare to the others sample. The highest value of tensile strength for sample C is 6.91 MPa and for sample B is 5.86 MPa while for sample A is 2.12 MPa is the lowest value of tensile strength under Brazilian test.

Direct Tensile Test

The direct testing procedure is carried out on the samples which require demanding processing conditions. Tensile stress is transferred to the ends of the samples using an araldite glued the steel plate with hooks on it. It is very important that the axis impact of the tensile matches with the axis of the sample without bending or torsion. The Direct Tensile test was performed on the 3 samples of cylindrical sandstone. In this test, the axial stress was applied directly to the samples and the result were obtained. Table 4 shows the sandstone samples after the failure.

Table 4: Table of Tensile Strength, Strain at Failure, and Young Modulus for Direct Tensile Test

Type of test	**Direct Test**		
No of Sample	**A**	**B**	**C**
Load P. kN	1.31	3.61	1.68
Tensile $\sigma_{t,}$ MPa	0.66	1.84	0.86
Vertical strain at failure, ε_f %	0.16	1.13	0.35
E = $\frac{\sigma}{\varepsilon}$, GPa	91	28	26

Data above shows the tensile strength of sample A, B, and C with variable value of data which is 0.66 MPa, 1.84 MPa and 0.86 MPa. The different tensile strength of sample there have many factors that can contribute to strength which is eccentricities occur during the testing and a weak plane on the sample and torsion maybe occurs. So, the average of tensile strength for all sample is 1.12 MPa for the Direct tensile test and the average Young Modulus (E) for all sample is 48 GPa.

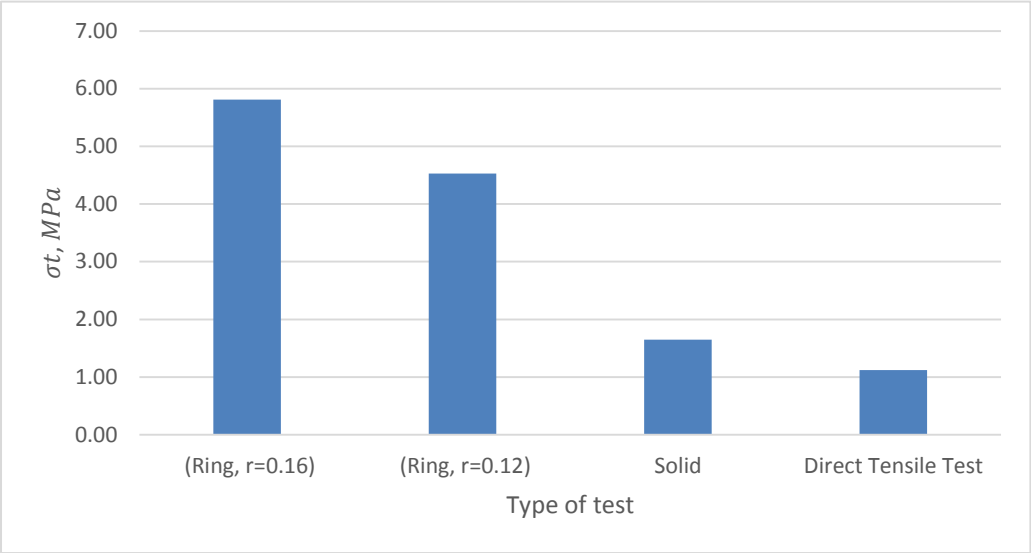


Figure 2: Comparison of Tensile Strength within 4 type of sandstone samples (Brazilian Test and Direct Test)

The Bar chart above shows the variation of tensile strength under Brazilian Test and the Direct Tensile test. The Direct Tensile Test shows the lowest tensile strength compare to the Brazilian Test for solid sample and ring disc sample with radius (r = 0.16) and (r = 0.12). The Brazilian test shows the highest value of tensile strength which is 5.81 MPa for (r = 0.16) and 4.52 MPa for (r = 0.12) and the solid samples is almost equal the value of the direct tensile strength which is 1.65 MPa and for Direct Tensile Test is 1.12 MPa. It is shown that the tensile strength is influence by the type of samples with different radius ratio.

Table 5: Ratio of Tensile strength (Direct Tensile Test per Brazilian Test) within 4 type of sandstone samples

Type of Test		**Average Tensile σt, MPa**	**Ratio Direct Tensile Test per Brazilian Test (DTS/BT)**	**Average Young Modulus E, GPa**	**Ratio Direct Tensile Test per Brazilian Test (DTS/BT)**
Brazilian Test	**Ring (r = 0.16)**	5.81	0.19	87	56
	Ring (r = 0.12)	4.53	0.25	71	68
	Solid	1.65	0.68	20	240
Direct Test		1.12	-	48	-

The Brazilian test data for solid disc sandstones shows nearest tensile value to the Direct Tensile Test compare to other ring disc sandstone samples. Solid disc sandstones are recommended as a method of measuring the material property for Brazilian test due to the result obtain and the sample preparation itself. Laboratory work shows that the f factor is 0.68 and according to Matthew A. P. and Mark S. D. [5] the factor f in DTS = f BTS, can be approximately 0.7 for sedimentary rocks.

CONCLUSION

This research presents the tensile strength of the sandstones under Direct Tensile Test and Indirect Tensile test.

1. Sandstones sample have been successful test with Brazilian test which is consist of solid disc sample, ring disc sample (r = 0.12 and r = 0.16).

2. When the radius ratio is increased, the tensile strength of sandstones will have increased.

3. Solid sample from Brazilian test give the nearest result ratio to the Direct Tensile test which is 0.68, for ring (r = 0.12) is 0.25 and (r = 0.16) is 0.19. From previous study, the ratio for solid sample is 0.7 for sedimentary rock.

REFERENCES

[1] Briševac, Z., Kujundžić, T., & Čajić, S. (2015). Current cognition of rock tensile strength testing by Brazilian test. *Rudarsko-geološko-naftni zbornik*, *30*(2), 101-128.

[2] Chen, C. S., & Hsu, S. C. (2001). Measurement of indirect tensile strength of anisotropic rocks by the ring test. *Rock mechanics and rock engineering*, *34*(4), 293-321.

[3] Claesson, J., & Bohloli, B. (2002). Brazilian test: stress field and tensile strength of anisotropic rocks using an analytical solution. *International Journal of Rock Mechanics and Mining Sciences*, *39*(8), 991-1004.

[4] YOU, M. Q., ZHOU, S. T., & SU, C. D. (2006). Direct Tensile Experiment of Rock Specimens Under Confining Pressure [J]. *Journal of Henan Polytechnic University (Natural Science)*, *4*, 000.

[5] Perras, M. A., & Diederichs, M. S. (2014). A review of the tensile strength of rock: concepts and testing. *Geotechnical and geological engineering*, *32*(2), 525-546.

[6] Colback, P. S. B. (1966, January). An analysis of brittle fracture initiation and propagation in the Brazilian test. In *1st ISRM Congress*. International Society for Rock Mechanics.

[7] Hudson, J. A. (1969, January). Tensile strength and the ring test. In *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts* (Vol. 6, No. 1, pp. 91-97). Pergamon.

Effect of Strength Anisotropy in Shale

Mohd Afnan Bin Saat, Rini Asnida Abdullah

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

asnida@utm.my

Keywords: Brazilian Test, Shale, Tensile Strength, Mode of Failure, Anisotropy

ABSTRACT. This paper study the effect of strength anisotropy in shale. The strength anisotropy was influenced by the lamination angle presence in shale. A series of Brazilian test was carried out to obtain the tensile strength, with regard to three lamination angles which are 0°, 30° and 90°. From the analyses, it was found that the tensile strength increases for sample lamination 0° to 30°, and the sample tested at 30° of lamination gave the highest tensile strength. The result is in good agreement tested in sandstone. The failure mode also were observed to classify the type of failure for every sample tested.

INTRODUCTION

Shale is a fine grained detrial sedimentary rock which is characterized by the laminated structure. The small scale of discontinuity is a common feature of shale. Lamination can give the result of sedimentary layering, extensile jointing, or fabric created through parallel excavation stress fracturing of massive ground [1]. Shale has made up of many thin layer and fissile through the lithification process. Lithification is a process that creates fine layering by compacting the silt and mud.Thus, lithification is the main process that lead to the lamination of shale. Present of lamination can give a biggest impact to the strength of sedimentary rock because it naturally act as importance roles in controlling the rock mass behavior. It can alter the behavior of sedimentary rock from isotropic to anisotropic. Anisotropy is the main factor of fracturing in shale because it has various mechanism that can create the fractures. Based on previous study, they concluded that the orientation of lamination can affect the compressive strength which $\beta=0°$ and $\beta=90°$ has the maximum compressive strength [2]. Therefore, effect strength anisotropy in shale of major importance because of the distinctive lamination exhibited by shale. Basically, other than the anisotropy, there are many factors that can effects the strength and deformation of shale such as moisture content and confining pressure. However, this study will only consider the anisotropy strength in shale.

Problem Statement

It is a common practice to use an indirect test to identify the tensile strength of the rocks, but for rocks that indicate the presence of lamination should be taken into consideration. Thus, the tensile strength is better to be identified by using Brazilian test.

Objectives

The objectives of this study are:

1. To carry out the Brazilian test in shale with three different lamination angle.
2. To determine the tensile strength with regard to lamination angle.
3. To monitor the mode of failure occurred in the tested sample.

Scope of Study

The effects of lamination on tensile strength is studied by performing the Brazilian test with regard to three different lamination angle which are 0°, 30°, and 90°. The equation from the Brazilian test will be used to determine the value of tensile strength and the mode of failure also will be observed as factor of the sample failure through tensile strength.

LITERATURE REVIEW

Shale is the weaker stones in the sedimentary rocks. It is due to the properties of itself that consist of silt and clay materials. But in present of lamination the strength of shale can changes and dependent on their anisotropy properties. Strength is one of the important parameter in rock mechanics engineering. The different process in performing the three major group (igneous, sedimentary, and metamorphic) of rock has their different nature of strength whether in rock mass or material properties. Most of the results from the laboratory test were used to supplement the field data in order to get the better interpretation. Shale is one of the sedimentary rock that not suited for uniaxial compression test [3]. For this study, the Brazilian test have been proposed as one of the indirect method to determine the tensile strength of shale. The elastic equation of isotropic is used in order to determine the tensile strength value.

Shale

Shale is a sedimentary rock that forms due to compaction of silt and clay-size mineral particles. It was a products that were produced by sediment rock because of the compaction and cementation. . Basically, when the silt and clay were compacted then it will form the shale. But, before the clay and silt was forms due to chemical weathering, the weathering breaks the mudstones and become the pieces of clay minerals and other small particles that often become the local soil [4]. Naturally, it was the properties of shale and it usually breaks into thin layers and most of them parallel to the otherwise indistinguishable bedding plane due to orientation of mineral flakes.

Lamination

Shear is the sedimentary rock that characterized by its laminated structure [1]. The means of laminated is the rock has made up of many thin layer and fissile means the rock were splits into thin pieces along the lamination [4]. Lamination can be the result of sedimentary layering, extensile jointing, or fabric created through parallel excavation stress fracturing of massive ground. Besides that, lamination is act as importance roles in controlling the rock mass behavior for example when there is a presence of lamination the behavior of sedimentary rock is changes from isotropic to anisotropic [2]. The strength of the lamination is based on the orientation of the major principle stress (σ) but the failure strength of the rock mass is not dependent on the vertical or horizontal direction, its dependent on the anisotropic properties.

Anisotropy

Shale is well known for its anisotropic which leads to complexity in the rock mass behavior [5]. The characterization of anisotropy is critical in shale due to the nature of grain alignments and various mechanism to create fracture in shale [6]. Anisotropy is responsible for the largest variations in seismic velocity that changes in the orientation of mineral or in the direction of seismic wave because of larger changes in velocity than can be accounted for by changing in temperature, composition or mineralogy [7]. Shales are inherently mechanical anisotropic and its strongly in vertical because of lithological and lamination. Besides, it also dependence by regular fracture of shale complex and differential horizontal stress [8].

Tranverse isotropy

Full anisotropy can be simplified to transverse isotropy when there is an axis of rotational symmetry [6]. In anisotropy there are two main types of anisotropy, is called transverse isotropy and polar anisotropy. It is called transverse isotropy because there is isotropy in the vertical and horizontal plane. From that, it has two transverse isotropy which is vertical transverse isotropy (VTI) and horizontal transverse isotropy (HTI). VTI is associated with layering and shale, it has found due to gravity factor while HTI is associated with fractures and cracks due to regional stress. Both of them has found due to dominant factor.

Strength of Shale Lamination

Shale is one of the weaker stones because it's a product of clay and silt during the sedimentary process which mean their strength can be classified as the weaker stone compared with other. Moreover, the present of lamination on shale can change their strength dependent. On the other hand the strength of shale will dependent on the anisotropic properties. In this study, the way to identify the strength of shale lamination is by using different orientation during testing. According to previous study, the orientation that give maximum value of compressive strength is $\beta = 90^\circ$ [7]. But some other researcher has got the value at $\beta = 30^\circ$ is the maximum value of tensile strength [9]. Besides that, the orientation of lamination can affect the tensile strength. The results from previous studies shows that the tensile strength along the lamination is lower than tensile strength across the lamination plane [6].

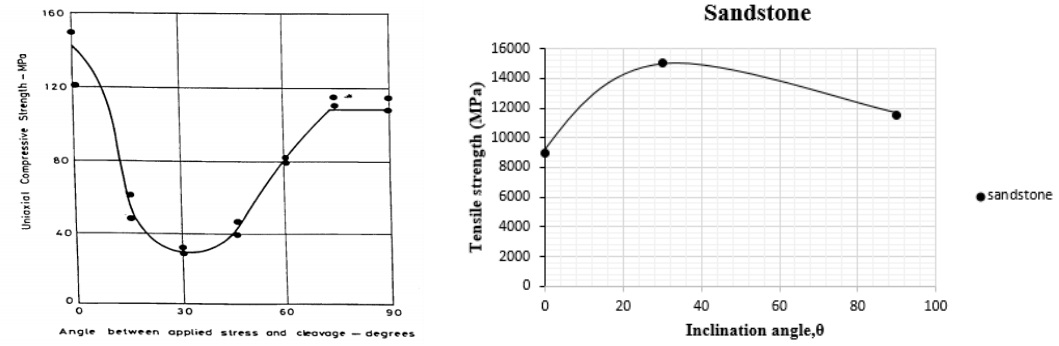


Figure 1: Graph strength Anisotropy in compression and tension [9].

Brazilian Test

Brazilian test or indirect tensile test of rock core is the common method in determining the tensile strength. This test also as an easy test to carry out. The tensile strength is calculated by using an equation. The Brazilian test has been used in geotechnical analysis [10]. Many researcher have studied the tensile strength of anisotropic rocks by using the Brazilian test with the equation for isotropic material.

$\sigma t = 2P / \pi(D)L$ **Eq.1**

The equation (1) is used to determine the tensile strength according to the reading value that were produced by Brazilian test. . When applied force (P) hit the sample, the failure will initiates at the center of the core sample and propagates centroid along the loading direction. The meaning of the failure will initiates at the center of core sample is when the ratio of the compressive to tensile stress is least and equal three [11]. In Brazilian test, a disc of material is subjected to the opposing normal strip loads at the disc periphery as shown in Figure (1).

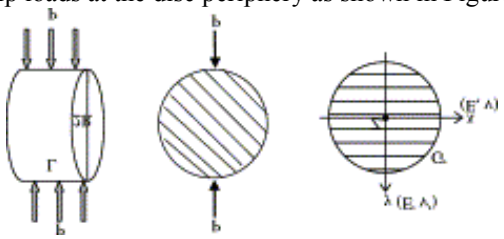


Figure 2: Material subjected in Brazilian test

METHODOLOGY

For this study the laboratory testing that has been proposed is Brazilian Test. Thus, the rock sample that required for these test is shale. The function of these test is to determine the rock characteristic especially the tensile strength.

Brazilian Test

The Brazilian test was found to be the best option for testing the weak and weathered rock such as shale rock materials. The Brazilian test apparatus and procedure enables economical testing of core or lump rock samples either a field or laboratory setting. The aim for this test is to determine the tensile strength of the rock samples. Therefore, the linear elastic calculations are used in order to identify the strength value [11]. Since the test is one of the indirect tensile test so the equation (1) are used in this study. In this Brazilian test the disc of the samples are subjected to two opposing normal strip loads. The P (N) is applying load, R (mm) is the radius, and L (mm) is thickness of the sample. From the equation (1) the tensile strength of rock can be calculated following the standard method of ISRM. The Brazilian test is an effective test in geotechnics and intended to estimate the indirect tensile strength of rock indirectly by the failure stress of diametrically loaded cylindrical or disc shape sample. The diametric loading of shale disc was performed with the triaxial loading frame which consist of the loading device used for applying and measuring the axial load to the specimen.

Thin Section

Every rock has their own mineralogy such as Alkalin feldspar, Quartz, lithic fragment, muscovite, hornblende and Plagioclase feldspar. All of the mineralogy can be obtained through thin section method which is can determine the percentage of the mineral composition for every rock. The thin section was analysed under XPL(Cross Polarized Light) and PPL(Plane Polarized Light) with different scale of magnification to identify each of the minerals under microscope. Since the sample for this study is shale or has been called as mudstone so the contaminant of the minerals are usually quartz, lithic fragment, alkali feldspar and muscovite. For this study the method are the using secondary data which is the test will be run with another group.

RESULTS AND DISCUSSIONS

Based on the recorded data that obtained from Brazilian test, the results for tensile strength were calculated using Microsoft Excel spreadsheet. All the test results, including mode of failure has been recorded and will be further discuss in this chapter. The results for thin section done by other group member also will be discussed in this chapter in order to identify the type of mineralogy for the rock tested.

Thin Section

Percentage of mineral composition obtained from rough counting on thin section denotes 30% of Quartz, 35% of Lithic Fragment, 35% Alkali Feldspar and 5% of Muscovite. The thin section was analysed under XPL and PPL with 10x magnification to identify each minerals under the microscope. The result shows this sample has aphanitic texture with smaller angular quartz cemented by lithic fragment and muscovite. The Lithic fragment was dominant in the sandstone sample due to sedimentation process. Muscovite was identified by the rainbow colour under XPL which has properties of crystal shape like sheet elongate parallel and show bird eye- extinction. Thus from the observation under microscope, this sample was named as Feldsphatic litharenite (Sandy mudstone).

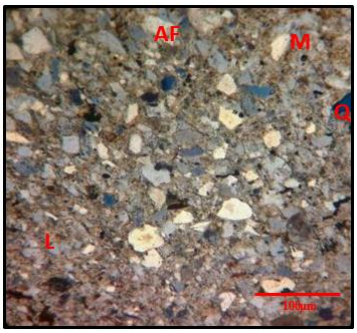


Figure 3: Photomicrograph of Mudstone.

Tensile Strength

By referring to the table below, it shows that all the calculation value for every sample tested. The value for tensile strength that were provide in that table is the highest value for each of the sample. So that, the value of an average tensile strength was calculated by using the maximum value. The value of tensile stress, vertical strain and young modulus has been tabulated in order to simplify all the results for this study and make it easier to do the discussion.

Tensile stress, $\sigma\tau = 0.636P/ Dt$; **Eq.2**

Vertical strain, $\varepsilon v = (\text{Displacement} / D) \times 100$; **Eq.3**

Table 1: All the calculation value for every sample tested.

Sample	Lamination angle, θ	Tensile stress, στ (kPa)	Vertical strain, εv (%)	Young modulus, E (kPa)	Average tensile stress, $\sigma\tau_{ave}$ (kPa)
A1	0	2391.36	0.98	2328.8	1615
A2		1537	0.74	1949	
A3		915.84	0.82	963.5	
B1	30	1845.26	1.11	1608.9	2185
B2		1424.64	0.88	1923.6	
B3		3286	1.32	2358.4	
C1	90	2299.38	1.22	1721	1844
C2		1850.18	0.8	2148.7	
C3		1382.61	0.72	1535.4	

Average Tensile Strength

Figure 2 show that the lowest value of tensile strength is at 0°, the strength increase at 30° and then the value were reduces again at 90°. This finding is in well agreement with previous study [10] . Other than that, previous study state that the strength will increase by increasing the lamination angle [1]. Which mean the strength at 90° is higher than at 0°. However, the opposite direction was observed for the effect lamination in compression. In which the value of compressive strength is higher at 0° and then the value recorded the lowest value at 30°. After that the value of compressive strength increased again at 90°. This is because when the loading applied is perpendicular to the lamination it will give minimal effect on the loading and gives rise to the highest compressive strength among the other lamination angle. In addition, previous study state that the failure strength should be corresponds to the tensile strength of the intact material or tensile strength of the layer. But it is only depends on the lamination angle which are $\theta = 0°$ and $\theta = 90°$. For this finding, the 0° of the failure strength is corresponds to the tensile strength of the layer and 90° is corresponds to the tensile strength of the intact material. It depending on how the lamination of the sample has been set up before the testing.

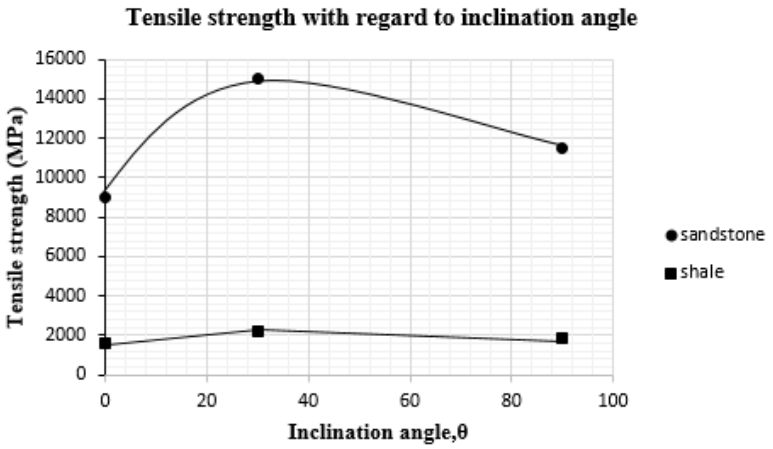


Figure 2: Graph average tensile strength with regard to lamination angle

Mode of Failure

In this part, the sample fracture has been recorded to identify the type of fracture that occurred for every sample. There are three type of fracture that can be classify for each sample which are layer activation, central fracture, and non-central fracture.

Sample A

All this sample shows some "layer activation" characteristic which is the fracture mostly occurred parallel to the isotropic layer when the loading applies through isotropic layer which is θ = 0°. This is because the sample has been loaded parallel to the weakness plane. That is why the sample are weak when the loading applied parallel to that layer. So it can be conclude that the fractures of sample A should be called as a "layer activation" in the type of mode failure.

Figure 3: Mode of failure for sample A

Sample B

The fractures of this sample are roughly parallel to the loading direction which is θ = 30° and they are located in the central part of the sample between the two loading lines. The central part is arbitrarily defined as 10% of the diameter on both sides of the central line. These fractures are called as "central fractures". However, for sample B2 and B3 the fractures occurred outside of the central part. They are not correspond to the layer activation, they are further called as "non-central fractures". The pattern are often curved lines, starting at or around the loading platens.

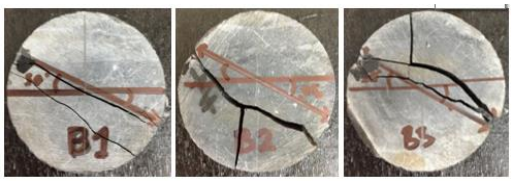


Figure 4: Mode of failure for sample B

Sample C

For sample C there are two cases of the fractures when the loading are perpendicular to the isotropic layer which is θ = 90°. One is the layer activation which occurred at sample C1 where the fractures are parallel to the isotropic layers. So the fractures of the sample is classified as "layer activation". On the other hand, sample C2 and C3 are clearly showed that the fractures are roughly parallel to the loading direction and located in the central part of the sample between two loading lines. Thus, the samples are called as "central fractures".

Figure 5: Mode of failure for sample C

CONCLUSION

- A series Brazilian test has been carried out on shale with three different lamination angle of 0°, 30°, and 90°.
- It was found that the 30° of lamination gave the highest value of tensile strength compared with the rest which is 2185kPa. Thus, this finding is in well agreement with the previous study.
- The layer activation is the fracture that occurred parallel to the isotropic layer and most of the sample A has shown that criteria. For central fracture, the fracture occurred at the center part of the sample. Mostly the sample C has shown that type of fracture. Lastly is non-central fracture, it occurred mostly in sample B where the sample fracture occurred around of the center part of the sample.

REFERENCES

[1] Diederichs, M. S., & Kaiser, P. K. (1999). Stability of large excavations in laminated hard rock masses: the voussoir analogue revisited. *International Journal of Rock Mechanics and Mining Sciences*, *36*(1), 97-117.

[2] Cheng, J., Wan, Z., Zhang, Y., Li, W., Peng, S. S., & Zhang, P. (2015). Experimental study on anisotropic strength and deformation behavior of a coal measure shale under room dried and water saturated conditions. *Shock and Vibration*, *2015*.

[3] Bailey, M. J. (1976). Degradation and Other Parameters Related to the use of shale in compacted embankments. *Joint Highway Research Project C-36-5L, engineering experiment station*, 210.

[4] KING, H. (Producer). (2005). Geology.com. *geology.com/rocks/shale.shtml*. Retrieved from http://geology.com/rocks/shale.shtml

[5] Anikoh, G. A., & Olaleye, B. M. (2013). Estimation of Strength Properties of Shale from Some of Its Physical Properties Using Developed Mathematical Models. *The International Journal Of Engineering And Science*, *2*(4), 1-5.

[6] Mokhtari, M. (2007). *Characterization of anisotropy in organic-rich shales: shear and tensile failure, wave velocity, matrix and fracture permeability*. Colorado School of Mines

[7] Anderson, D. L. (1998). *Chapter 15: Anisotropy*. Boston: Blackwell Scientific Publication,c1989.

[8] Jarosiński, M. (Producer). (2014). Polish Geological Institute. *infolupki.pgi.gov*. Retrieved from http://infolupki.pgi.gov.pl/en/gas/mechanical-properties-shale-rocks

[9] Tavallali, A., & Vervoort, A. (2013). Behaviour of layered sandstone under Brazilian test conditions: Layer orientation and shape effects. *Journal of Rock Mechanics and Geotechnical Engineering*, *5*(5), 366-377.

[10] ISRM. (1985). Suggested method for Brazilian test. *International Society of Rock Mechanics Commission on Testing Methods*.

[11] Claesson, J., & Bohloli, B. (2002). Brazilian test: stress field and tensile strength of anisotropic rocks using an analytical solution. *International Journal of Rock Mechanics and Mining Sciences*, *39*(8), 991-1004.

The Bearing Capacity of Marine Clay Treated with Optimum Percentage of Magnesium Chloride, $MgCl_2$

Muhammad Firdaus Bin Roslan, Siti Norafidah Jusoh

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

snorafida@utm.com

Keywords: Marine Clay; Magnesium Chloride; Stabilizer; CBR; UCS; Bearing Capacity.

ABSTRACT. Marine clay, a soil in which contains weak engineering properties. By soil improvement, any structures can be carried on the top of the soil. For this study is aimed to determine the bearing capacity of marine clay that has been treated with a polymer, as one of the chemical stabilizer is Magnesium Chloride ($MgCl_2$). The objectives of the study were to determine; to investigate the bearing capacity of untreated marine clay in order to understand its basic strength; to evaluate the unconfined compressive strength and optimum percentage of $MgCl_2$ of marine clay treated with varies percentage of Magnesium Chloride ($MgCl_2$) (0%, 2%, 4%, 6%, 8% and 10%) added to the marine clay at different curing time 3, 7, 14 and 28 days; to compare the result between untreated marine clay with treated marine clay with $MgCl_2$ on the improvement of bearing capacity of marine clay; and to determine the bearing capacity of the marine clay treated with $MgCl_2$ using California Bearing Capacity test. The optimum moisture content (OMC) and maximum dry density (MDD) found from the previous study by M.S Suhaini on 2016 on marine clay at Teluk Intan, Perak. The samples of compacted marine clay treated with Magnesium Chloride ($MgCl_2$) were tested in laboratory for unconfined compressive strength (UCS) test. From the compaction test, the OMC and MDD of marine clay were found as 38% and 1.21 Mg/m3 respectively. The UCS of the compacted untreated marine clay is 52 kPa. The strength of untreated marine clay increased when the soil was mixed with various of percentage of $MgCl_2$. From the results obtained, the optimum percentage of $MgCl_2$ used is 4%. The UCS strength increased to 77 kPa at 3 days of curing. Then the strength increased to 82 kPa for 7 days of curing. But the strength is decrease simultaneously at 65 kPa and 73 kPa for 14 days and 28 days of curing time respectively. Based on the results, its shows that the strength of treated marine clay generally increased until curing period of 7 days then decreased with curing period.

INTRODUCTION

Soil stabilization that can operates in various ways such as mechanical, biological, physical, chemical and electrical technique can be a tools to solve this problematic soils. Among these, chemical is receiving the most attention in order to improve the soil strength parameter [1]. Mostly the geotechnical engineers in construction industry practically use chemical soil stabilization in various ways for example, for road construction, slope stabilization and erosion control, foundation and embankment treatment and improving the coastline for construction. This popularity is due to their low cost and convenience, particularly in geotechnical projects that require a high volume of soil [2]. Soil stabilizers can divide into two parts, traditional and non-traditional. For non-traditional stabilization, on this studies using Magnesium Chloride ($MgCl_2$). Magnesium chloride (chemical formula $MgCl_2{:}XH_2O$) is a salt of magnesium and chlorine. These salts are typical ionic halides, being highly soluble in water. The hydrated magnesium chloride extracted from brine or seawater. Magnesium chloride also is one of many chemical substances that used for dust control, soil stabilization and wind erosion mitigation.

Problem Statement

The marine clay of considerably low strength put limitation on the possible highway embankment load and prone to large settlement due to high deformability and low permeability [3]. Besides that, swelling of marine clay leads potential to destroy the building foundation just a few years only [4]. In term of climatic conditions on the construction site, the constructed pavement on the marine clay (which is marine clay as subgrade) will have less durability, which requires lot of maintenance cost. In order to improve the strength of marine clay, the aim of this study would provide the best solution is chemical stabilization using Magnesium Chloride ($MgCl_2$) based on the characteristic on the solution with varies percentage of $MgCl_2$. Besides that, the design of bearing capacity can be determined in order to reduce the settlement of marine clay in the construction site.

Objectives

The objectives of this study are:

1. to carried out review on previous research on physical properties of marine clay, soil stabilization by using Magnesium Chloride, $MgCl_2$
2. to investigate the bearing capacity of untreated marine clay in order to understand its basic strength.

3. to evaluate the unconfined compressive strength and optimum percentage of $MgCl_2$ of marine clay treated with varies percentage of Magnesium Chloride ($MgCl_2$) (0%, 2%, 4%, 6%, 8% and 10%) added to the marine clay at different curing time 3, 7, 14 and 28 days.

4. to compare the result between untreated marine clay with treated marine clay with $MgCl_2$ on the improvement of bearing capacity of marine clay.

5. to determine the bearing capacity of the marine clay treated with $MgCl_2$ using California Bearing Capacity test.

Scope of Study

The primary objective of this final year project is to determine the bearing capacity of marine clay treated with $MgCl_2$. Before conducting the laboratory test, the previous research had provided the physical properties of untreated marine clay which had been done on the similar sample. The sample of untreated marine clay was obtained from Teluk Intan, Perak. The sample mixed with different percentage of Magnesium chloride, $MgCl_2$ and tested under the different curing period of 3, 7, 14, and 28 days. All samples that were treated with chemical undergo curing periods. The chemical content used for this study was 0%, 2%, 4%, 6%, 8% and 10% based on the percentage of $MgCl_2$ mixed with water.

LITERATURE REVIEW

Marine clay specifically is a type of clay found in coastal regions around the world. In the northern region, it can sometimes be quick clay, which is notorious for being involved in landslides. Different place makes different properties of marine clay. When clay is deposited in the ocean, the presence of excess ions in seawater causes a loose, open structure of the clay particles to form, a process that known as flocculation. Once stranded and dried by ancient changing ocean levels, this open framework means that clay is open for water infiltration. From that point, construction on marine clays presents a geotechnical engineering challenges. The most common problems in marine clay areas is the settlement of ground. In certain periods, the soil loses moisture and shrink which causing a gap under the construction.

Geotechnical problems posed by marine clay can be handled by various ground improvement techniques. Marine clay can be densified by mixing it with cement or similar binding material in specific proportions. An application of marine clay treated with Magnesium Chloride ($MgCl_2$) has been studied by the previous researcher [5].

There are several methods of soil stabilization but it can be divided into two categories which are mechanical and chemical stabilization. Traditional additives include cement, lime, fly ash and bituminous materials [6], while that have been researched that the fundamental stabilization mechanisms of traditional stabilizers have been identified [7]. A researcher [8] studied that the use of traditional soil stabilizers such as lime or cement can change the pH of improved soil, with the potential to cause negative environmental impacts including retarded vegetation growth, reduction in groundwater quality and even potentially human health problems.

One of the most significant sources of CO_2 emissions in the world is cement production, with approximately one ton of CO_2 being produced during the production of one ton of cement; consequently, it is estimated that 5 % of the CO_2 that is produced in the world annually can be attributed to cement production [9]. Particulate air emission in the form of cement dust is another environmental problem. To overcome these issues, a number of researches more focusing on the use of non-traditional soil improvement additives which may present a more sustainable solution for some applications [6].

The non-traditional additives can help to increase soil strength with curing time [6]. For non-traditional additives, there are various of combination consist of enzymes, liquid polymers, resins, acid, silicates, ions and lignin derivatives [8]. The use of $MgCl_2$ becomes more common because it is potential to improve the geotechnical properties of problematic soils. Some studies reported on the successful application of $MgCl_2$ solution to improve the swell potential, strength characteristic and dispersibility properties [9]. In the developing of world nowadays, chemical substances such $MgCl_2$ solution do not corrode vehicles, damaging the cement and asphalt either way harm plants or living creatures have long been used to de-ice roads in regions that experience harsh winters, such as North America, Scandinavia and Europe [10].

A researcher had done a study on $MgCl_2$ as soil stabilizer [11]. There were two samples used which are kaolin and bentonite. $MgCl_2$ used for the study are 2 %, 4%, 6%, 8%, 10%, and 12% by dry weight of the soils, and curing for 3, 7, 14, and 28 days in controlled room temperature (27ºC). The $MgCl_2$ improved the unconfined compressive strength (UCS) of bentonite and kaolin significantly. The UCS of both bentonites mixed with $MgCl_2$ and kaolin mixed with $MgCl_2$ for 7 days curing period were higher than the unstabilized soil samples. The highest UCS obtained were 520 kPa for the soil samples mixed with 8% $MgCl_2$ and curing for 7 days, which it is doubled from the unstabilize soil. The optimum percentages of $MgCl_2$ solution are 8% for bentonite and 10% for kaolin. The rate of the strength development in the first 7 days was higher than that in the thereafter although UCS increased with curing time. This indicates that most of the chemical reaction happened at early stage of curing.

A research on peat soil stabilized using $MgCl_2$ done on 2015 [12]. The $MgCl_2$ used for the study are 3%, 6%, 9%, 12%, and 15% by dry weight of the soils, and curing for 3, 7, and 28 days. The researcher found that the strength of peat soil mixed with $MgCl_2$ increased with time. The peat soil mixed with 6% $MgCl_2$ is the highest value of

compressive strength is 96 kPa after 28 days curing, which is seven times more compared to the untreated soil. It is indicated that most part of the soil stabilized reactions happened within the first 3 days. Besides, it was clear that for the samples treated with higher $MgCl_2$ content which is more than 6%, a lower compressive strength was achieved.

According to Latifi [14], most of the chemical reactions happened at the early stage of curing, indicating the suitability of the $MgCl_2$ stabilization in projects with a tight schedule. A research stated that the strength increased at early 3 days after stabilization and contantly increased from 7 to 28 days [13].

METHODOLOGY

There are various laboratory tests and analysing to get the characteristics for marine clay treated with different percentages of Magnesium Chloride ($MgCl_2$) each sample. The laboratory works consisted of a series tests on physical and mechanical properties of marine clays mixed with magnesium chloride to determine the sustainability of improving marine clay in terms of bearing capacity and shear strength. This research methodology consisted of three key activities: preparation samples for marine clay treated with Magnesium Chloride; Unconfined Compressive Strength test on treated marine clay samples; and bearing capacity analysis.

Laboratory Test

Laboratory work is focus on determine the physical properties of the marine clay such as shear strength, natural moisture content, liquid limit, plastic limit, plasticity index, specific gravity, maximum dry density and optimum moisture content. After the first phase of laboratory work done on determine the physical properties of marine clay, start to prepare the sample need to be test by referring the Table 2 below. All of the sample will be compacted and will be test on unconfined compression test with curing time of 3,7,14 and 28 days. Table 1 below shows the type of laboratory test that has been conducted for this test.

Table 1: List of laboratory test

No.	Test	Standard Method
1	Unconfined Compressive Strength Test (UCS)	BS 1377: Part 7: 1990: 7
2	California Bearing Ratio Test (CBR)	BS 1377: Test 16: 1975

Marine Clay treated with Magnesium Chloride sample preparation

The soft Marine clay was obtained from Teluk Intan Perak and been stored in the geotechnical laboratory UTM, Johor Bharu for further analysis. The $MgCl_2$ is obtain in the geotechnical laboratory UTM. The sample of marine clay is stored in plastic bags in dry condition. The sample then will be prepared into six different proportions and every proportion will be prepared into 12 samples. The chemical used in this study, Magnesium chloride ($MgCl_2$) in the solid form. The $MgCl_2$ is dissolved in distilled water to form a solution. The solution stirred by using stirring hotplate. There are five different concentrations of MgCl2, which are 2%, 4%, 6%, 8% and 10% by weight of the magnesium chloride and untreated sample as a control variable.

Table 2: Propotion of Sample with $MgCl_2$

Sample	Mixing Percentage
1	Soft Marine Clay + 0% magnesium chloride ($MgCl_2$) + water
2	Soft Marine Clay + 2% magnesium chloride ($MgCl_2$) + water
3	Soft Marine Clay + 4% magnesium chloride ($MgCl_2$) + water
4	Soft Marine Clay + 6% magnesium chloride ($MgCl_2$) + water
5	Soft Marine Clay + 8% magnesium chloride ($MgCl_2$) + water
6	Soft Marine Clay + 10% magnesium chloride ($MgCl_2$) + water

Uncofined Compressive Strength Test (UCS)

Six samples were prepared with the different percentage of $MgCl_2$ which are 0%, 2%, 4%, 6%, 8% and 10%. The samples were cured for 0, 3, 7, 14 and 28 before running the test. The samples were prepared using cylinder mould with 38 mm diameter and 76 mm height. The samples were compacted using compression machine and extrude by the extruder. The specimens were placed in bottle after extruded and then placed them in a box for curing process. After curing days, each sample was weighted to determine the water content. The load was applied to each sample at a displacement rate of 1.52 mm/min and the loading was continually applied until the sample fail. The loading is continued until the soil develops an obvious shearing plane or the deformations become excessive which considered failed. Finally, the sample was oven dried to determine its moisture content. The maximum load per unit area is defined as the unconfined compressive strength. Hence, the undrained shear strength measured in an unconfined test is expressed in terms of the total stress.

Bearing Capacity Analysis

California Bearing Ratio (CBR), is a penetration test for evaluation of the mechanical strength of natural ground. The CBR rating was developed for measuring the load-bearing capacity of soils used for building roads. The CBR can also be used for measuring the load-bearing capacity of unimproved airstrips or for soils under paved airstrips. The harder the surface, the higher the CBR rating. For CBR test, the samples were prepared for 3 samples which are used for the tests and both of readings are taken as average from these 3 samples. For each sample through the compaction into CBR mold with for each layer undergo for 62 blow of 4.5 hammer and set for 5 layers. After the compaction, the samples are under-go for the CBR test.

RESULTS AND DISCUSSION

All the laboratory tests had been carried out to achieve the objectives of the study.

Physical Properties of Marine Clay

The soil properties results shown consistency with previous researcher thus can be used for this project. Based on the table below, the liquid limit obtained in current study has the same results with the soil at Teluk Intan, Perak which were 78%. The plastic limit obtained in current study is in between the range of 23% to 47%, which is 41%. The plasticity index obtained in current study has the highest value compared to the other previous researchers. The result shows that there was a slight different between each other except for liquid limit even though the location for the sample taken was the same.

Table 3: Physical Properties of marine clay

Researchers	Location	Physical Properties			
		LL (%)	PL (%)	PI (%)	Specific Gravity (SG)
Current study (2017)	Teluk Intan, Perak	78	41	37	2.68
Aziz (2015)	Teluk Intan, Perak	78	47	31	2.50

Uncofined Compressive Strength (UCS) Test

From the compaction test, the OMC and MDD of the marine clay were found as 38% and 1.21 Mg/m3, respectively. According to Aziz (2015), the OMC and MDD of marine clay in Teluk Intan are 40% and 1.21 Mg/m3, respectively. Figure 1 shows the graph of dry density and moisture content. To compare with previous researchers, the MDD has the same value with marine clay in Teluk Intan, Perak as reported by Aziz (2015) which is 1.21 Mg/m3, while the OMC is slightly different. The difference between the value of the OMC of the current study and OMC of Aziz (2015) is 2%. The results of MDD and OMC obtained from the compaction test had been used in sample preparation for UCS tests on marine clay mixed with $MgCl_2$.

From the Figure 2, the highest Unconfined Compressive Strength is 82 kPa when sample treated with Magnesium Chloride, $MgCl_2$ at 4%. And the optimum curing period for the treated marine clay to obtain this strength during the 7 days curing period. While the lowest strength is obtained when the sample treated with 10% of $MgCl_2$ at 3 days curing period. These shown that the optimum of percentage for marine clay treated with $MgCl_2$ is 4% at curing period of 7 days.

Mostly, various percentage of $MgCl_2$ shows drastically changes when achieved on 14 days curing period since the effect of $MgCl_2$ to improve the strength of marine clay is not efficient. This reduction of strength happened because of the nature of water-based stabilizer and improperly compaction during the preparation of the samples.

Compared to sample of marine clay treated with 8% of $MgCl_2$, its shows the changes of the strength which increase when curing period of 14 days. This proved that the sample has lower permeability at initial stage of curing period, and the permeability increase after 14 days due to pozzolanic reaction in the treated soil. Besides, the soil sample improves in compressibility significantly due to long term reactions where it has developed strong and permanent bond. There are some cases which the stabilizing agents take time to react. The reactions between stabilizing agent and soil particles have changed the properties of soils and increases the compression strength and shear strength of soil which makes the soil more stable. Other than that, the rate of increase in strength is not stable during 7 to 14 days because the soil is still in the modification process where soil particle involved flocculation and rearrangement of particles.

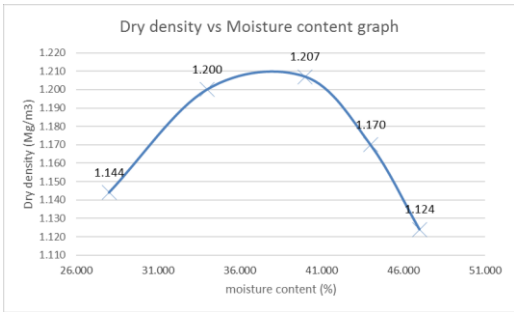


Figure 1: Graph of dry density and moisture content

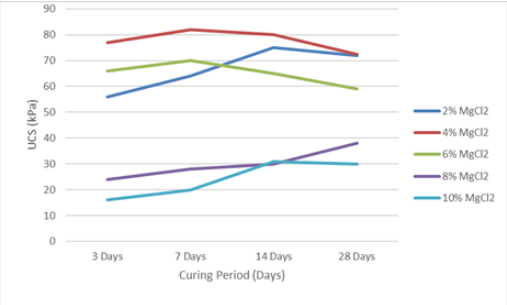


Figure 2: Relationship between UCS and curing period for various percentage of $MgCl_2$

Table 4: UCS at various curing periods

Sample	Unconfined Compressive strength (kPa)				
	0	3 days	7 days	14 days	28 days
Untreated Marine Clay	52	NA	NA	NA	NA
Marine Clay + 2% $MgCl_2$	NA	56	64	75	72
Marine Clay + 4% $MgCl_2$	NA	77	82	80	73
Marine Clay + 6% $MgCl_2$	NA	66	70	65	59
Marine Clay + 8% $MgCl_2$	NA	24	28	30	38
Marine Clay + 10% $MgCl_2$	NA	16	20	31	30

Note: NA = Not Availabe

Figure 3 shows the relationship between UCS and various percentage of $MgCl_2$. The highest strength is 82 kPa at 4% of $MgCl_2$ while the lowest strength is 16 kPa at 10% of $MgCl_2$.

Therefore, the optimum percentage of marine clay treated with Magnesium Chloride, $MgCl_2$ is 4%. The UCS of treated marine clay was higher that the untreated marine clay sample which is increased by 30 kPa more than before. The rate of strength development in the first 7 days was higher than other curing periods although the UCS increased with the curing time. This indicates that the most of the chemical reaction happened at the early stage of curing. Besides, it was clear that for the samples treated with higher $MgCl_2$ content more that 4%, a lower compressive strength was achieved.

From the previous Unconfined Compressive Strength (UCS) test, it can be concluded that the optimum percentage of Magnesium Chloride ($MgCl_2$) is 4% at 7 days curing period. Thus, this result has been used for the next test which is marine clay is mixed with the optimum percentage of $MgCl_2$. Next the California Bearing Ratio test proceeded.

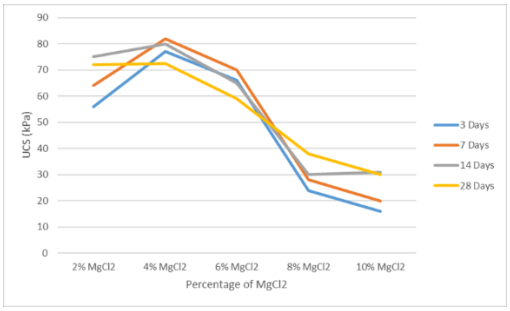


Figure 3: Relationship between UCS and various percentage of $MgCl_2$

California Bearing Ratio Test (CBR)

The optimum percentage of Magnesium Chloride ($MgCl_2$), 4% are used and mixed with marine clay and compacted with mould. For this test, the samples are prepared for 3 samples. The reasons why should prepare for 3 samples because from the results that obtained, take the highest value to analysis the value of CBR. Samples also cured with curing time of 7 days to follow the optimum percentage of $MgCl_2$ that achieved at 7 days curing period in previous conducted test. The tables below are shown the results for the 3 samples on California Bearing Ratio test.

Table 5: CBR value for both upper and lower samples

Sample	2.5mm (Upper)	2.5mm (Lower)	5.0mm (Upper)	5.0mm (Lower)
A (%)	0.72	0.58	0.68	0.58
B (%)	0.49	0.38	0.58	0.45
C (%)	0.38	0.29	0.45	0.39

By referring Figure 1, the Maximum Dry Density (MDD) is 1.21 Mg/m3 and the Optimum Moisture Content (OMC) is 38%. Thus at 95% MDD is 1.15 Mg/m3. Generally, the CBR value at 2.50 mm penetration will be greater than that at 5.00 mm penetration and such in case, take the value at 2.50 mm as the CBR value. But if the CBR value corresponding to a penetration of 5.00 mm exceeds that of 2.50 mm, the samples or the tests are fail. Thus, should repeat the test. And in other condition, if the identical results follow, take the value corresponding to 5.00 mm as the CBR value.

The result of Sample A has been taken as control to observe with the untreated marine clay. Figure 4 shows the graph of load versus penetration of Sample A. Since the Sample A is taken as a successful sample because the value of penetration at 2.50 mm is higher penetration at 5.00 mm, the sample is not failed. In conclusion the value of CBR is 0.72%. Compared to the soaked CBR for 100% Marine Clay which is the CBR value is 1.754% based on Figure 5, the CBR value for treated marine clay is lower than untreated one. Hence, the bearing capacity for marine clay treated with $MgCl_2$ is lower than untreated marine clay. Its observed that the CBR value of the marine clay has not improved at all on addition of optimum percentage of Magnesium Chloride, $MgCl_2$.

The soaked CBR of the soil on stabilizing found to be 0.72% and not satisfying standard specification. So finally, it is concluded from the above results that the stabilizers marine clay is not suitable to use as a subgrade material for the construction of West-Coast Expressway at Teluk Intan, Perak and also for various foundations of buildings.

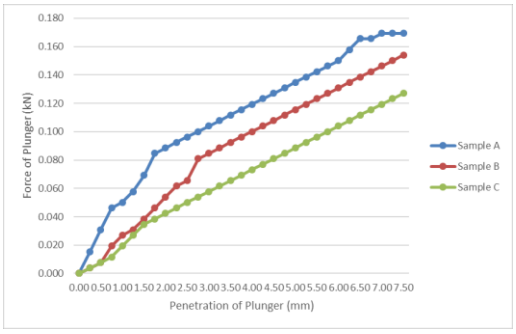


Figure 4: CBR for Treated Marine Clay

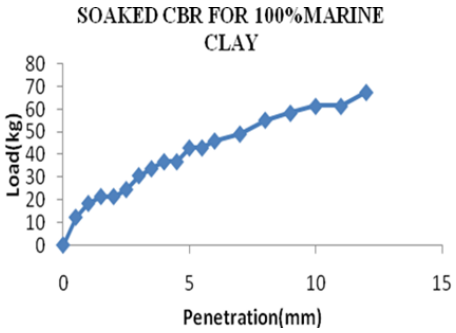


Figure 5: CBR for Untreated Marine Clay

CONCLUSION

1. It is observed that the plastic limit of the marine clay is in between the range of 23% to 47%, which is 41%.
2. It is observed that the OMC and MDD of the marine clay were found as 38% and 1.21 Mg/m3.
3. It is observed that the strength of untreated marine clay with Magnesium Chloride, $MgCl_2$ is 52 kPa.
4. It is observed that the highest Unconfined Compressive Strength is 82 kPa when sample treated with Magnesium Chloride, $MgCl_2$ at 4%.
5. It is observed that the optimum curing period for the treated marine clay to obtain this strength during the 7 days curing period.
6. The CBR value for treated marine clay is 0.72%. Less than the soaked CBR which is 1.754% and hence not suitable for any construction.

REFERENCES

[1] Al-Mukhtar, M., Lasledj, A., & Alcover, J. F. (2010). Behaviour and mineralogy changes in lime-treated expansive soil at 20 C. *Applied clay science*, *50*(2), 191-198.

[2] Latifi, N., Marto, A., & Eisazadeh, A. (2015). Analysis of strength development in non-traditional liquid additive-stabilized laterite soil from macro-and micro-structural considerations. *Environmental Earth Sciences*, *73*(3), 1133-1141.

[3] Desai, S. S., Choudhury, D., & Salunkhe, J. S. (2015). Ground Improvement of Marine Clay for Highway Construction in Mumbai, India. In *IFCEE 2015* (pp. 2262-2273).

[4] Rajasekaran, G., & Rao, S. N. (1997). The microstructure of lime-stabilized marine clay. *Ocean*

Engineering, *24*(9), 867877-875878.

[5] Latifi, N., Rashid, A. S. A., Ecemis, N., Tahir, M. M., & Marto, A. (2016). Time-dependent physicochemical characteristics of Malaysian residual soil stabilized with magnesium chloride solution. *Arabian Journal of Geosciences*, *9*(1), 58.

[6] Latifi, N., Eisazadeh, A., & Marto, A. (2014). Strength behavior and microstructural characteristics of tropical laterite soil treated with sodium silicate-based liquid stabilizer. *Environmental earth sciences*, *72*(1), 91-98.

[7] Raod, K., Rao, K. D., & Pranav, P. (2012). a Laboratory Study on the Stabilization of Marine Clay Using Saw Dust and Lime. *Ijesat International Journal of Engineering Science & Advanced Technology*, (24), 851–862.

[8] Kang, X., Asce, S. M., Kang, G., Chang, K., Ge, L., & Asce, M. (2014). Chemically Stabilized Soft Clays for Road-Base Construction. Journal of Materials in Civil Engineering, 27(7), 1–9.

[9] Turkoz, M., Savas, H., Acaz, A., & Tosun, H. (2014). The effect of magnesium chloride solution on the engineering properties of clay soil with expansive and dispersive characteristics. *Applied Clay Science*, *101*, 1-9.

[10] Choquette, M., Bérubé, M. A., & Locat, J. (1987). Mineralogical and microtextural changes associated with lime stabilization of marine clays from eastern Canada. *Applied Clay Science*, *2*(3), 215-232.

[11] Latifi, N., Rashid, A. S. A., Siddiqua, S., & Horpibulsuk, S. (2015). Micro-structural analysis of strength development in low-and high swelling clays stabilized with magnesium chloride solution—A green soil stabilizer. *Applied Clay Science*, *118*, 195-206.

[12] W.H. Hasmida (2015). Universiti Teknologi Malaysia. Peat Soil Stabilisation Using Magnesium Chloride

[13] Marto, A., Yunus, M., Zurairahetty, N., Pakir, F., Latifi, N., Nor, M., ... & Tan, C. S. (2015). Stabilization of marine clay by biomass silica (non-traditional) stabilizers. In *Applied Mechanics and Materials* (Vol. 695, pp. 93-97). Trans Tech Publications.

Effect of Joint Roughness Coefficient on Discontinuity Shear Strength

Noor Husna Abdul Malik, Rini Asnida Abdullah

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

asnida@utm.my

Keywords: Joint roughness, Shale, Shear Strength

ABSTRACT. This study presents the correlation between Joint Roughness Coefficient (JRC) and shear strength of joints in Shale. The influence of surface roughness and shear strength are verified and explanations on the effect are given. Basic friction angle is the frictional angle for sliding of smooth and planar surface. The effects of joint roughness on shear strength are investigated through a laboratory testing. The experimental results from seven shear test on samples of joint of different roughness are presented; six of them are secondary data. Schmidt Hammer Test is carried out to obtain the value of Joint Compressive Strength (JCS) and provide an estimate on the required applied normal stress during the shearing. Comparison of surface roughness is by visually comparing the roughness obtain on the comb to the standard profile chart. The shear strength is calculated using three different failure criterion. From the analysis, the difference between Mohr-Coulomb failure criterion and Barton-Bandis failure criterion are not significant to the shear strength because the roughness of the sample can be considered as smooth.

INTRODUCTION

The majority of rock masses behave as discontinuities. Accurate estimation of the shear strength of rock discontinuities is one of the important aspects in many rocks engineering project. The stability analysis must satisfy high claims of both safety and profitability. All rock masses contain discontinuities such as joints, bedding plane, plane within a shear zone etc. at shallow depth where failure of intact rock materials is minimal because of low stresses. Shear strength of rock joints depends on the factors like stiffness of surrounding rock mass, shear rate, joint roughness, scale effect, joint conditions, shear direction, degree of weathering and humidity conditions. According to Maksimović (1996), typical rock discontinuities usually display non-linear failure criteria. The equation of Barton-Bandis criterion is based on three index parameters which is the joint compressive strength, joint roughness coefficient and friction angle. These entire indexes can be measured either in the laboratory or in the field (Barton & Choubey, 1977). International Society for Rock Mechanics (ISRM) has listed the guidance on testing procedures for direct shear test as it shows a significant impact on determination of basic frictional parameters.

Problem Statement

It is a common practice to use Mohr-Coulomb to estimate the shear strength, but for the rock bodies that indicate the presence of discontinuities, joint roughness coefficient and joint compressive strength should be taken into consideration. Therefore, it is believed that the shear strength of shale is better to be estimated using Barton-Bandis criterion.

Objectives

The objectives of this study are:

1. To determine the shear strength of shale using direct shear test.
2. To study the effect of Joint Roughness Coefficient.
3. To identify the relationship between shear strength and normal strength.

Scope of Study

The effect of joint roughness coefficient and joint compressive strength is studied by performing direct shear test on shale.

LITERATURE REVIEW

The shear strength is the controlling factor of failure modes such as sliding on the fracture surfaces, which are the weakest point of the rock mass. The rock mass consists of intact rock and fractures. Sliding on the fractures is caused by failing shear strength between joint and it is the most frequent stability failure. In both civil and mining engineering, it is common to carry out a laboratory testing on an intact rock samples. Mostly, the samples are tested on Brazillian tests,

triaxial tests or UCS. However, direct shear test on rock mass are commonly disregard and decisions about behavior of rock fracture have to be taken based on core logging data, site observations and fracture mapping data [1].

By deepening the understanding of fracture behavior, the study benefits equally civil engineering and deep mining projects by the possibility of reducing time and cost losses as well as preventing future accidents [2]. The difference between contacting and non-contacting joint usually result in widely different shear strengths and deformation characteristics. Compressive strength and roughness are important in the case of unfilled joint. Many researchers has proposed different parameters and correlation in order to obtain strength parameters [3].

Table 1: Parameters and correlation to obtain strength parameter

Topic	Description
Shale	Shale is a fine-grained sedimentary rock originally from the compaction of silt and clay-size particles commonly known as mud forms from the weathering by-product of other rocks. Shale consists of heterogeneity that leads to difficulties in the behavior of rock mass [4].
Joint Compressive Strength (JCS)	Compressive strength of joint wall is an important parameter in the shear strength, any related process that results in a reduction of compressive strength that also contribute to reduction of shear strength [5]. The relationship between rebound number and joint compressive strength can be defined in the following relationship: $\log_{10}\ \mathrm{JCS} = 0.00088(\mathrm{g})(\mathrm{R}) + 1.01$ **Eq.1**
Joint Roughness Coefficient (JRC)	The joint roughness coefficient is a number estimated by comparing the appearance of a discontinuity surface with standard profiles. For the small scale laboratory specimens, the scale of the surface roughness will be approximately the same as the profiles illustrated [6].
Direct Shear Test	The analysis of the shear strength of rock joints are necessity for most rock engineering projects and compulsory for quantification of the influence of factors such as surface roughness, impersistence and infill for the joints . Basic parameters for friction are best determined by direct shear testing in the laboratory [7].
Mohr-Coulomb Criterion	According to Coulomb friction law, the rock mass visualize the joint behavior by a single surface parameter that is the average roughness angle. Thus, the Mohr-Coulomb criterion describes a linear relationship between normal and shear stresses at failure [8].
Barton-Bandis Failure Criterion	Barton-Bandis failure criterion is an empirical JRC-JCS model to estimate the shear strength of rock discontinuities [9]. This criterion is non-linear, and relates the shear strength to the normal stress is given by the following equation: $\tau = \sigma_n \tan[\,\phi_b + \mathrm{JRC}\log_{10}(\frac{\mathrm{JCS}}{\sigma_n})\,]$ **Eq.2** where τ is the peak shear strength; σ_n is the effective normal stress; φ_b is the basic friction angle; JRC is the joint roughness coefficient and JCS is the joint wall compressive strength.
Dilation angle	In order to prove the influence of surface roughness with the shear strength, the researcher performs a shear test using a 'saw-tooth' specimen [10]. As a result, the shear displacement in these specimens moving up the inclined faces which caused dilation of the specimen. The shear strength of Patton's saw-tooth specimens can be represented by the following equation: $\tau = c + \sigma_n \tan(\phi + i)$ **Eq.3** where i is the angle of the saw-tooth face (dilation angle)

METHODOLOGY

This research methodology consists of 4 key activities; tilt test to measure friction angle of the rock surfaces, roughness profiling on the joint surface and rebound hammer test and direct shear test.

Tilt Test
Tilt test is basically a test for measuring the friction angle of the rock surfaces. The tilt test is normally performed on dry joints to avoid any possibilities of joint water pressure and with the correlation with Schmidt hammer test that was measured on dry joints. The equipment consists of an adjustable inclined plane on which the rock sample is placed separated along the surface where roughness is to be measure. Then, the plane is slowly tilted until sliding of the upper part of the sample on the lower one occurs. The tilt testing was repeated five times to reduce possible errors during inclination measurements and the mean value was taken.

Roughness Profiling
Linear profiling can be done by using a roughness profiler which gives a useful basis of parameters related to the measurement of roughness. The roughness profiler will only came out with a single sample of surface profile. In most cases, each sample needs at least three profiles and most typical profiles were selected. The direction of measurement is commonly perpendicular to direction of specimen surface. The roughness profiler scale is only to describe the roughness on a 10 cm long sample. The values of a discontinuity are from the smoothest to the roughest range from 1 to 20.

Rebound Hammer Test
The test is done by applying the SH perpendicular to the discontinuity wall of interest. The SH consists of a spring-loaded piston which is released when the plunger is pressed against a surface. The impact from the piston transfers the energy to the sample or materials. The energy can be recovered depends on the either damage resistance or hardness of the material. The impact from spring-loaded piston of the SH is enough to make such movement to the surface that is being tested and the rebound number will obviously be low. It is normally release a 'drummy' sound and this result should be ignored. It is preferably to have a representative set of results for each surface of interest. It is suggested to perform the test in a group of 10 rebound per unit area by applying the hammer to a new part of the surface before each new impact. The five lowest rebound number of each group should be excluded in the calculation of mean value of rebound number.

Direct Shear Test
Sample Preparation. Core samples with the joint plane were trimmed to the required length and the final length must be such that there is minimal length of 30 mm on either side of the fracture. The trimmed core samples were the matched accordingly and hold together but before placing the sample in the shear box, the steel wire that hold the core sample was cut to allow shearing at the joint plane. During casting, the orientation of the selected fracture plane was accordingly adjusted to be in horizontal position when set in casting mould and the grout was left to cure for about 72 hours. The cast sample was air-dried before tested so that the shear strength obtained is under dry condition.

Normal Load. Throughout the shearing process, the normal stress was maintained at constant level as such this test termed as single-stage direct shear test. Each sample was either sheared to a maximum displacement of about 20 mm, or beyond its peak strength, at shearing rate of about 10 mm/min. A constant normal stress is obtained by normalizing the normal load with the cross-sectional area of the piston which can be calculated as follows:

Normal load, Ln (kN) = (Normal stress, σn) x (Area of joint surface, A) **Eq.3**
Pressure on gauge, Pn (MPa) = (Normal load, Ln) / (Area of piston, Ap) **Eq.4**
where Ap = 0.00203 m^2

RESULTS AND DISCUSSION
The test result in term of shear strength and displacement is summarized in table below followed by the plot of shear stress versus horizontal displacement along with the picture of sample to verify the relationship.

Table 1: Summary of the test result

No	Horizontal Load (MPa)	Vertical Load (MPa)	Horizontal Disp. (mm)	Vertical Disp. (mm)	Shear Load (N)	Gross contact area (m^2)	Shear Stress (MPa)
1	0	0	0.015	0.086	0	$5.703x10^{-5}$	0
2	0	0	0.444	0.979	0	0.002	0
3	0	0	1.008	1.631	0	0.004	0
4	0.047	0	1.210	2.081	94.733	0.004	0.021
5	0.983	0	4.862	8.370	1996.167	0.018	0.111
6	1.000	0	5.220	9.088	2030.000	0.019	0.105
7	1.000	0	5.220	9.080	2030.000	0.019	0.105
8	0.917	0	5.220	9.080	1860.833	0.019	0.096

9	1.413	0	5.238	9.258	2869.067	0.019	0.148
10	1.310	1.230	5.465	9.391	2659.300	0.020	0.131
11	1.637	2.433	6.140	9.706	3322.433	0.023	0.146
12	1.540	2.543	6.190	9.784	3126.200	0.023	0.136
13	1.480	2.730	6.301	9.794	3004.400	0.023	0.129
14	1.350	2.997	6.413	9.793	2740.500	0.024	0.115

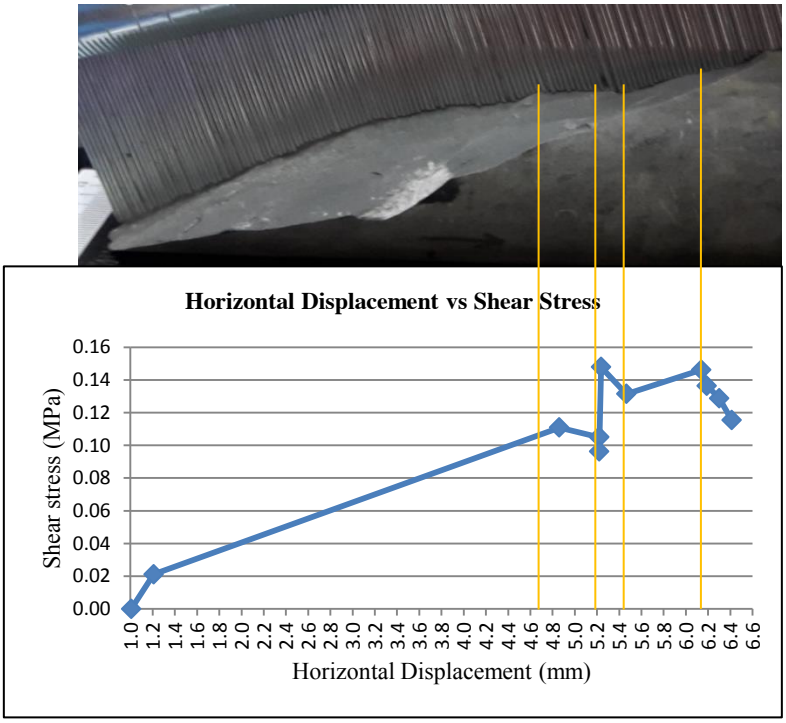


Figure 1 Graph of horizontal displacement versus shear stress

The shear stress increases linearly with the displacement and the samples behave elastically. The curve becomes non-linear and the fluctuation of the shear strength was observed in the plot above which can be attributed to the roughness and surface texture, the sample override on each other, thus increase the shear strength. All normal load used during the test and shear stress obtained are listed in Table 2 and graph of shear stress vs normal stress plotted in the figure below.

Table 2: List of shear stress with respect to the normal stress

No	Normal Stress (MPa)	Shear Stress (MPa)
1	0.8	0.411
2	1.0	0.899
3	1.3	0.446
4	1.5	0.649
5	1.8	0.745
6	2.2	0.826

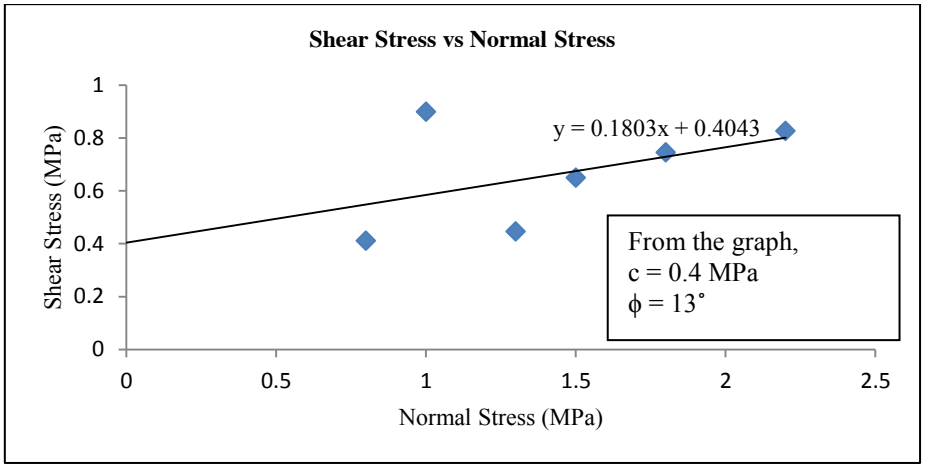


Figure 2 Plot of normal stress versus shear stress

The graph shows the trend of the shear strength increasing with normal stress. The trend may vary as the strength is dependent to the degree of roughness which often measured using joint roughness coefficient. From the graph, the slope is equal to the friction angle and the intercept of the line to the shear stress axis are correspond to cohesion.

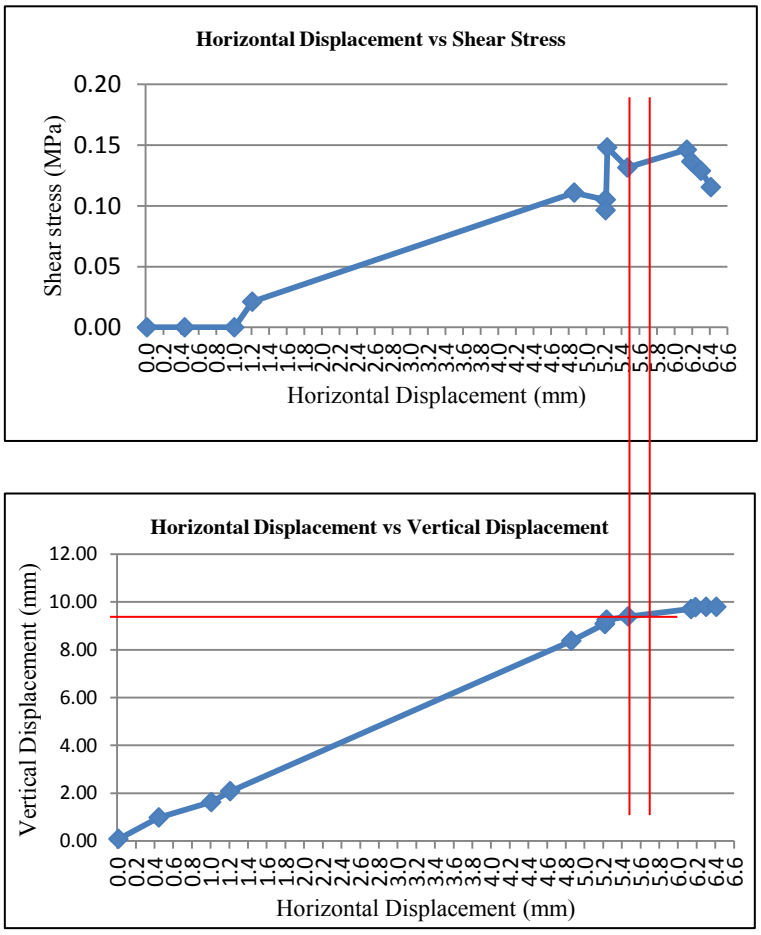


Figure 3 Determination of dilation angle

There is a change from dilation to shearing of rock and it relies on the compressive strength of the rock on the fracture surface and the displacement distance. Non-smooth surface that is originally uninterrupted and engage with each other will have friction angle of (ϕ + ì). The value of ì corresponding to the graph above is 27˚. Table below summarize all values for calculation of shear strength.

Table 3: Values for parameters of shear strength

Parameters	Values
Joint Roughness Coefficient (JRC)	13
Rebound number (R)	34
Joint Compressive Strength (JCS)	51.68
Friction angle (ϕ)	13˚
Cohesion (c)	0.4 MPa
Normal stress (σ_n)	1.0 MPa
Dilation angle (ì)	27˚

CONCLUSION

- Shear strength obtain from different failure criterion are listed as follows:

  a) Mohr-Coulomb : 0.86 MPa

  b) Barton Bandis : 0.87 MPa

  c) Shear strength with dilation angle : 1.24 MPa

- The difference between Mohr-Coulomb failure criterion and Barton-Bandis failure criterion are not significant to the shear strength because the roughness of the sample can be considered as smooth.

- The shear strength increases with the normal stress.

REFERENCES

[1] Melin, H. (2012). Controlling parameters for normal and shear behaviour of rock fractures-a study of direct shear test data from SKB.

[2] Sanei, M., Faramarzi, L., Fahimifar, A., Goli, S., Mehinrad, A., & Rahmati, A. (2015). Shear strength of discontinuities in sedimentary rock masses based on direct shear tests. *International Journal of Rock Mechanics and Mining Sciences*, *75*, 119-131.

[3] Singh, B., & Goel, R. K. (1999). *Rock mass classification: a practical approach in civil engineering* (Vol. 46). Elsevier.

[4] Anikoh, G. A., & Olaleye, B. M. (2013). Estimation of Strength Properties of Shale from Some of Its Physical Properties Using Developed Mathematical Models. *The International Journal Of Engineering And Science*, *2*(4), 1-5.

[5] Barton, N., & Choubey, V. (1977). The shear strength of rock joints in theory and practice. *Rock Mechanics and Rock Engineering*, *10*(1), 1-54.

[6] Ge, Y., Kulatilake, P. H., Tang, H., & Xiong, C. (2014). Investigation of natural rock joint roughness. *Computers and Geotechnics*, *55*, 290-305.

[7] Hencher, S. R. (1989). Laboratory direct shear testing of rock discontinuities. *Ground Engineering*, 24-31.

[8] Johansson, F., & Stille, H. (2014). A conceptual model for the peak shear strength of fresh and unweathered rock joints. *International Journal of Rock Mechanics and Mining Sciences*, *69*, 31-38.

[9] Kveldsvik, V., Nilsen, B., Einstein, H. H., & Nadim, F. (2008). Alternative approaches for analyses of a 100,000 m3 rock slide based on Barton–Bandis shear strength criterion. *Landslides*, *5*(2), 161-176.

[10] Patton, F. D. (1966, January). Multiple modes of shear failure in rock. In *1st ISRM Congress*. International Society for Rock Mechanics.

Geomorphology of Karak Highway Contributed to Debris Flow

Nor Zarina Chok, Edy Tonnizam Mohamad

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

edy@utm.my

Keywords: Debris flow, Karak Highway, Geomorphology, Rainfall.

ABSTRACT. The occurrence of debris flow on November 2015 have resulted severe damages at the KM 52.4 Karak Highway. The aim of this study is to identify the geomorphology at KM 52.4 Karak Highway as well as to assess the contributing factors towards the occurrence of debris flows at the study area. So, to reduce the harm brings by the debris flow, it is important to study the triggering mechanisms of the debris flow. Through the knowledge of mechanisms of debris flow, the appropriate solution to reduce the occurrence of debris flows at Karak Highway can be decided. Aerial photograph play an important role in obtaining the data and analysing the slope angle, lineaments and the drainage systems. In addition, through Malaysian Meteorological Department, the daily and hourly rainfall data can be obtained. However, the geology and geotechnical data will be obtained from the previous studies. Based on data, the slope angle and the drainage pattern at the study area has helped to assist the occurrence of debris flow on November 2015. While, the triggering factor for the incident are the eight days of rainfall which have the high rainfall amount that can caused the debris flow to occur. The precipitation has caused overflow of water from the river and the catchment point. The debris flow also contributed by the slope angle of the source zone which is 26.6°. In addition, the major direction of dominant lineament at the area which has the same direction as the debris flow pathway at 52° of North East direction. In a nutshell, the occurrence of debris flow at Karak Highway was triggered by the rainfall that was assisted by the catchment and drainage pattern, slope angle, lineaments, geology and geotechnical of the study area.

INTRODUCTION

Debris flow is one of the phenomenon's which occurs in Malaysia occasionally. Since Malaysia is a tropical country which has a very high intensity of rainfall especially at the end of the year. So, the occurrence of debris flow will be triggered by the intensity of rainfall especially at the end of the year [1]. Among the several different natural consequences, debris flow is one which can occur under the normal undergoing land forming processes or be triggered due to certain triggering factors. The triggering mechanism, in most of the cases is also a natural process, for example severe rainstorm, earthquakes, ice/snow melt, etc.

Problem Statement

The undergoing natural events are considered to be disaster when it affects the human life. As for debris flow, the catastrophes often cause fatalities, road blockage and intense damage to property which results in economic losses [2]. Direct debris flow damage includes loss of human life, destruction of houses and facilities, damage to roads, rail lines and pipelines, vehicle accidents and train derailments, environmental damage from product spills, damage to agricultural land, livestock, and forest stands, disruption of water supply systems, devaluation of fisheries, and many other losses that are difficult to quantify [3].

Objectives

The objectives of this study are as below:

1. To identify the geomorphology at KM 52.4 Karak Highway surrounding area.
2. To assess the contributing factors towards occurrence of debris flow.

Scope of Study

The scope of this study is focused on the occurrence of debris flows on 11 November 2015 at km 52.4 Karak Highway by using aerial photography from Google Earth to assess the geomorphological factors and lineament pattern, rainfall data from the Meteorology Malaysia Department will also be used to obtain its relationship towards debris flow incident as happened on 11 November 2015.

LITERATURE REVIEW

Debris flows was originated when the poorly sorted rock and soil debris are mobilized from hill slopes and is being channel by the addition of water. The mechanisms that can affect the occurrence of debris flow are the unconsolidated fine-grained rock and soil debris, steep slopes, have high intensity of source of moisture and sparse vegetation. Most common moisture sources are from precipitation, snow melt, glacial outburst floods.

Mechanisms of Debris Flow

In the area where debris flows are bound to occur, there are a few factors that contribute to the occurrence of this phenomenon such as high rainfall intensity, very steep slope and sandy clay soil types which is easily change to liquidity soil [1].

There are lots of reasons when the strength of rocks and soils on sloppy terrain is decreasing such as the weathering and also other physical and chemical actions, but whatever the reasons behind the reduction of the shear strength of soils on the hill slope, water plays a lead role [4]. As [5] mention that hourly precipitation of just 35 - 40 mm is sufficient to trigger major flows affecting the entire slopes. But there are also cases which tremendous debris flows can sometimes happen at lower threshold values. Besides, in practice many debris flows may begin as the hill slope form, but during the flowing of debris down the slope, they may enter channel type features, forming their own channel flow tracks [6], simply explain, the features such as drainage, gully, stream and so on, act as an assistant during the flow of debris. Furthermore, the catchment and drainage pattern also play as a lead role to cause the debris flow, of course with the help of rainfall.

Geomorphology is the study of the earth's surface forms and also the process of changes that happen on the land surface. There are up to four zones can be delineated in each debris flow: an upper failure zone, a middle transport/erosion zone, a lower deposition zone, and a sediment-laden floodwater zone immediately downstream from the debris flow terminus [7].

METHODOLOGY

Aerial photography is the process of taking photographs from the air, which can be obtained from Google Earth. The aerial photos will show the land cover with everything that was visible at the time of the photo. It is often difficult to see elements of the landscape on the ground, there also might have some features that can be easily missed. That is why; aerial photography method is needed to obtain the landscape which is difficult to obtain on foot, as an example, the lineaments of the study area. Through the aerial photographs, the catchment and drainage patterns of the study area can be understood.

Since one of the objectives on this study is about the effect of the rainfall on the occurrence of debris flow at Karak Highway, so it is necessary for this study to obtain the rainfall data on the study area. The rainfall data of the study area can be obtained at the Meteorological Malaysia Department near the study area. Interpretation of data involving the initial interpretation through aerial photographs by using Google Earth, Earth Explorer and Wikimapia application from the internet and also the rainfall data obtained. The rainfall data that have been obtained will be analysis which month has the higher rate of rainfall at the study area during the year 2015. From the analysis, there will be relationship made with the geomorphology of the area. There also have some calculation made by using simple equation to find the slope angle at the study area. As for the lineaments occurred from the aerial photograph, by using the Georose software, the rose diagram can be plotted and the major direction can be discovered. Due to these, the lineaments can help to discover area of faults at the study area.

RESULTS AND DISCUSSION

The results presented in the following section include aerial photograph, lineament studies, historical data and the rainfall data. There are also images from the site visit on 25th March 2017.

Geomorphology

The Figure 1 below shows the three process of debris flow. The source which started the debris flow to happen, where the catchment point cannot sustain the overflow of water from the river. Then, there the transport zone, where the sediment flowing down the channel system until it reaches the deposition zone.

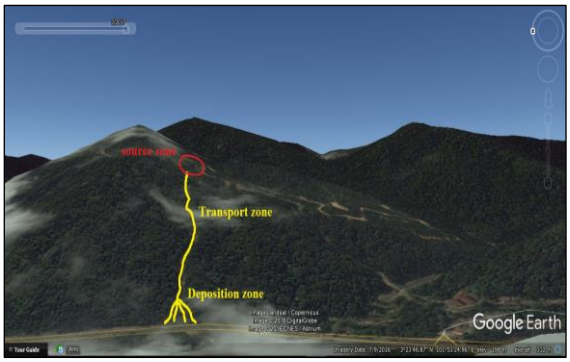


Figure 1: The Geomorphology of Debris Flow 2015. (Google Earth).

The Table 1 below shows the elevation and slope gradient for each zone during the occurrence of debris flow at the study area.

Table 1: The elevation and slope gradient for each zone during debris flow event

Study Area	Parts	Elevation (m)	Slope Gradient (°)
KM 52.4 Karak Highway	Source zone	430 - 468	26.6°
	Transport zone	180 - 430	20.6°
	Deposition zone	160 - 180	12.5°

Geology and Geotechnical

The Figure 2 below has showed that the area is located within the main range granite of Peninsular Malaysia and is deeply weathered fined to medium grained granite, which can be seen in the Figure 3 below [3]. There are other studies also have been made due to the same event of debris flow at the area. The debris flow event that have occurred at KM 52.4 Karak Highway are located within the main range of granite, part of the granite body which is grouped in the Mesozoic late Orogenic granite [2]. The Table 2 below shows the weathering condition of the granite rock at the study area.

Table 2: The weathering condition of the granite rock [2]

Study Area	Geology of Source Area	Weathering Condition
KM 52.4 Karak Highway	Upstream area is granite	Grade II - Grade III

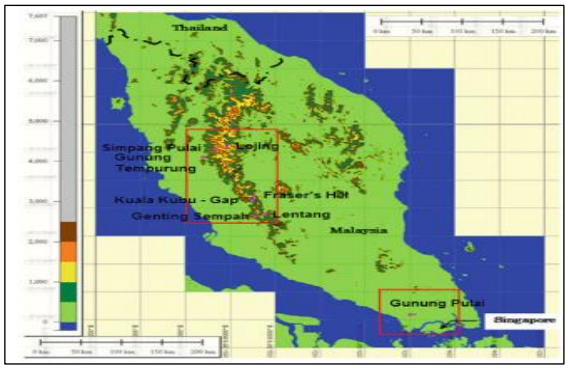


Figure 2: The incidents of debris flow that occurred on 2 November 2004 at KM 52.4 Karak Highway is located at the main range of granite. [3]

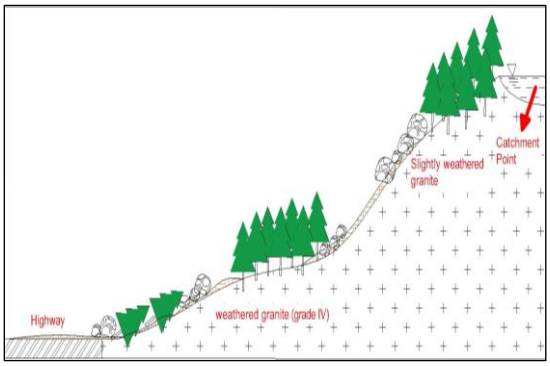


Figure 3: The illustration of debris flow and the weathering grade for granitic rock at the area. [3]

Lineament

The rose diagram shows the major direction of the lineaments at the study area. The major direction of the dominant lineament at the affected area is the same as the dominant direction at the plotted rose diagram. This can be seen in the Figure 4 below.

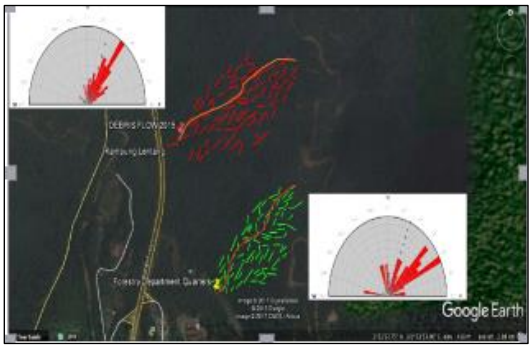


Figure 4: The rose diagram for at the affected area. (Google Earth).

Catchment and Drainage Pattern

The Figure 5 below shows the condition of the study area before and after the debris flow of 2015 has occurred. The figure shows the area that have been affected due to the debris flow incident and the description for each number have been explained in the Table 3 below. The catchment point shows in the Figure 6 below have an area of 102 m^2 and perimeter of 40 m.

Figure 5: The situation of the study area before and after the debris flow incident. (Google Earth).

Table 3: The description for each area

NO.	DESCRIPTION
1	There are channel flow tracks that have been created due to the debris flow occurrence and flow to the KM 52.4 Karak Highway direction.
2	There is runoff area due to the debris flow occurrence.
3	There are channel flow tracks that have been created due to the debris flow occurrence and flow to the Pahang Forestry Department quarters.

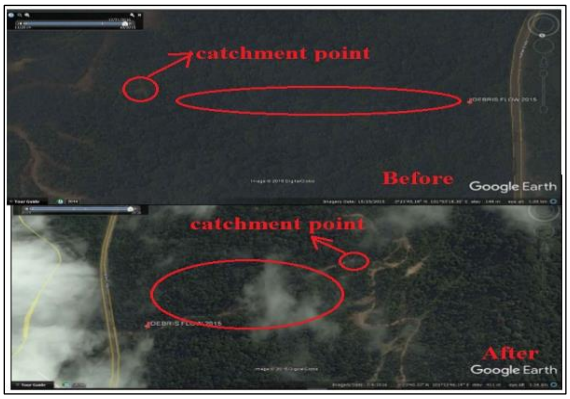


Figure 6: The channel system that have been created due to the debris flow incident.(Google Earth)

Rainfall Data

The chart below shows the rainfall amount that have been recorded at 'Hospital Bentong' station. From the chart shown in the Figure 7, the highest rainfall amount during 2015 was on November with 420.8 mm of rain, followed by January and May with 274.8 mm and 235.0 mm respectively. 26 number of rain days was the highest number of rain days that have occurred on November 2015. While the months that record the lowest amount of rainfall was on

February with 44.2 mm of rainfall. There were only 10 number of rain days on that month. Followed by the second lowest of rainfall amount was on September with 45.6 mm of rainfall amount. The total of rainfall amount on 2015 at the 'Hospital Bentong' station is 1966.6 mm, result from 186 number of rain days.

The Figure 8 shows the daily rainfall amount for the month of November 2015 at the 'Hospital Bentong' station. The rainfall amount that have been recorded was from the 1st until the 30th of November 2015. During the month of November, there were four days that have 0 mm of rainfall. The total rainfall that have occurred on November 2015 has the highest amount during that year which has produced 420.8 mm of rain. The total number of rain days on that month are 26 days.

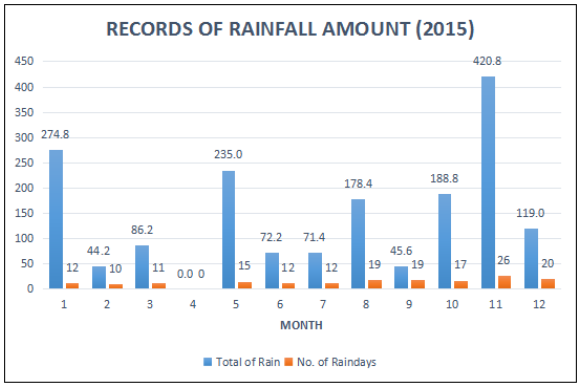


Figure 7: The rainfall amount for each month during the year of 2015, Hospital Bentong Station. (Meteorological Malaysia Department)

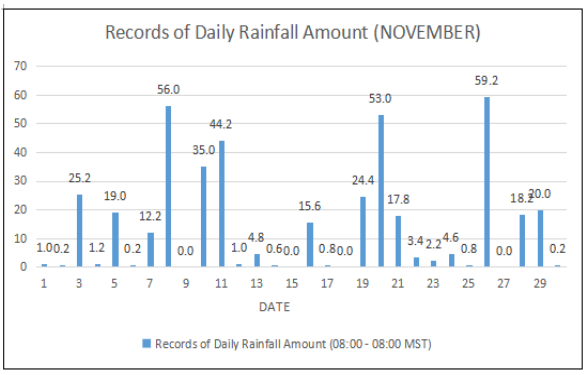


Figure 8: The daily rainfall amount for the month of November during the year of 2015, 'Hospital Bentong' Station. (Meteorological Malaysia Department)

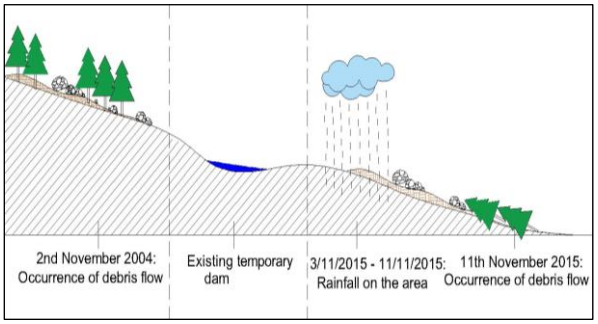


Figure 9: The timeline of the occurrence of debris flow at KM 52.4 Karak Highway

Figure 9 above shows the timeline of the event that have occurred at the study area. In 2004, the debris flow has happened on the same area as 2015 debris flow which according to [8], the tracks of older debris flows can be reactivated each 1 - 10 years, locally even each 1 - 5 years. The debris flow event at the study area has supported the facts that debris flow does not always originate on new places and it is usually renew on places where it already occurred in the past. Thus, younger flows are originate by the reactivation of older ones especially due to extreme rainfalls [8];[5].

There are existing temporary dams at the study area with an area of 102 m^2 and perimeter of 40 m is the meeting point of 4 natural channel system. The overflow water from the river had accumulated on that particular meeting point.

According to The Straits Times that published on 12th November 2015, the department's deputy director-general (operations) Soiman Jahid, the heavy rains over the past few days caused the catchment to overflow and to pick up sediment, turning it into the debris flow. According to [9] statement, the shallow translational slides could be triggered by high-intensity of short-duration rainfall (130 mm daily rainfall) and moderate-intensity rainfall episodes (from 174 mm in 5 days to 217 mm in 15 days), while deep-seated failures are mainly caused by the low-intensity prolonged rainfall episodes (from 333 mm in 30 days to 793 mm in 90 days).Which explained that the debris flow event is one of the rainfall-induced debris flow, where it have different mechanisms than the earthquake-triggered debris flow. According to [10], fundamentally, earthquakes affect the stability of slopes in two ways, firstly, the ground shaking may reduce the frictional strength of the substrate by shattering of rock mass. Secondly, the seismic acceleration may generate the tensile stress, causing tensile cracking in the slope. While rainfall triggered debris flow to occur by increasing the moisture content, which increase the pore water pressures above critical value necessary to trigger the debris flow.

On the other hand, lineament and geomorphology of the area have been found as major contributing factor. The lineament of the affected area can be seen in the Figure 4 where it has shown that the major direction of the dominant lineament at the affected area are the same as the route of debris flow occurrence. The Figure have shown that the major direction of lineament for the KM 52.4 Karak Highway area is at 52° of North East direction. While at the Forest Department quarters area, the major direction of lineament at the area is at 28° of North East direction.

Moreover, the occurrence of debris flow was assisted by the geomorphology of the area where there are three subareas that affected by debris flow event at the study area which are the source, transport and deposition zone. Each zone have different elevation and slope gradient. The gradient of slope does give effect to the occurrence of debris flow, where the high of slope gradient will speed up the transportation of debris and increase the force. Where according to [11], the source of debris flow usually found at the area with steep slope, which have the slope gradient of more than 20° and the deposited zone have the slope gradient of 2° to 15°.

There are major types of slope failures that have occurred mainly along major highways and residential areas due to the weathered granitic rocks. Granitic rocks are known to be very sensitive to weathering and are vulnerable to landslides and debris flow.

CONCLUSION

Four important parameters, which are precipitation, geomorphology of the study area, lineament, and the drainage pattern, were extract mostly using aerial photography. The relationships between these four factors can be determined through the understanding on the occurrence of debris flow at the study area. The few days of rainfall at the area have caused the overflow water from the river and the catchment point, with the assistance of slope angle of the area, landslides can occur. Moreover, the area is located in the weakly weathered to heavily weathered of granitic rock and also have the types of silty sand with little gravel soils.

The importance of geomorphology as a factor influencing the debris flow is apparent from this study. Moreover, to asses the contributing factors towards the debris flow event, the considerations of the rainfall amount and the condition of ground surface of the study area are crucial. Where in this study, there are more than one mechanisms that contributing to the occurrence of debris flow on November 2015 at KM 52.4 Karak Highway.

The study area has undergone the same event twice include the latest occurrence on 2015 which have clearly shown that there are other possibilities that the same event can occur again in the future. Therefore this area should be given special attention and some measures that should be planned carefully by the authorities especially on hilly area that has steep slopes with high potential for debris flow to occur.

REFERENCES

[1] Bahrin Jaafar, K. (2016, April). Debris flow study in Malaysia. In *EGU General Assembly Conference Abstracts* (Vol. 18, p. 10656).

[2] Kasim, N., Taib, K. A., Mukhlisin, M., & Kasa, A. (2016). Triggering mechanism and characteristic of debris flow in Peninsular Malaysia. *American Journal of Engineering and Research*, 112-119.

[3] Jamaluddin, T. A. (2006). Faktor Manusia dan Kegagalan Cerun di Malaysia (IN MALAY), Human Factors and Slope Failures in Malaysia.

[4] Costa, J. E. (1984). Physical geomorphology of debris flows. In *Developments and applications of geomorphology* (pp. 268-317). Springer Berlin Heidelberg.

[5] Kotarba, A. D. A. M. (2007). Geomorphic activity of debris flows in the Tatra Mts and in other European mountains. *Geographia Polonica*, *80*(2), 137-150.

[6] Nettleton, I. M., Martin, S., Hencher, S., & Moore, R. (2005). Debris flow types and mechanisms. *Scottish road network landslides study*, 45-67.

[7] Cenderelli, D. A., & Kite, J. S. (1998). Geomorphic effects of large debris flows on channel morphology at North Fork Mountain, eastern West Virginia, USA. *Earth Surface Processes and Landforms*, *23*(1), 1-19.

[8] Krzemień, K. (1988). The dynamics of debris flows in the upper part of the Staroroboci̜ańska Valley (Western Tatra Mts.). *Studia Geomorphologica Carpatho-Balcanica*, *22*, 123-144.

[9] Trigo, R. M., Zêzere, J. L., Rodrigues, M. L., & Trigo, I. F. (2005). The influence of the North Atlantic Oscillation

on rainfall triggering of landslides near Lisbon. *Natural Hazards*, *36*(3), 331-354.
[10] Huang, R. (2015). Understanding the mechanism of large-scale landslides. In *Engineering Geology for Society and Territory-Volume 2* (pp. 13-32). Springer, Cham.
[11] Osanai, N., Mizuno, H., & Mizuyama, T. (2010). Design standard of control structures against debris flow in Japan. *Journal of Disaster Research*, *5*(3), 307-314

Beach Profile Changes at Teluk Gorek Mersing using Real Time Kinematic Global Positioning System (RTK GPS)

Nurul Afifi Syarkina Azhar, Muhammad Azril Hezmi, Radzuan Sa'ari

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

azril@utm.my, mradzuan@utm.my

Keywords: Beach profile changes; Beach Sand Density; RTK GPS.

ABSTRACT. Beach profile changes are related to various factors such as wave, tide, wind rose and current effect. This study investigates beach profile changes and to compare soil density parameter with previous study at Teluk Gorek, Mersing Johor. There are total of 14 cross-sections line with offset of 30m and 100 m apart and there are 15 points of samples was carried out between the cross-section line. The monitoring work of beach profile and sampling was done on January and April 2017 during the spring tide season to investigate the presence of erosion and accretion at study area. The estimation of erosion and accretion were performed by comparing the beach profile between January and April. The result shows the beach have experience both erosion and accretion during the period of study. The soil density changes varies to the erosion and accretion process. As a conclusion, the mapping beach is slightly changes during the period of study and the density parameter also changes as the beach profile changes.

INTRODUCTION

Malaysia is a country that has a long coastline with correlated the coastal zone about 4800 km and has an equatorial monsoon climate. Throughout the year, the temperature is uniformly high and the dry and wet season are not particularly marked as the heavy rainfall may be experienced anytime and anywhere of the year. The changes in direction and also the monsoon wind speed are responsible to the division of the four season to occur. Malaysia faced the North-east Monsoon from October to March and South-west Monsoon from late May to September. This seasonal rhythm has a major impact on coastal process. The coastal zone area is a most valuable national strength for marine and the associated aquatic life. The coastal zone also such an attractive commercial, residential, recreational areas and also it has its own aesthetic value. The coastal zone is about approximately 1380 km (27 %) are facing to erosion of varying degrees of severity and the coastal erosion affects every state in Malaysia (The National Coastal Erosion Study, 1985). The coastal changes are due to several factors such as wind, tides, wave and current effect. The soil transportation also may contribute to changes of beach profile.

Problem Statement

Most of the beach in Malaysia especially beach that facing South China Sea experienced erosion. This erosion is due to the strong wind together with wave received from South China Sea. In my study at Teluk Gorek, Mersing, the development of the area together with natural forces like wind, tide and current will change the coastline. Since the topographic data collected during previous study at Teluk Gorek is not enough, therefore, this study will investigate further about the beach profile by using RTK GPS.

Objectives

The objectives of the study are as follows:

1. To assess the beach profile changes at Teluk Gorek using Real Time Kinematic (RTK GPS).
2. To compare soil density parameter between January 2016 to April 2017.

Scope of Study

This study had investigated soil density parameter of Teluk Gorek beach due to beach profile changes by comparing a series of data collection by using RTK GPS. The survey on the beach topography is conducted in order to obtain the profile changes of the existing beach profile and was conducted during the spring tides to acquire the maximum profile

beach changes. Besides, this study was conducted to estimate the rate of erosion and accretion by comparing series of beach profiling data from previous study. As for basic soil properties investigation, about 30 soil samples were collected from the study area. This sample is taken from fifteen different points which means two samples for each point. The soil samples were analyzed to get density and moisture content of the samples and being compared with previous result.

LITERATURE REVIEW

There are a lot of research and study previously done regarding the beach profile monitoring. Numerous methods are used during the field works starting from the levelling up to the midair photography. Beach profile monitoring is applicable in the coastal engineering to provide useful information for the management process and the coastal monitoring studies. When the data was recorded, the graphic depiction of the contour of the beach profile can be produced and created the cross section and topography for other purpose. In most cases, the changes of the beach profile are watchfully correlated to the erosion problem that occur at the beach.

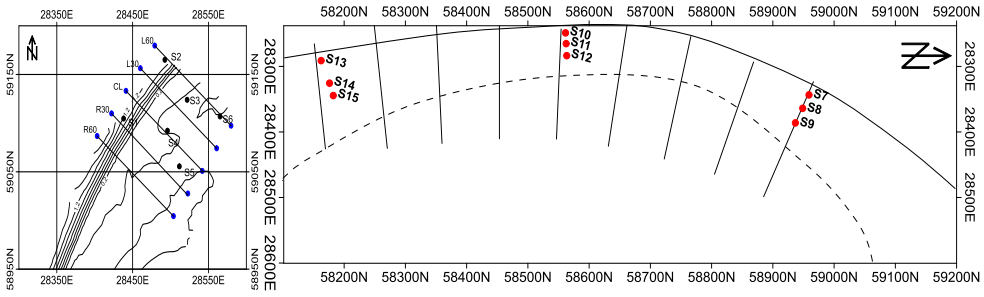
Malaysia is a country that has an equatorial monsoon climate, the temperature are usually high over the year. Wet or dry seasons are not predominantly well-marked because there are heavily rainfall that may be occur at anywhere and anytime throughout the year. The most momentous piece of the climate is the seasonal rhythm where it was the wind that establish ultimately regulates the seasons that occur in Malaysia. The changes in speed and direction of the monsoon wind are liable for the division of the four seasons to be occur.[4] They are can be known as North-east Monsoon, South-west Monsoon and two transitional periods. This cyclic pace has major impact on the coastal process[5]. It is a long wave that travel across the oceans and then transmitted into the inlets, creek, estuaries, bays or lagoon around the coastline[6]. The position of the swash zone, shoaling and surf zone is budged with the tide horizontally and vertically during the tidal process.

The bulk density indirectly provides a measure of the soil porosity. Soil porosity is the ratio of the volume of soil pores to the total soil volume [8]. Thus the bulk density of a soil is inversely related to the porosity. The bulk density of the sediments generally increases with depth and time, but trapping of water can cause a local decrease in the density, the location and magnitude of this density decrease due to trapping of water depend on the sediment core length and type of sediment for each type of sediment and shear stress, the erosion rate is a unique function of bulk density and decreases as the bulk density increases.

METHODOLOGY

The methodology flow of this study is as follows:

1. Identify the study area
2. Collect data and soil samples from study area.
3. Conduct laboratory soil analysis to obtain soil data in order to relate and strengthen the beach
4. profile changes produce from RTK GPS.
5. Analysed data and produce results.



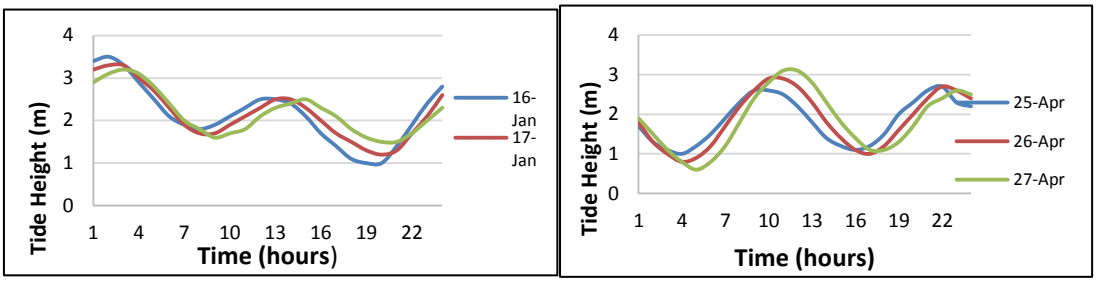
a) Area 1 b) Area 2

Figure 1 Cross-section area of study with wind speed direction

RESULTS AND DISCUSSION

Study of beach profile changes and climate change effect on beach sand density at Teluk Gorek, Mersing was carried out on January 2017 and April 2017 during spring tide using RTK GPS technique for mapping the area of study and to find location for sampling. A total of 14 beach profile cross-section line with offset of 30 m and 100m apart was established to monitor the presence of erosion and accretion. In this chapter, discussion will be focused on findings and

analysis of the result obtain in order to estimate the presence of either erosion or accretion during the study period and compare the soil density between January 2016 to April 2017. Beach profile changes were influenced by several parameters as shown in Figure 3. Figure 3 is used as parameter before start the fieldwork. For January 2017 the highest value of tide height was 3.8m while in April 2017 was 3.1m.



a) January b) April

Figure 3 Tidal Curves between January 2017 and April 2017

Figure 4 shows the beach profile cross-section for Area 1 and 2. Area 1 was undertaken at the same area with by [10] and the Area 2 was performed in current study to have better overview on the beach profile area of Teluk Gorek. Combination of Area 1 and 2 will show whole result of beach profile changes as Area 1 data contain limited result of Teluk Gorek hence the Area 2 was proposed to cover overall of Teluk Gorek Beach. For area 1, there are 5 cross-sections which were L60, L30, CL, R30 and R60. Profile line at CL is located at the middle of the other profile. It acts as a control profile to other cross-section. For second area, there are nine cross-sections were obtained with 100m apart for each cross-sections. Profile line at Line 1 as the first cross section of the other profile. It acts as the control profile to other cross section. According to the result of the study, variations of the profile line have been recorded as shown in

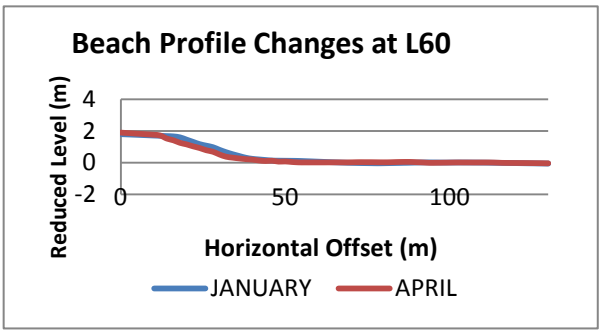
Table 1 (a) and (b) within the period of study on January and April 2017. Overall profiles shown accretion and erosion process within that period especially at the intertidal zone where the area is most affected by waves and tides.

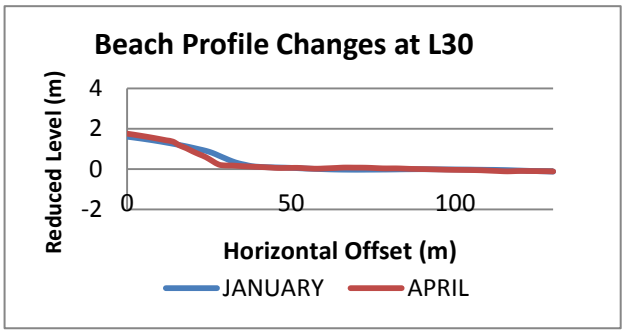
Table 1a Area 1 of Erosion and Accretion (m^2)

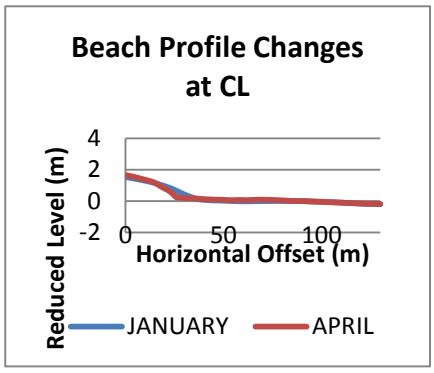
Line	L60	L30	CL	R30	R60	Average
Erosion (m^2)	-7.87	-5.99	-3.93	-4.44	-10.02	-32.25
Accretion (m^2)	2.25	4.04	4.37	4.62	1.60	16.88

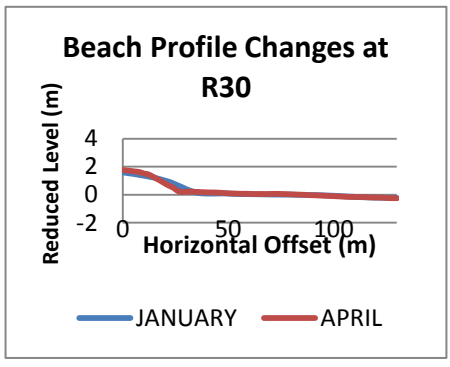
Table 1b Area 2 of erosion and Accretion (m^2)

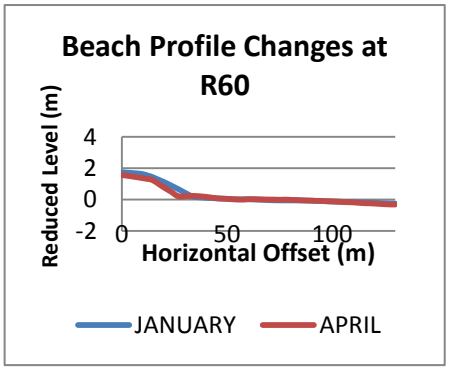
Line	1	2	3	4	5	6	7	8	9	Average
Erosion (m^2)	-29.534	-17.653	-19.196	-1.107	0.000	-3.186	-4.968	-0.149	-10.371	-9.574
Accretion (m^2)	2.576	1.667	0.380	15.389	54.966	15.869	0.646	7.942	7.447	11.876











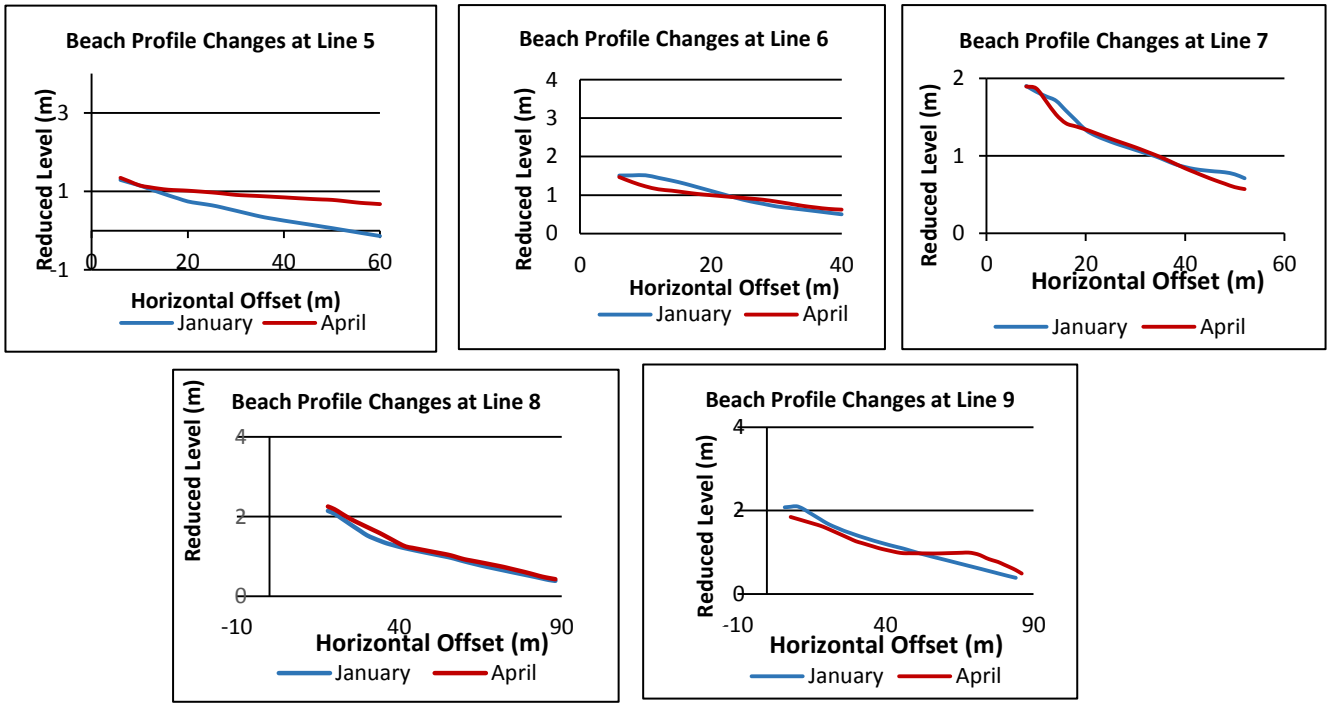


Figure 4a Beach profile cross section for Area

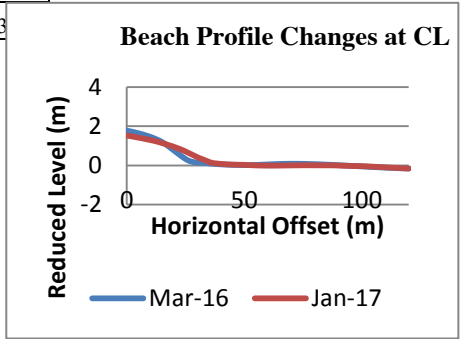
Figure 4b Beach profile cross section for Area 2

Comparison was conducted between prior study by [10] and current study in Area 1 to evaluate the profile changes for the long term effect. Figure 4a shows with previous study of beach profile which on March 2016 until January 2017, accretion process take place (Table 2) because the reduced level for overall beach profile in January 2017 is higher than March 2016.

In area 2 there are erosion and accretion processes taken place at each profiles within the study period which is on January and April 2017.As in Table 1, profile Line 5 undergoes the largest accretion process while profile Line 1 undergoes the largest erosion process. The average area of erosion is -9.574m^2 and accretion is 11.876m^2. In conclusion, there are erosion and accretion process happen at the beach during the period of study.

Table 2: Area of Erosion and Accretion (m^2) for March 2016 and January 2017

Lines	L60	CL	R60	Average
Erosion (m^2)	-1.91	-1.13	-3.10	-6.14
Accretion (m^2)	8.46	4.49	10.36	23.3



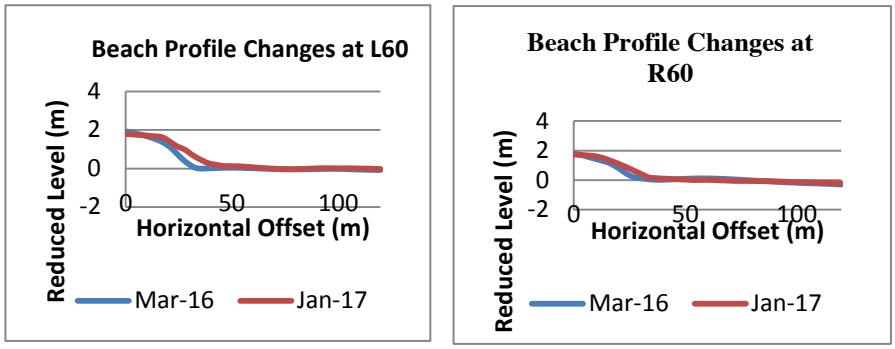


Figure 5 Beach profile cross section for 2016 and 2017

During the study period from March 2016 to January 2017, most of the accretion take place at the intertidal zone while during January 2017 to April 2017, most of erosion process occurred at the study area due to the wind rose and tidal effect. The soil samples taken at the study area were being tested for the further analysis. From the analysis, a graph was plotted for each of the soil samples. Figure 6 shows the bulk density for every sample taken from the site in January and March 2016, January and April 2017 respectively and the value as in Table 3.

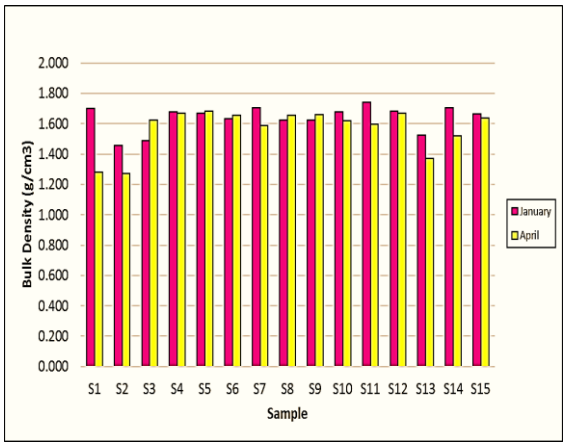


Figure 6a Bulk Density for January and April 2017 In Area 1 and 2

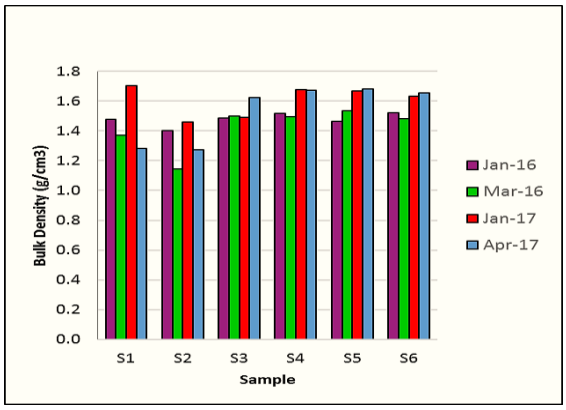


Figure 6b Comparison of bulk density between January 2016 to April 2017

Table 3a Bulk density value for January and April 2017 in Area 1 and 2

Sample	January	April	Percentage Difference (%)
S1	1.701	1.281	-24.668
S2	1.457	1.272	-12.693
S3	1.489	1.624	9.091
S4	1.678	1.671	-0.403
S5	1.669	1.683	0.811
S6	1.633	1.656	1.381
S7	1.705	1.586	-7.011
S8	1.624	1.656	1.944
S9	1.624	1.658	2.083
S10	1.678	1.620	-3.495
S11	1.741	1.597	-8.290
S12	1.683	1.669	-0.804
S13	1.525	1.369	-10.207
S14	1.705	1.520	-10.847
S15	1.665	1.635	-1.762

Table 3b Bulk density between January 2016 to April 2017

	Bulk Density (g/cm3)								
Sample	January 2016	March 2016	Percentage Difference (%)	March 2016	January 2017	Percentage Difference (%)	January 2017	April 2017	Percentage Difference (%)
S1	1.478	1.369	-7.382	1.369	1.701	24.268	1.701	1.281	-24.668
S2	1.400	1.143	-18.333	1.143	1.457	27.460	1.457	1.272	-12.693
S3	1.487	1.499	0.784	1.499	1.489	-0.687	1.489	1.624	9.091
S4	1.516	1.493	-1.538	1.493	1.678	12.391	1.678	1.671	-0.403
S5	1.464	1.534	4.781	1.534	1.669	8.811	1.669	1.683	0.811
S6	1.522	1.481	-2.682	1.481	1.633	10.230	1.633	1.656	1.381

The assessment of density soil samples for the January 2016 and April 2017 in Table 3a shows there are difference for each sample and Sample 1 shows the largest difference between samples taken in this period. Analysis for January 2016 and March 2016 in Table 3b shows that there was significant different in sample 2 which contain highest bulk density for March 2016 and January 2017, the bulk density was decrease and undergo accretion process at most area. Graph of beach profile with reduced level of sample is plotted as in Figure 7. The cross section lines are exactly on the sample points. The difference in reduced level for each sample is tabulated in Table 4.

Table 4: Difference in Reduced Level of Samples

Sample	Reduce level on January 2016	Reduce level on March 2016	Difference (m)	Reduce level on March 2016	Reduce level on January 2017	Difference (m)	Reduce level on January 2017	Reduce level on April 2017	Difference (m)
S1	1.044	1.262	0.218	1.262	1.270	0.008	1.270	1.036	-0.234
S2	1.03	1.292	0.262	1.292	1.207	-0.085	1.207	1.100	-0.107
S3	0.003	-0.042	-0.045	-0.042	0.061	0.103	0.061	0.056	-0.005
S4	0.008	0.176	0.168	0.176	0.014	-0.162	0.014	0.063	0.049
S5	-0.078	-0.160	-0.082	-0.160	-0.109	0.051	-0.109	-0.137	-0.028
S6	-0.067	-0.060	0.007	-0.060	0.016	0.076	0.016	0.048	0.032
S7	-	-	-	-	-	-	0.982	1.194	+0.212
S8	-	-	-	-	-	-	-0.015	0.029	+0.044
S9	-	-	-	-	-	-	-0.098	0.061	+0.159
S10	-	-	-	-	-	-	1.415	1.148	-0.267
S11	-	-	-	-	-	-	0.776	1.188	+0.412
S12	-	-	-	-	-	-	0.377	0.564	+0.187
S13	-	-	-	-	-	-	1.483	1.37	-0.113
S14	-	-	-	-	-	-	0.716	0.95	+0.234
S15	-	-	-	-	-	-	0.363	0.479	+0.116

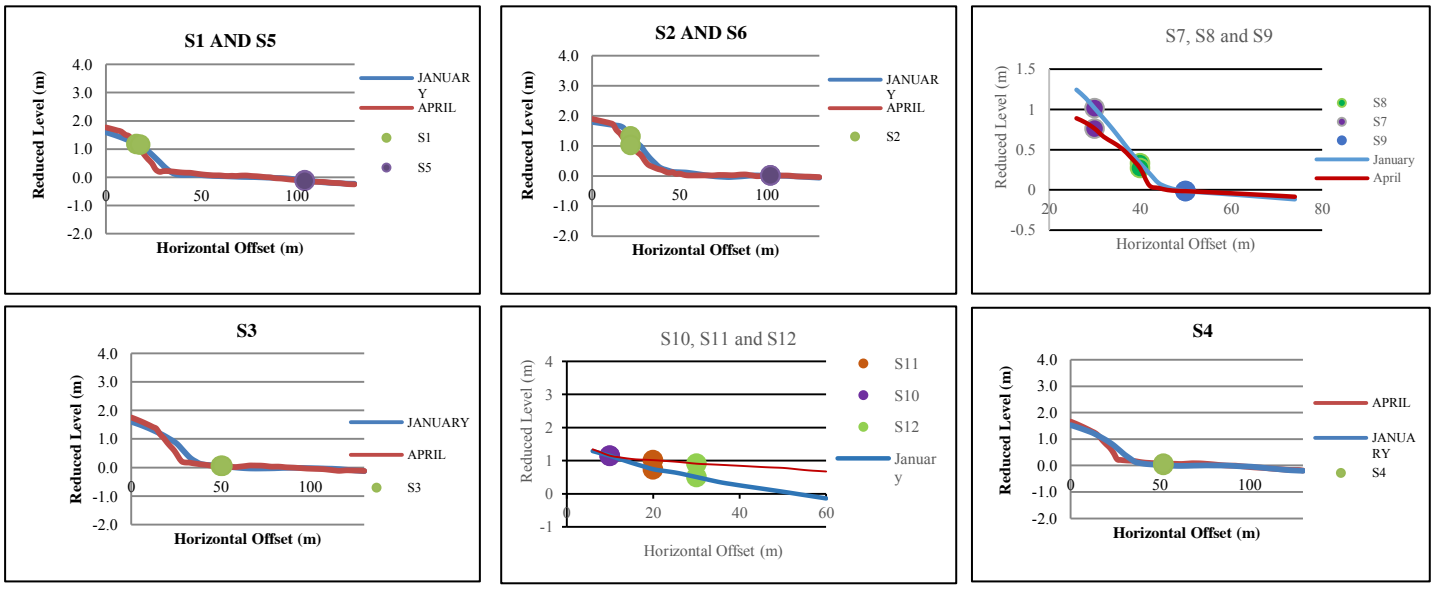


Figure 7 Beach profile cross section

CONCLUSION

Beach profile lines have been successfully generated and the erosion and accretion process have been determined to have happened throughout the study period. Although the changes of certain area are not as significant, it still can be concluded that the coastline shows variations in the beach profiles each time the data is collected. Basically, it gives the idea that the beach is constantly changing with respect to time. As for the long term effect, the profile lines show that most of the area shows the accretion process while for the short term analysis, from January to April 2017, most of the area experienced erosion. All these processes affected by the wave action and the tidal process.

REFERENCES

[1] Bird, E.C.F (2000). *Coastal Geomorphology: An introduction*. John Wiley and Sons Ltd, Chichester, pp. 322
[2] Phillips, (2013). Winds, sea levels and North Atlantic Oscillation (NAO) influences: An evaluation. Global and

planetary change, 100, pp.145-152.
[3] Faridah Jaffar Sidek. (2015). *Beach Types and Coastal*. Universiti Teknologi Malaysia.
[4] Gaines and Denny,2007 *Encyclopedia of Tidepools and Rocky Shores*,. University of California Press, Berkeley and Los Angeles, pages 604–609
[5] Othman, (1994). Value of mangroves in coastal protection. Hydrobiologia, 285: 277–282.
[6] Dean, G. R. and Dalrymple, A. R. (2004). Coastal Processes with Engineering Applications. Cambridge University Press.
[7] Ibrahim, (2013).*Journal of Clean Energy Technology*,pp 167
[8] Been, K. (1981). "*Non-destructive soil bulk density measurements using X-ray attenuation*." Geotech. Testing J., 4, 169-176.
[9] Shafikah (2017). *Soil Claasification Mapping at Teluk Gorek Mersing*
[10] Maziati (2016) Case study of beach profile changes at Teluk Gorek

Soil Classification Mapping at Teluk Gorek Mersing

Nurul Shafikah Ma'rof, Muhammad Azril Hezmi, Radzuan Sa'ari

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

azril@utm.my, radzuans@utm.my

Keywords: Particle Grain Size; Erosion; Accretion.

ABSTRACT. This paper present the mapping of a soil classifacation based on the particle size distribution of sieving. A study was conducted along the Teluk Gorek Beach Mersing, Johor to obtain the soil properties at the beach to produce soil classification mapping and Soil Water Characteristic Curve (SWCC). The study area was divided to eleven beach profile cross sections with offset of 100 m apart to monitor the presence of erosion and accretion using Real Time Kinematic Global Positioning System (RTK GPS). The field work to collect the data was done on January and April 2017 during spring tide. The estimation of erosion and accretion were performed by comparing the soil properties and classification obtained on January and April. The result shows that the beach profiles have experienced both erosion and accretion during the period of study. As the conclusion, the beach profile changes and the soil properties along the study area also changes during the period of the study.

INTRODUCTION

The coastline in Malaysia faced the erosion every year because of many factors. The factors that might affect the erosion in shoreline are tides, current flow, and waves. The erosion is serious issues that need to be concerned by everyone since the consequences will affect the population and the sectors that involves with it. The erosion that happens at the shoreline will eventually change the beach profiling. The erosion in location may result in accretion of beaches and changing their profile [1]. The soil properties in the shoreline are different with the soil properties at the mainland. Therefore, this study will collect the data about the particle size distribution of the beach soil and the effects due to the beach profiling changes.

Problem Statement

The place is facing the South China Sea and exposed to the Northeast Monsoon from the October until March every year. The monsoon will affect the shoreline that cause erosion at some place and accretion at the other place. This study will investigate the effect of particle size distribution due to beach profile changes and to determine Soil Water Characteristic Curve (SWRC) due to tidal changes. The beach profile will be taken using the Real Time Kinematic Global Positioning System (RTK GPS) at Teluk Gorek Beach and the soil sample will be analyses using sieve analysis at the geotechnical laboratory at the university.

Objectives

The objectives of this study are:

1. To compare the particle grain size distribution at Teluk Gorek shorelines from January 2016 to April 2017.

2. To determine Soil Water Characteristic Curve (SWCC) on the shorelines of Teluk Gorek.

3. To establish soil classification mapping for monitoring shorelines profile changes due to the effect erosion and accretion.

Scope of Study

This study is to obtain the soil properties at the Teluk Gorek Beach by comparing the result that will be obtain in the January and March 2017 during the spring tide. The soil sample will be analyses to get the particle grain size distribution and compared between the two months. Besides that, the beach profiling will be conducted using the RTK GPS and crossed reference with the result before this to obtain the changes in the shoreline of the beach. The changes will affect the soil properties since there is erosion and accretion happens at the beach, especially during Northeast Monsoon (October to March). There will be spring tide plus the wind of Northeast Monsoon that will cause a very strong wind that produce waves that hit the beach shoreline. High tide will cause erosion in some place and accretion as the result of it.

LITERATURE REVIEW

The coastal zone is the interface between the land and water that borders the shoreline. The coastal zones are continually changing due to the environmental factors such as waves, tides and current. The dynamic interaction of the land and ocean along the shoreline affects the shoreline borders through accretion and erosion of the coastal area. Sediment will be transported gradually as the particles in the waves move cyclic towards the shoreline and the sediment will be deposited and cause the accretion. The energy reaching the coast becomes high especially during storms. The energy that been produced make coastal zones areas highly vulnerability to natural hazards. According to [2], nearly 30 percent of the Malaysian coastline is undergoing erosion and approximately 1380 km facing the erosion problem as reported in the Department of Irrigation and Drainage [3] in the year 2005. The erosion along the shoreline basically happens due to the few environmental factors which are waves, tides and currents that hit the shoreline daily.

The shoreline is affected by the wind from the oceans causing the dynamic motions and produced the waves. In the open ocean waves, the water molecules move in orbital paths as waves pass. The movement of the water molecules is greatest at the sea surface and decrease gradually as the depth decrease. This wave is considered as the wave base because the motion nearly zero at the depth of one-half the wavelength. The wavelength is the distance between two successive crests or high spots. At the shoreline, the waves become slower as the depth shallower towards the shore. The waves from the oceans will produced sedimentation as it winnowed away the fine sediments (silt and clay) and leaving behind the coarse grain sediments (sand and gravel).

The co-oscillating tides of the Pacific and Indian basins mainly affect the sea levels along the coast of Malaysia. Tides result from the gravitational attraction of the sun and the moon on the oceans. Tides affect the shoreline and thus it changes the beach profile. Generally there are three types of tides on the earth [4]. In Peninsular Malaysia the tides are mixed on the east coast and semi-diurnal on the west, whereas tides in Sabah and Sarawak are usually mixed, except for diurnal tides between Bintulu and Kuala Baram

Current patterns in the South China Sea are monsoon-controlled flowing southeast during the Northeast Monsoon and northeast during Southeast Monsoon [5]. Currents are the combination of longshore currents, crosshore currents, rip currents and undertow. Generally, the nearshore current can be generated from wind and tide. Wind that generates current usually formed at the surface of the ocean and dominated by offshore wind conditions. Wind intensity and duration determined the magnitude of currents and it is influenced by the monsoons. Besides that, the current that generated by wind can determine extent of plume spread and oil spills. The tide that generates currents usually formed inside the ocean. The currents formed due to differences in tidal range of the ocean and the currents formed inside the oceans. The large differences in tidal range produce fast currents and vice versa. The strong tidal currents usually occur at tidal inlets and constricted channels at river mouths and the common speed is 1m/s.

The changes of beach profiling takes place through the erosion, transport and deposition of material that is either eroded by waves and currents or brought to the coast, e.g., by rivers. Erosion and accretion may have substantially different management implications depending on the persistence of coastal change and the physical extent of change relative to the original shore [6]. Erosion is most typically considered to occur where there is a loss of vegetation, impact to infrastructure or loss of amenity. Erosion is further distinguished by the speed of development, with rapid (acute) erosion or progressively developing (chronic) erosion. Coasts where acute erosion is largely caused by a single storm system, the erosion is sometimes termed storm bite and is typically parameterized according to storm severity [7]. The sediment volume loss from above water level is also known as storm bite.

The first comprehensive study of the Malaysian shoreline and its coastal erosion problems have been done by the National Coastal Erosion Study (1984-1986). The study revealed a serious situation at the shoreline that can be declared as the national problem by the government. The erosion along the shorelines not only because of the natural phenomenon but it is also because of the human activities along the shorelines. The example of erosion problems causes by the human activities such as the development that very close to the active zones of the beach without control. The National Coastal Erosion Study identified that 45 of 74 erosion sites are cause by the development in the highly urbanized and agricultural-developed west coast of Peninsular Malaysia [8].

METHODOLOGY

The collection data was taken twice during spring tide in January 2017 and April 2017. Both data will be compared to analyse the soil properties that produce soil classification mapping. The research methodology flow (Figure 1) of this study is as follows:

1. Planning.
   - The planning phase involve the selection of the study area and the suitable time to collect the data.
2. Field work to collect data from study area.
   - Locate the sample using Real Time Kinematic Global Positioning System (RTK GPS).
   - Conduct in situ bulk density test.
   - Collect data to produce beach profile topography using RTK GPS.
3. Data processing.
   - Laboratory work such as sieve analysis, Pycnometer test and SWCC.
4. Analysis of data
   - Analysed the data to produce soil classification mapping.
5. Result and conclusion.
6.

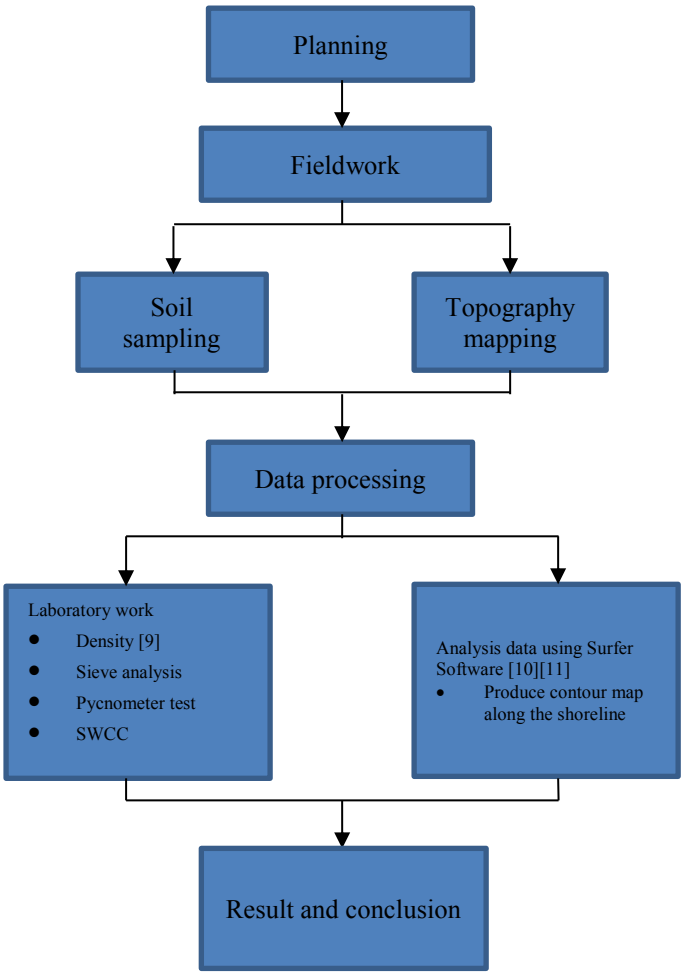


Figure 1: Flow of the methodology

RESULTS AND DISCUSSION

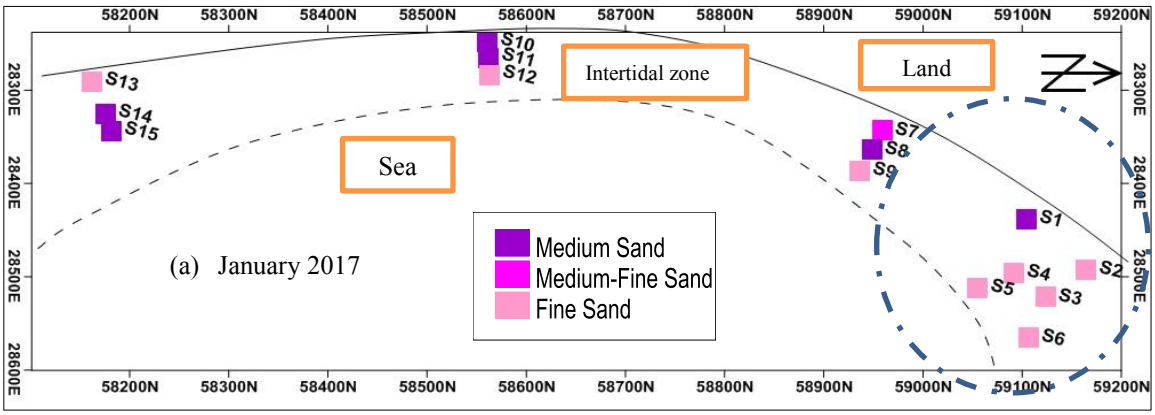
In order to assess the particle size distribution of a granular material dry sieve test was conducted. The grain size analysis is widely used in classification of soils. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used.

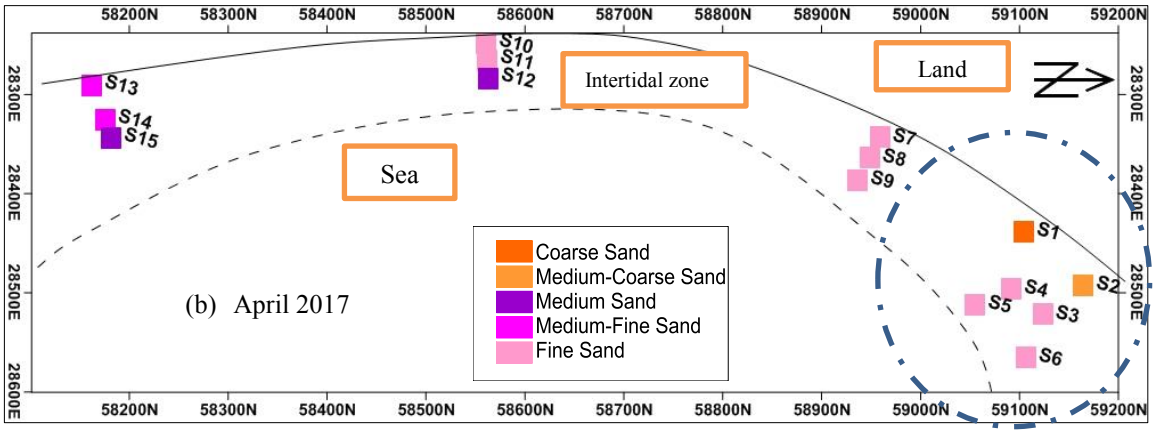
Particle size distribution (PSD) curve was analysed to determine the soil classification. The PSD curve between January and April 2017 data collection have been compared. From the graph, value of D60, D30 and D10 was obtained and coefficient of unniformity, C_u and coefficient of curvature, C_c is calculated. Based on the calculation from the graph, the soil in January and April is classified as poorly graded sand according to British Soil Classification System

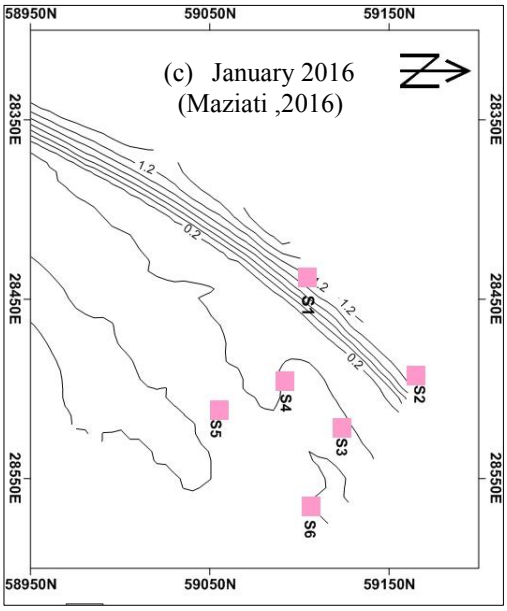
(BSCS). Result of sieve analysis will determine the class of sand more specifically into three major group which are coarse sand, medium sand and fine sand.

The classification of the sand was establish in Figure 2 (a) and (b) for January and April 2017 to monitor the short term effect of monsoon changes along the shoreline. The classification mapping shows that there are changes in the sand classification due to monsoon changes. The monsoon changes affect the environmental factors such as wind that produce strong wave that hit the shoreline. For example, sample 1 is classified as medium sand in January but changes to coarse sand in April which means there are erosion process occur within two months.

The prior study by [12] (see figure 2 (c) and (d)) was used to compare with the current stuy. However, the study by [12] only covered the area that involve only Sample 1 until Sample 6. [12] study was done in January and March 2016 and there are likely the same period as current study. Long term study shows that the classification of sand changes for Sample 1 and Sample 2 that located near the shore. This phenomena may due to the strong waves, current and tides to transport the fine sand away from the shore and left the coarser sand.







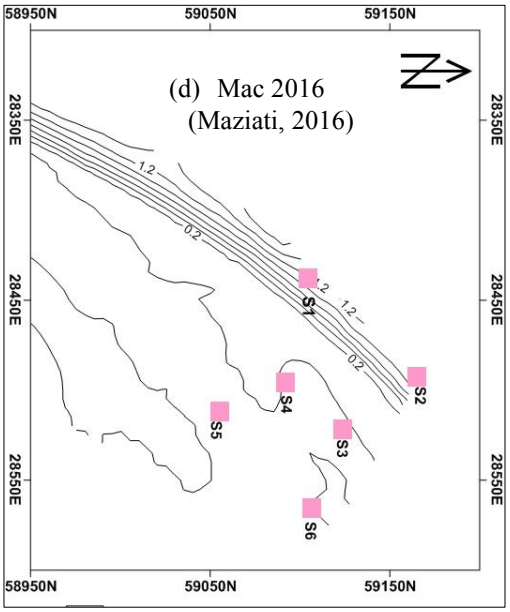
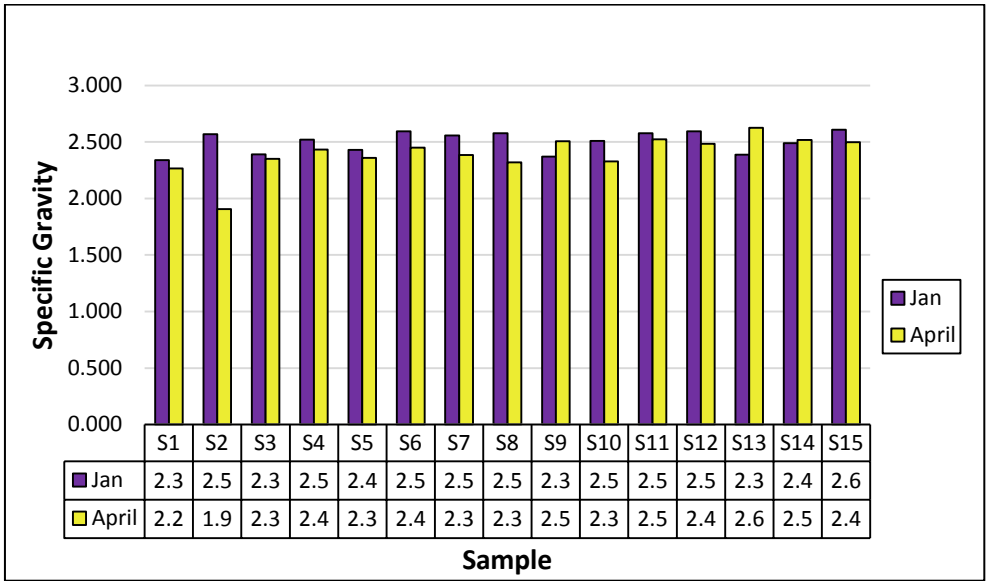


Figure 2: Sand Classification Mapping from January 2016 to April 2017.

Specific gravity (SG) analysis was conducted using Pycnometer test as an addtional basic soil parameter to monitor the changes of beach profiles . The Pycnometer test result shown in Figure 3 found the changes of PSD may effect the specific gravity (SG) of the soil on shorelines. However, PSD wasnot the only contributing factors on changes of SG. Other factors contributing to the changes of SG is the density of the particle and the minerology of the soil. For example is Sample 2 in January is fine sand (SG:2.57) and changes to medium-coarse sand (SG:1.905) in April thus give lower specific gravity value. In conclusive, SG may be influenced by the PSD but it is also determine by the density and its minerology. Table 1 shows the range of the SG in this project.



	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jan	2.3	2.5	2.3	2.5	2.4	2.5	2.5	2.5	2.3	2.5	2.5	2.5	2.3	2.4	2.6
April	2.2	1.9	2.3	2.4	2.3	2.4	2.3	2.3	2.5	2.3	2.5	2.4	2.6	2.5	2.4

Figure 3: The comparison of specific gravity between January 2017 and April 2017

Tabel 1: Range of specific gravity in Teluk Gorek beach.

Classification of sand	Range
Coarse	2.2
Medium-Coarse	1.9
Medium	2.3 – 2.6
Medium-Fine	2.5 – 2.6
Fine	2.3 – 2.5

In addtion to PSD and specific gravity, soil water characteristic curve was also been estabished to be part of soil properties mapping for Telok Gorek, Mersing. Pressure plate extractor and hanging column methods were used to establish the soil water characteristic curve of the study area (Figure 4). The analysis was done only for Samples 2, 5, 8, 11 and 14 due to few limitation. However, due to limited time frame of the study preliminary study of SWCC only was conducted for sample in January 2017. In general, the shape of the curves are similar which converge at higher suction (between 20- 100kPa). However, at lower suction the moisture content value a slight different which may due to the percentage of fine granular. The shape SWCC is influnced by material properties such as the grain size distribution, the clay content minerology and density of soil and the pore fluid characteristics [13][14].

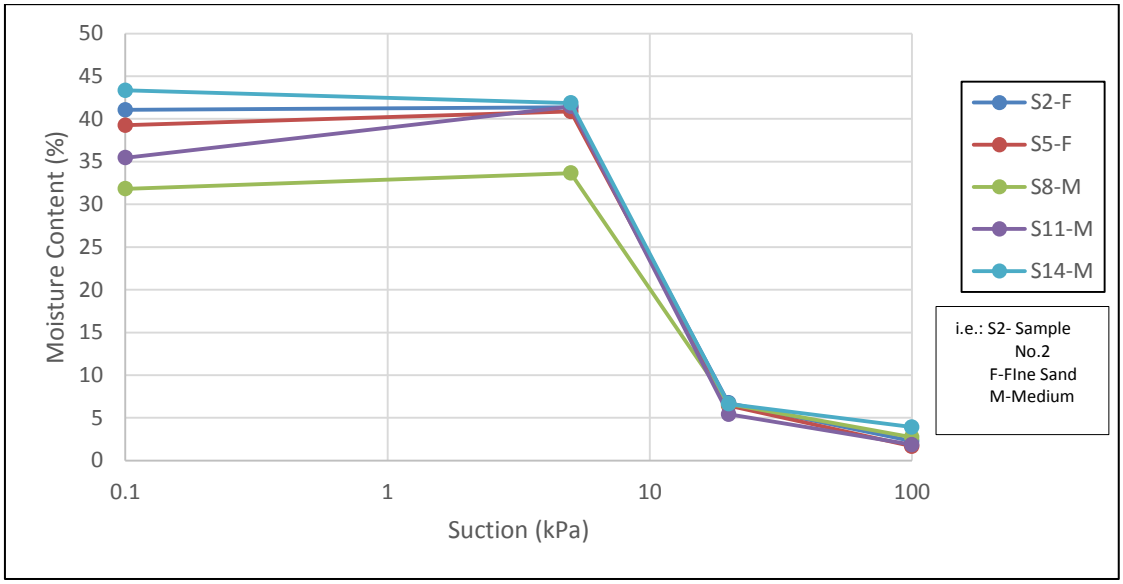


Figure 4`: SWCC results for study area in January 2017

CONCLUSION

This study present the beach profile changes on soil properties of beach sand at Teluk Gorek. Total 15 sample have been analysed through sieve analysis, specific gravity analysis and 5 sample for soil water characteristic curve. The analysis shows that the particle size of sand changes during the period of study. This is because there are process of accretion and erosion take place at the study area may due to monsoon changes since January 2016 to April 2017 (Northeast Monsoon from October to March) that effect the environmental factor such as waves, tides and current. The specific gravity test support the sieving analysis as the coarse sand have high porosity, it allow more water to diffuse in the soil thus give low specific gravity value. Besides that, the soil water characteristic curve produce shows that the soil gradually decreased as suction getting higher. This research gives advantages in understanding the effect of variation in particle size distribution on specific gravity and porosity in the soil.

REFERENCES

[1] Rodriguez, A. B., 2012. Marine Geology. *One-year along-beach variation in the maximum depth of erosion resulting from irregular shoreline morphology,* Volume 291-294, pp. 12-23.

[2] Othman, M.A. 1994. Value of Mangroves in coastal protection**.** *Hydrobiologia*, 285: 277-282.

[3] Department of Irrigation and Drainage Malaysia. (2015, April 21). *Coastal Management - Activities*. Retrieved December 18, 2016, from The Official Portal for Department of Irrigation and Drainage Malaysia: http://www.water.gov.my/activities-mainmenu-184

[4] Davidson-Arnott, R., 2010. *Introduction to Coastal Processes and Geomorphology*. United States: Cambridge University Press.

[5] Yaacob. (2014). A study on the Surface Water Movements Due to Tides Off the Kuala Terengganu Coast. *Second National Workshop on Tides*. Terengganu: Univesiti Putra Malaysia.

[6] Eliot, Matt, 2016. *Coastal sediments, beaches and other soft shore*. Gold Coast: National Climate Change Adaption Research Facility

[7] Mariani, A., Shand, T.D., Carley, J.T., Goodwin, I.D., Splinter, K., Davey, E.K., Flocard, F. and Turner, I.L., 2012. Generic design coastal erosion volumes and setbacks for Australia. *Water Research Laboratories at the University of New South Wales, Prepared for Antarctic Climate and Ecosystems Cooperative Research Centre*.

[8] Ghazali, Nor Hisham M., 2006. Coastal erosion and reclamation in Malaysia. *Coastal erosion and reclamation in Malaysia*, 9(2), pp. 237-247.

[9] Syarkina, A. N. A., 2017. Beach Profile Changes Using RTK GPS.

[10] Aqilah, Z. N., 2017. Monitoring Beach Profile Changes at Teluk Gorek, Mersing.

[11] Azlin, B. N., 2017. Monitoring Shoreline Changes at Teluk Gorek, Mersing.

[12] Maizati, M. A., 2016. Beach Profile Changes at Teluk Gorek Beach a Case Study.

[13] Vanapalli, S., Fredlund, D. and Pufahl, D. (1999). The influence of soil structure and stress history on the soil–water characteristics of a compacted till. *Géotechnique*, 49(2), pp.143-159.

[14] Hillel, D. (2003). Introduction to environmental soil physics. Academic pres. Retrieve from: https://books.google.com.my

Unconfined Compressive Strength and Shear Strength of Marine Clay Treated by Magnesium Chloride

Zafri Nasrullah Mohamed Ali, Siti Norafidah Jusoh

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

snorafida@utm.my

Keywords: Marine Clay; Unconfined Compressive Strength; Shear Strength; Magnesium Chloride.

ABSTRACT. Weak engineering properties of marine clay cause the engineering structures damage. It requires a soil improvement before any construction can be carried out. This study aimed at determining the strength of marine clay stabilized by magnesim chloride ($MgCl_2$). The objectives of the study were to obtain the physical properties of marine clay, determine the unconfined compressive strength and shear strength of marine clay treated by the $MgCl_2$ at various curing period. The physical properties were obtained from the literature review as from the previous study used the same marine clay from West-Coast Expressway (WCE) project. The optimum moisture content (OMC) and maximum dry density (MDD) obtained are 38% and 1.21 Mg/m^3 had been used in mixing marine clay with 2 %, 4%, 6%, 8% and 10% of $MgCl_2$ by weight. The UCS of the compacted untreated marine clay is 52 kPa. The strength of untreated marine clay increased when the soil was mixed with $MgCl_2$. From the Unconfined Compressive Test, it was found that the optimum percentage of $MgCl_2$ added to stabilized the marine clay is 4%. The strength of marine clay decreased as the $MgCl_2$ added more than 4%. The UCS for the optimum percentage added to marine clay was increased to 77 kPa and 82 kPa at 3 and 7 days of curing. Then the strength decreased to 80 kPa and 73 kPa on 14 and 28 days of curing, respectively. It shows that generally the strength increased with 7 days curing periods and decreased after 7 days curing period. The cohesion, *c* and internal friction angle, Ø value obtained were 6.52 kPa and 14.5º. Strength development with time can be explained by the growth of cementitious product that weld the soil particles together and fill the pores in marine clay and $MgCl_2$. Soil repulsion occur that effect in reducing the strength of soil as the positive surcharge increase.

INTRODUCTION

Construction on soft marine clay area either for highway, buildings or any civil engineering work will be a challenging process as our country Malaysia have vast amount of soft marine clay. These soils may be loose, expansive, dispersive, highly compressible or highly permeable. Dispersive and expansive soils are considered problematic, and these soil properties cause serious problems for many engineering structures [12]. To improve the properties of soft clay soil, there are many available methods such as sand drain, piling, using admixtures and many more. For this project,

this study will focus on strengthen the soft marine clay by adding magnesium chloride ($MgCl_2$) into the soft marine clay. The soil selected in this study was marine clay, obtained from the West-Coast Expressway (WCE) project in Teluk Intan, Perak. The area has up to 30 m depth of soft marine clay. Previous findings show that lots of traditional stabilizers contain of calcium can cause excessive expansion. With some non-traditional of stabilizer products, improved engineering properties can be achieved via obtaining higher compacted soil densities [10]. However, non-traditional additives comprise of many different chemical agents that are varied in their components and in the manner, they react with the soil (Latifi *et al.*, 2013). The effects of a magnesium chloride ($MgCl_2$) solution on the swell potential, strength characteristics and properties of clay soils were investigated [1, 13]. Therefore, in this study, a soft marine clay soil sample taken from from the West-Coast Expressway project in Teluk Intan, Perak were mixed with the magnesium chloride ($MgCl_2$) with different percentage to get the optimum percentage of magnesium chloride ($MgCl_2$) via unconfined compressive test.

Problem Statement

The soft marine clay generally loose, expansive, dispersive, highly compressible and highly permeable. It has very low in compressive strength that can cause problem to the construction that do on this type of soil. Several methods are applied to encounter this problem to achieve or improve the soil properties to make sure the geotechnical engineering problem reduce during construction. All the methods of stabilize the soil are included of mechanical, biological, chemical and electrical techniques [7]. As the chemical technique get more attention, this type of soil stabilizer can be categorized as traditional and non-traditional additives.

The commonly use stabilizers such as lime, cement, zeolite, gypsum, industrial waste and fly ash can be classified as traditional stabilizers. This type of traditional stabilizers, produce negative impact to the environment such as cement. As example, during the production of cement, carbon dioxide (CO_2) is release to the air where it will give negative impact to our environment. Therefore, in order to overcome the used of traditional stabilizers, eco-friendly non-traditional additive, magnesium chloride ($MgCl_2$).which is highly soluble in water can be used to treat problematic soil, marine clay. Magnesium chloride ($MgCl_2$) is salt type chemical compound which give no effect to the environment and easily can be extracted through sea water. Besides that, the negative environmental impact could be later saved and reduced.

Objectives

The objectives of this study are:

1. to collect data on the physical properties of the pure soft marine clay as the sample to be treated via literature review

2. to investigate the bearing capacity of untreated marine clay in order to understand its basic strength

3. to determine the unconfined compressive strength and optimum percentage Magnesium Chloride of treated marine clay by using different percentage of magnesium chloride ($MgCl_2$) (0%, 2%, 4%, 6%, 8%, 10% and 12%) added to the marine clay at different curing time 3,7,14 and 28 days

4. to compare the result between untreated marine clay with treated marine clay with $MgCl_2$ on the improvement of bearing capacity of marine clay

5. to determine the maximum resistance to shear stresses of marine clay sample with the optimum percentage of magnesium chloride ($MgCl_2$) via shear strength test

Scope of Study

The sample involved in this study was collected West-Coast Expressway (WCE) project at Teluk Intan, Perak. The sample is tested by adding different percentage of magnesium chloride ($MgCl_2$) 2%, 4%, 6%, 8% and 10% by the soil weight at different curing period of 3, 7, 14, 28 days. Before conducting the laboratory tests, data on the physical properties of untreated soft marine clay and magnesium chloride ($MgCl_2$) are being collected from the previous research that had been done on the same sample. The study focuses on the effects of magnesium chloride ($MgCl_2$) on compressive strength of soft marine clay by conducting laboratory test of unconfined compression test and direct shear test.

LITERATURE REVIEW

Many construction industries are facing the problem of soft soil construction because soft soil has high compressibility, low shear strength and low permeability. Due to these characteristics, the problem of excessive settlement could be occurred after construction. Clay has particle sizes less than 0.02 mm and can be easily break to this

size. In geotechnical engineering, clay is a kind of cohesive soil, which is very weak, and its strength will decrease by influence of climate or the water content in the soil [6].

Chemical stabilization is one of the methods on soil stabilization in improving the strength of the soil. Chemical stabilization operates by adding soil stabilizers or other particle binding energy to increase the physical and engineering properties of the soils. It can be categorized into to type which is traditional stabilizers and non-traditional stabilizers. Cement lime, fly ash and bituminous product can be classified as traditional stabilizers. The examples of non-traditional stabilizers are magnesium chloride, sodium silicate and xanthan gum or any variation combination of chemical agents that interact with the soil. In this recent years, non-traditional stabilizers get more attention on improving the strength of the soft soil.

The use of traditional stabilizer has been used for a long time such as lime and cement to enhance the geotechnical properties of surplus soil, allowing for their use in some fashion on given project site [9]. A lot of traditional stabilizers produce chemical compounds or gases during production process that will contribute to global warming or ozone depletion. The use of traditional soil stabilizers such as lime or cement can change the pH of improved soil, with the potential to cause negative environment impacts including retarded vegetation growth, reduction in groundwater quality, and even potentially human health problems. As example, the production of cement produces carbon dioxide (CO_2) gas emissions in the air that will give negative impact to the environment. Coal combustion residues (CCR) are referring to the residue produced during the coal combustion regardless of ultimate utilization or disposal. It includes fly ash, boiler slag and fluidized bed combustion ash and other solid particle. The fly ash can be used to increase the strength of soft clay by mix together by chemical stabilization method.

Various products of non-traditional soil stabilizer which are not calcium based potentially effective alternative for treating soils. These non-traditional chemical stabilizers are usually sold as concentrated liquids diluted with water at the construction site, then either spread on the soil before compaction or pressure injected to treat deeper soil layers [5]. Non-traditional stabilizers comprises of a variation combination of chemical agents that interact with the soil such as magnesium chloride ($MgCl_2$) and sodium silicate (TX-85).

The usage of $MgCl_2$ is becoming more common, its potential to improve the geotechnical properties of problematic soils is receiving increasing attention. Some studies reported on the successful application of $MgCl_2$ solution to improve the swell potential, strength characteristics and dispersibility of problematic soils [1]. In North America, $MgCl_2$ have been used for a long time as the solution do not corrode vehicles, damage cement and asphalt or harm plant or living creatures. As example, the solution is applied to non-paved roads during the spring or summer month for dust suppression and road stabilization.

From previous study, to minimize coarse particle scattering, prevent from ice formation, control dust on road, the bischofite was applied on the road [4]. Hexahydrated magnesium chloride or bischofite can be classified as a salt. Bischofite is a hydrous magnesium chloride mineral with the formula $MgCl_2 \cdot 6H_2O$. This formula is belong to the halides group and is a sea salt concentrated dated from the Permian period. The main bischofite compound is magnesium chloride can be up to 350 g/L [8]. This chemical shows high potential in improving the strength of soil that can overcome the geotechnical engineering problem for construction of structure.

The unconfined compressive strength (UCS) test is a type of unconsolidated-undrained test which used to determine the maximum compressive value for each samples. The magnesium chloride ($MgCl_2$) improved the compressive strength of the bentonite and kaolin significantly [9]. Shear strength is another important feature in geotechnical engineering or, more specifically, the stability of slopes, shallow foundations, cuts, fills, dams, pavements design and the stresses on retaining walls [5]. Shear strength is the ability of soil to support the load of a building or to remain stable at its location defines as the strength of the soil. The strength of the soil is important for engineers during the design process.

METHODOLOGY

The main objective of the research is to study the effect on strength of marine clay treated by magnesium chloride. Unconfined Compressive Test (UCT) and Direct Shear Test were conduct to get the data on strength of marine clay treated by magnesium chloride. This research methodology consisted of 4 key activities: collection data on properties of marine clay, preparation of sample, unconfined compressive strength and direct shear strength. The flow of the study shown in Figure 1.

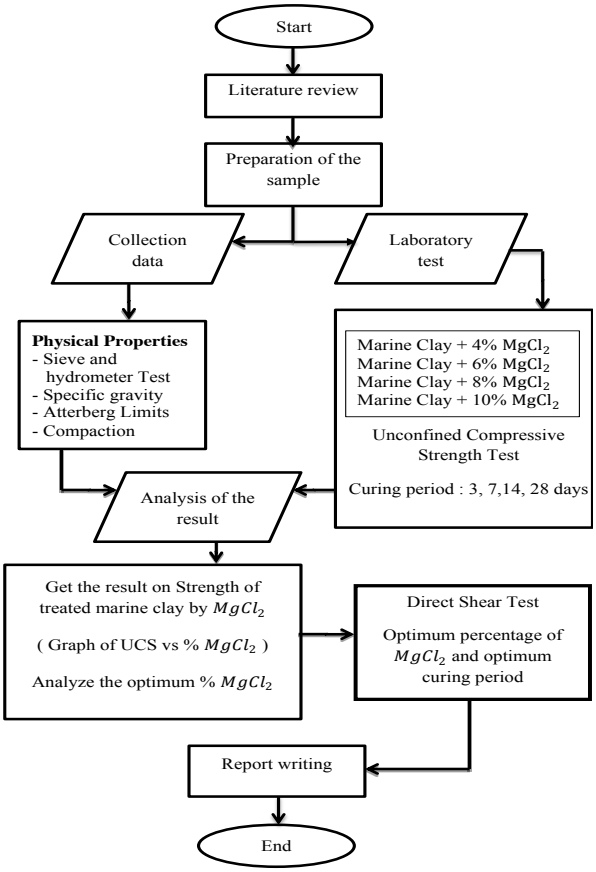


Figure 1: Methodology flow chart

Collection Data on Physical Properties of Marine Clay

The soft Marine clay was obtainedfrom the West-Coast Expressway (WCE) project in Teluk Intan Perak. The data was collected from the previous research on the same type of sample. The data for index properties are plastic limit, liquid limit, plasticity index, specific gravity, maximum dry density and optimum moisture content. All of the data is taken after the soil is being test through several test such as cone penetration test, field vane shear test, specific gravity test and compaction Test.

Preparation of Sample

The soil sample used in the study was dried at 105 °C in a drying oven and then ground and passed through a sieve to obtain a uniform distribution. Different amounts (0, 2, 4, 6, 8, and 10% by dry weight of the soil) of the magnesium chloride solution were added and mixed into the prepared soil sample. All mixing was performed manually, and special attention was paid to obtaining a homogeneous mixture in each step. The optimum water content and maximum dry density values needed to prepare the samples for use in strength tests for each magnesium chloride additive percentage were determined. In Table 1, mix proportions used in preparing samples are presented in detail. Curing times of 3, 7, 14 and 28 days were used in this study. A minimum of three samples for each curing time were prepared in order to provide adequate data to validate the results.

Table 1: Type of sample prepared for UCS test

Sample	Mixing Percentage
1	Soft Marine Clay + 4% magnesium chloride ($MgCl_2$) + water (OMC)
2	Soft Marine Clay + 6% magnesium chloride ($MgCl_2$) + water (OMC)
3	Soft Marine Clay + 8% magnesium chloride ($MgCl_2$) + water (OMC)
4	Soft Marine Clay + 10% magnesium chloride ($MgCl_2$) + water (OMC)

Unconfined CompressiveTest

The unconfined compressive strength test (UCT) has been used on all specimens based on British Standard 1377 part 7:1990 with a constant stress rate at 16 mm/min [2, 3]. Each specimen was compressed until peak load was achieved where the applied load was recorded by a data acquisition system. The UCS test is to determine the compressive strength of treated and untreated soil using sodium silicate as stabilizer. Triplicate sample were used to get a consistent and accurate result.

Direct Shear Test

Direct shear tests were performed on untreated specimens and stabilized specimens prepared at the optimum additive amount, based on the results from the UCS tests, to determine the shear strength properties. Direct shear tests were conducted in accordance with standard procedures [2, 3]. Direct shear specimens were prepared by compacting untreated or stabilized soil mixtures in a steel box with a 60 mm length 9 60 mm width 9 20 mm height. Direct shear testing of specimens was performed by applying a constant strain rate of 0.6 mm/min to the specimens inside the shear boxes, until the soil failed or reached a maximum horizontal displacement of 10 mm. This total shear displacement was chosen based on the capability of the machine used. Tests were performed at three different normal stresses: 15, 28, and 56 kPa. Tests conducted on untreated and stabilized specimens under different normal stresses were used to plot relationships between failure normal stresses and shear stresses and to determine the associated Mohr–Coulomb shear strength parameters.

RESULTS AND DISCUSSION

Physical Properties of Marine Clay

The physical properties had been determined on the same soil obtained from West-Coast Expressway (WCE) project [11]. For this study, the physical properties obtained by Sukairi (2016) have been selected as the baseline for this study. The value of liquid limit, plastic limit, plasticity index and particle density of the sample had been obtained by Sukairi (2016). The value of the physical properties of marine clay obtained shown in Table 2.

Table 2 : Physical properties of marine clay [11]

Properties	Marine Clay
Liquid limit (%)	78
Plastic limit (%)	41
Plasticity index (%)	37
Specific gravity	2.68
OMC (%)	38
MDD (Mg/m^3)	1.21

Unconfined Compressive Strength (UCS)

The result from Unconfined Compressive Test in Figure 2 shows the untreated marine clay Unconfined Compressive Strength is 52 kPa. The result from Unconfined Compressive Test for the magnesium chloride ($MgCl_2$) content of 2%, 4% and 6% shows an increment in Unconfined Compressive Strength (UCS) gain up to 7 days curing period. For 3 days of curing period, 2% of magnesium chloride ($MgCl_2$) stabilizer content gain strength from 52 kPa to 56 kPa, 4% of magnesium chloride ($MgCl_2$) stabilizer content gain strength from 52 kPa to 77 kPa and 6% magnesium chloride ($MgCl_2$) stabilizer content gained strength from 52 kPa to 66 kPa. For 7 days of curing period, 2% of magnesium chloride ($MgCl_2$) stabilizer content gained strength from 52 kPa to 64 kPa, 4% of magnesium chloride ($MgCl_2$) stabilizer content gained strength from 52 kPa to 82 kPa and 6% magnesium chloride ($MgCl_2$) stabilizer content gained strength from 52 kPa to 70 kPa. After 7 and 14 days of curing period, the strength started to decrease for 4% and 6% of magnesium chloride ($MgCl_2$) content. For 2% of magnesium chloride ($MgCl_2$) content of stabilizer, the marine clay started to decrease in strength after 14 days. For 14 days of curing period, 2% of magnesium chloride ($MgCl_2$) stabilizer content gained strength from 52 kPa to 75 kPa, 4% of magnesium chloride ($MgCl_2$) stabilizer content gained strength from 52 kPa to 80 kPa and 6% magnesium chloride ($MgCl_2$) stabilizer content gained strength from 52 kPa to 65 kPa.

The result from Unconfined Compressive Test for the magnesium chloride ($MgCl_2$) content of 8% and 10% shows a decrement in Unconfined Compressive Strength (UCS). For 3 days of curing period, 8% of magnesium chloride ($MgCl_2$) stabilizer content strength decrease from 52 kPa to 24 kP and, 10% of magnesium chloride ($MgCl_2$) stabilizer content strength decrease from 56 kPa to 16 kPa. For 7 days of curing period, 8% of magnesium chloride ($MgCl_2$) stabilizer content strength decrease from 52 kPa to 28 kP and, 10% of magnesium chloride ($MgCl_2$) stabilizer content strength decrease from 52 kPa to 20 kPa. For 14 days of curing period, 8% of magnesium chloride ($MgCl_2$) stabilizer content strength decrease from 52 kPa to 30 kP and, 10% of magnesium chloride ($MgCl_2$) stabilizer content strength decrease from 56 kPa to 31 kPa. For 28 days of curing period, 8% of magnesium chloride ($MgCl_2$) stabilizer content strength increase from 52 kPa to 38 kP and, 10% of magnesium chloride ($MgCl_2$) stabilizer content strength decrease from 56 kPa to 30 kPa.

Figure 3 shows the relationship between UCS and curing period for various percentage of magnesium chloride ($MgCl_2$). In the figure it shows that the strength of marine clay increase when the marine clay treated by using 2%, 4%, and 6% of magnesium chloride ($MgCl_2$). Normally, the strength increased during curing can be explained through the cementing gel material (hydrates), formed through pozzolonic reactions.When the marine clay treated by using 8% and 10% of magnesium chloride ($MgCl_2$), the marine clay strength decreases. From Figure 3, it shows that the optimum percentage to treat marine clay is 4% where it has the highest strength. The strength is increase by curing period up to 7 days and its start to decrease the strength when the treated marine clay exceeds 7 days. This indicated that the greatest part of the marine clay treated by magnesium chloride ($MgCl_2$) reactions happened within 7 days. For the marine clay treated by magnesium chloride ($MgCl_2$) more that 6%, a lower compressive strength was achieved. This might be because of precautions that did not take in handling chemical during mixing the marine clay and magnesium chloride ($MgCl_2$). Both the chemicals and marine clay are sensitive and need special precaution to handle them Besides, this was probably due to the increase of positive surcharge and the subsequent repulsion of soil particles inside the mixture [5]. The degradation of strength could also have been due to the amount of alkaline stabilizer, which exceeded the requirement for chemical reaction in the samples. Based on the Figure 2 and 3, 4% of magnesium chloride ($MgCl_2$) was chosen as the optimum value for addition to the marine clay.

Figure 2: The UCS of marine clay treated by $MgCl_2$

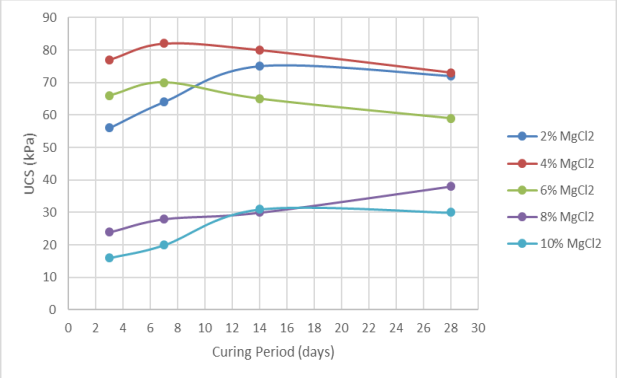


Figure 3: Relationship between UCS and curing period for various percentage of $MgCl_2$

Shear Strength

The failure envelope of the 4% magnesium chloride ($MgCl_2$) stabilized marine clay at 7 days curing period with c of 6.52 kPa and Ø of 14.53 as shown in Figure 4. It is found that the shear strength parameters obtained in this study were the smallest among the other researcher [5, 9]. The cohesion value was the smallest among the other researcher and it show a very big different. For internal friction angle value, the value did not give a big different. The internal friction angle value in this study is similar with Latifi et al. (2015) which is 14.5 [9]. The value for cohesion have a big different may be caused by several factor. For magnesium chloride ($MgCl_2$) stabilization of marine clay, strength development with time can be explained by the growth of cementitious product that weld the soil particles together and fill the pores in marine clay and magnesium chloride ($MgCl_2$). Due to the electrically charged nature of marine clay particles, direct interaction between marine clay and magnesium chloride occurs and increase the attractive forces. If the positive surcharge increase, soil repulsion could occur that will effect in reducing the strength of soil.

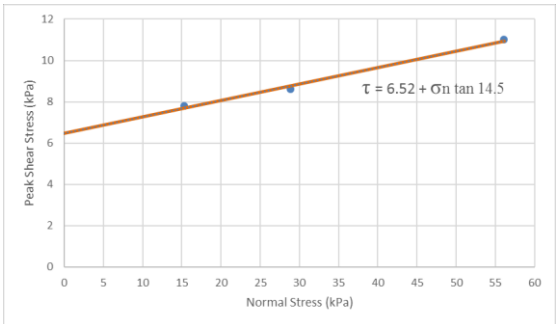


Figure 4: Failure envelope of a $MgCl_2$ stabilized marine clay at 7 days curing times

CONCLUSION

This study was undertaken to investigate the influence of magnesium chloride percentage and curing time on the unconfined compressive strength and shear strength of treated and untreated marine clay. The conclusions of the study carried out are as follows:

1. The liquid limit for the marine clay is 78%, plastic limit 41% and the plasticity index is 37%. The specific gravity of the sample is 2.68. The value of maximum dry density (MDD) and the optimum moisture content (OMC) are 1.21 Mg/m^3 and 38%.

2. The result from Unconfined Compressive Test shows the untreated marine clay unconfined compressive strength is 52 kPa.

3. The results of the unconfined compressive strength test showed that 4 % of magnesium chloride ($MgCl_2$) at 7 days curing period, 82 kPa was the optimum amount of this stabilization process for the selected marine clay.

4. The unconfined compressive strength significantly increased with the curing time periods. The unconfined compressive strength of the mixtures increased up to 7 days and decreases from 14 to 28 days curing time period.

5. The unconfined compressive strength of the soil specimens has increased with increment of magnesium chloride contents. However, the unconfined compressive strength reduces with increment of magnesium chloride ($MgCl_2$) after 4 %.

6. The results of the direct shear test showed the cohesion value is 6.52 kPa and internal friction angle 14.5º for 4% of magnesium chloride added to marine clay with 7 days of curing period.

REFERENCES

[1] Acaz, A., 2011. *The Effect of Magnesium Chloride Solution on Swell, Dispersibility and Strength Characteristics of Problematic Clay Soil* (in Turkish with English Abstract). (M.Sc. Thesis) Eskisehir Osmangazi University, Graduate School of Natural and Applied Sciences, Eskisehir, Turkey.

[2] British Standards Institution (1990). *British Standard methods of test for soils for civil engineering purposes:* Part 1, General requirements and sample preparation. London, BS1377.

[3] British Standards Institution (1990). *British Standard methods of test for civil engineering purposes:* part 7, shear strength tests (total stress). London, BS1377

[4] Ketcham, S.A.,Minsk, D.L., Blackburn, R.R., Fleege, E.J., 1996. *Manual of practice for an effective anti-icing program: a guide for highway winter maintenance personnel* (report no: FHWA-RD-95-202). A Report Presented to Federal Highway Administration by US Army Cold Regions Research and Engineering Laboratory. New Hampshire, Hanover

[5] Latifi, N., Marto, A. and Eisazadeth, A. (2013). *Structural Characteristics of Laterite Soil Treated by SH-85 and TX-85 (Non-Traditional) Stabilizers*. EJGE, Vol. 18, pp. 1707-1718.

[6] Liu, C., & Evett, J. B. (2005). *Soils and Foundations*. Jurong, Singapore Prentice Hall, Pearson Education South Asia Pte Ltd.

[7] Marto A, Latifi N, Sohaei H (2013) *Stabilization of laterite soil using GKS soil stabilizer*. Electron J Geotech Eng (EJGE) 18:521–532

[8] Marto A., Mohd Yunus N., Pakir F., and Latiffi N. (2014). *Stabilization of Marine Clay by Biomass Silica (Non Traditional) Stabilizers*. Applied Mechanics and Material Vol.695: 93-97.

[9] N. Latifi, A.S.A. Rashid, S. Siddiqua, S. Horpibulsuk (2015), *Micro-Structural Analysis of Strength Development in Low- and High Swelling Clays Stabilized with Magnesium Chloride Solution – A Green Soil Stabilizer*, Applied Clay Science 1-18.

[10] Randolph, R.B., (1997). *Earthmaterials catalyst stabilization for road bases, road shoulders, unpaved roads, and transportation earthworks*. Transportation Research Record 1589, TRB. National Research Council,Washington, D.C., pp. 58–63.

[11] Sukairi, S. (2016). *Strength of Marine Clay Stabilized Using Geopolymer*. Skudai Johor: Universiti Teknologi Malaysia.

[12] Turkoz, M., Savas, H., Acaz, A., and Tosun, H. (2014). *The effect Magnesium Chloride solution on the engineering properties of clay soil with expensive and dispersive characteristic*. Applied Clay Science, 1-9.

[13] Turkoz, M., Savas, H., Tosun, H., (2011). *Stabilization of problematic clay soils with magnesium chloride solution*. J. Fac Eng. Archit, Gazi Univ.6(1), 233–242.

Geomorphology and Geological Hazard in Ringlet, Cameron Highlands

Zairinhani binti Zulkifly, Edy Tonnizam Mohamad

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

edy@utm.my

Keywords: Geo-hazard; Flooding; Geomorpgology; Lineament; Soil Loss; Sedimentation Yield.

ABSTRACT. Geomorphology factor is important in flood event study for the control mitigation purposes. The interactions of flooding, sedimentation and channel behavior can be related with the geomorphology as the change of river geomorphology occurs with the flood frequency and the propensity within an area. The key objectives of this research is to understand the geomorphology in terms of lineament pattern of Bertam Reservoir and its relation with the high intensity of rainfall that contribute to the flooding event occurrence in 2013 and 2014 in Bertam Valley, Cameron Highlands. There are three factors towards the events being studied, which is lineament pattern, soil loss rate and sedimentation rates on Sultan Abu Bakar Dam. From the research, all factors including the rainfall intensity contributes to the rapid rise of the dam sedimentation that causes the flooding event in the Bertam Valley. Soil erosion is the major cause for concern since its occurrence in the area still increasing. Deforestation and land clearing in the Cameron Highlands for agricultural, urbanization and infrastructure development has resulted in widespread soil erosion over the

land surface. Excessive sediment deposited in the Ringlet Reservoir affects the storage and the useful life of the reservoir.

INTRODUCTION

Geologic hazards or geo-hazard are the natural process or state that may lead to the widespread of damage or risk in the earth. It is involved either in long-term or short-term geological process and the impact of geo-hazard may occur in small features. However in most events, the occurrence of geo-hazard can be lead to the disastrous event involving human live and damage to the environmental as well as affected the socio economy activities. Recently we can see that many incidents of geo-hazard happen in Malaysia due to environmental degradation involving some tragic consequences as the effect from the negative environment exploitation on the local land.

Dams have provided benefit to the development of civilization, and improve human standard of living. There are almost 51 recorded dams in Malaysia where 60% of the dams are of earth fill type, under different ownerships [1]. Even though the dam failure tragedy has yet to occur in our country, the affect by the dam sedimentation slowly showing the sign that could lead to the failure in the future. As an example, in October 23, 2013, flash flooding occurrence below the Ringlet Reservoir coupled with the existing siltation resulted from the rapid rise of the water level in Sultan Abu Bakar Hydroelectric Dam in Bertam Valley, Cameron Highland. As the impact from this event, the massive flood hit into Bertam Valley that is located downstream of the dam and damage 100 houses in Kg Bertam Valley and led to the death of four peoples. The damage is quite big though the procedure of controlled release of water from the dam has been taken by Tenaga Nasional Berhad (TNB) whom responsible in managing the power dam. Following year, in November 5, 2014, Cameron Highland experience the same flooding event just like before due to the heavy rain which led the Sultan Abu Bakar Dam to release the excess water from the reservoir into the Bertam Valley River.

Both flooding events are similar to the super flood in Indus Basin back in 2010 which affected all the provinces and regions of Pakistan that killed 1,600 peoples, caused damage totaling over $10 billion, and inundated an area of about 38,600 km^2. This flood was Pakistan's most damaging on record. [2].

Problem Statement

Flooding is one of the geo-hazard occurrences that frequently happen in Malaysia and usually cause loss of lives and destructions of properties and environment. There are several factors that contribute to the flood event such as high intensity of rainfall, disposal of wastetage materials into rivers and land use activities. A shallow reservoir has reduced volume to retain water, hence high volume of rainfall and surface runoff raise the water surface of the reservoir rapidly up to the danger levels. Geomorphology and erosion enhance the rapid rise of the sedimentation stage in the dam reservoir which affected the capacity of the dam in Bertam Reservoir. By records, in just 35 years of operation since construction in 1963, almost 52% of Sultan Abu Bakar Dam storage capacity was already taken up by sediments which left the reservoir's balance lifespan of 4 years if there are no mitigations measures were undertaken [3].

The land use development in the surrounding area of the dam increased rapidly with the agricultural activities and tourism development caused soil erosion and sedimentation that leading to flash floods occurrence in Bertam Valley.

Objectives

The objectives of this study are:

1. To identify the geomorphology and lineament of Bertam Reservoir.

2. To assess the relation between geomorphology and rainfall towards the geological hazards in Bertam Valley.

Scope of Study

This study is focusing on dam sedimentation and flooding hazard which is prone to the Bertam Valley, Cameron Highland. Besides, the study will relate the geomorphology of the study area with the soil erosion that contribute to the rapid sedimentation in Sultan Abu Bakar Dam that caused the flooding event to the area in radius 1.3 km downstream from the dam spillway. The other factors such as development of land use in the area will be justified whether it has the relation to the problem.

LITERATURE REVIEW

Geomorphology is the study of Earth's physical land surface features or landforms such as rivers, hills, plains, beaches, sand dunes, and myriad others. The nature and rate of geomorphic processes change with time, and some landforms were produced under different environmental conditions. In high latitudes, many landforms are relicts from the Quaternary glaciations; however in certain places, some landforms occur from millions and hundreds millions of years ago [4].

Lineament can be defined as the landforms that related to the features in the underlying bedrock [5]. The discontinuities in rocks frequently result in linear or curvilinear morphological features along the intersection of a fracture plane or the surface expression of a fault. The correlation between the structures mapped such as the fault

trends on the field and lineament system will enables the lineaments to be regarded as representative of the structural indications of the particular areas. The lineaments can affect the stability of rock masses and contribute to the structural weakness and cause the slope movements. The orientation of lineaments and drainage patterns are the factors of the deformation of the soil [6].

Soil erosion is the detachment, entrainment, and transport of soil particles by the agents, such as water, wind, and gravity [7]. The process called land degradation can be categorized as either geological or accelerated surface soil erosion. The accelerated soil erosion occurred from human activities that expose the soil surface to enable the erosive agents such as rain to wash away the topsoil. The amount of silt or sediment delivered into water systems through the processes of entrainment, transportation, and deposition is a function of changes in surface drainage patterns, terrain roughness, vegetation, and climatic conditions. Water is the most significant agent of soil erosion especiallyin the tropic country when the rainfall intensity is very high. The removal of vegetative cover and the breakdown of soil structure through compaction and loss of organic matter often reducing the infiltration process and this will accelerate runoff and the entrainment of soil particles.

Sedimentation is the aggradations process of sediment on the land surface or on the bed of a watercourse [8]. During heavy rainstorms, the sedimentation in drainage systems and in rivers leads to the raising of bed levels which resulting in flash floods occurrence where the process depends on the geomorphic and hydraulic characteristics of the drainage system. The deposited sediment tends to remain in place for certain periods of time until the rain flushing the sediment downstream.

The terms of dam can be referred to any barrier erected to obstruct or control the flow of water [8]. The function of dam can be defined as storage dam; barrages; and diversion dam. In addition, these structures regulate the head upstream and release discharge to the downstream.

METHODOLOGY

The study will be focused on the sedimentation that occur at Sultan Abu Bakar Hydroelectric Dam which shows the rapid sedimentation rate compared to the design life cycle of the dam. The factor that contribute to the sedimentation such as soil erosion, lineament and rainfall intensity will be studied whether it affect the rate of sedimentation. Besides, the information of lineaments and physical profile of the landform will be justified whether it is contributes to the geo-hazard occurrence in the study area so that the good mitigation could be proposed to prevent the repetition hazard occur in the study area.

Universal Soil Loss Equation (USLE)

Universal Soil Loss Equation (USLE) is an erosion model designed to predict the longtime average soil losses in runoff from specific field areas in specified cropping and management systems [9]. The reversed USLE (RUSLE) and modified USLE (MUSLE) often used to estimate the surface erosion and sediment yield.

The evaluation of soil loss involving five parameters or factors such as rainfall pattern, soil type, topography, crop system, and management practices. The formulas of USLE are shown in the following equation:

$$A = R.K.LS.CP \qquad \textbf{(Eq. 1)}$$

Sediment Yield Estimation

Sediment yield estimation can be estimated by using the MUSLE method to calculate the sediment yields of a catchment as a result of a specific storm event. In MUSLE, rainfall energy factor is replaced with a runoff factor and optimizes hydrological process of sediment yield prediction. The MUSLE's equations for sediment yield estimation are shown below:

$$Y = 89.6(VQ_p)^{0.56}\,(K.LS.C.P) \qquad \textbf{(Eq. 2)}$$

RESULTS AND DISCUSSION

The soil loss and the sedimentation rate at the area surrounding Sultan Abu Bakar Dam will be estimated by relating to the lineament pattern and geological features of the area. The analysis of the data for the study area are divided into three parts such as geomorphology in regards to the lineament pattern of the area, the annual soil loss estimation and the sedimentation rate estimation of Sultan Abu Bakar Dam.

The lineament pattern has been analyzed by using manual method on the aerial photograph extracted from Google Earth application. The study area surrounding Sultan Abu Bakar Dam has been divided into six small units labeled from Group A to Group F as shown in Figure 1. From Google Earth data extraction, the lineament length, slope and the degree of the strike transferred into the GeoRose software to generate the Rose Diagram. Rose Diagram is a method to visualize the directional data that consists of direction measurements or orientation on the paper.

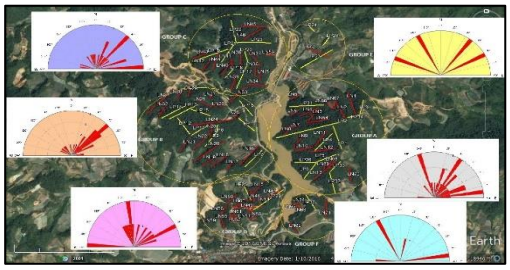


Figure 1: Lineament pattern and Rose Diagram of study area

The soil loss estimation has been analyzed in the study area to measure the rate of soil loss for the period of 2013 and 2014. Soil loss is one of the factors that contribute to the rapid rise of sedimentation in the reservoir dam. The R-factor that has been used is based on the annual rainfall data on 2013 and 2014 so that the comparison can be made for the time period to relate the factors that contributes to the repetition flooding event in study area.

Form the analysis of soil loss rate, the rate has been increased in each group area and the class of potential soil loss has been downgraded for Group A, B, C, and F (*Refer to Table 1 and Table 2*). Group F shows the higher rate of soil loss in both years with Extreme potential of soil loss in 2013 and Exceptional in 2014. The value of soil loss rate has been increased from 86.36 ton/ha/yr to 119.22 ton/ha/yr in just a year apart. It is because; the land uses types of the area are bare soil since the area is cleared for the construction of Jalan Ringlet-Sungai Koyan new road. Since the area is in the critical potential of soil loss, any other development shall be avoided to reduce the rate of sedimentation generation into reservoir.

Although Group D and Group E class of potential soil loss maintain in the same class, the value of the rate keep increasing. Though Group C's study area contains more forestry of land use, the development behind the hill has change the type of land use to be rangeland by an active agriculture activities and land clearing. This condition gives the potential of soil loss rate at the Severe with Class 5 in 2014 from Class 4 in 2013. In addition, the steepness of the slope and strike degree of lineation contributes to the high rate of the soil loss at this area.

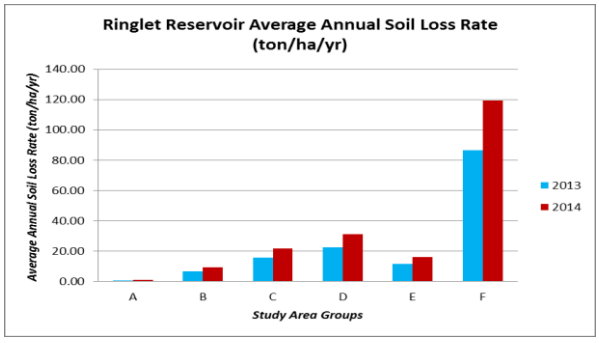
By looking at the comparison between both years as in Figure 2, the trend of soil loss rate can be clearly seen as the rate of soil loss increase from 2013 to 2014 for each group of study area especially for the Group F. Apart from slope steepness and land cover factor that contribute to the soil loss rate, the rate also linearly relate to the increasing amount of annual rainfall for 2013 and 2014. The amounts of annual rainfall are represented by the R-factor which increases from 24.96 MJ.mm/ha/hr.yr in 2013 to 34.46 MJ.mm/ha/hr.yr.

Table 1: Average Annual Soil Loss Estimation in 2013

GROUP	R factor	K factor	LS factor	CP factor	Land use	Soil Loss (ton/ha/yr)	Class	Potential
A	34.46	0.0659	158.7	0.003	Forest	1.08	2	Low
B	34.46	0.0659	60	0.069	Rangeland	9.40	3	Moderate
C	34.46	0.0659	137.9	0.069	Rangeland	21.61	5	Severe
D	34.46	0.0659	90	0.152	Agriculture	31.07	5	Severe
E	34.46	0.0659	46.8	0.152	Agriculture	16.15	4	High
F	34.46	0.0659	75	0.7	Bare soil	119.22	7	Exceptional

Table 2: Average Annual Soil Loss Estimation in 2014

GROUP	R factor	K factor	LS factor	CP factor	Land use	Soil Loss (ton/ha/yr)	Class	Potential
A	24.96	0.0659	158.7	0.003	Forest	0.78	1	Very Low
B	24.96	0.0659	60	0.069	Rangeland	6.81	2	Low
C	24.96	0.0659	137.9	0.069	Rangeland	15.65	4	High
D	24.96	0.0659	90	0.152	Agriculture	22.50	5	Severe
E	24.96	0.0659	46.8	0.152	Agriculture	11.70	4	High
F	24.96	0.0659	75	0.7	Bare soil	86.36	6	Extreme



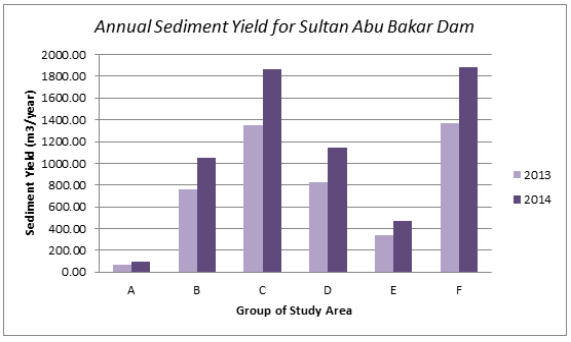


Figure 3: Annual sediment yield for Sultan Abu Bakar Dam

Figure 2: Ringlet Reservoir Average Annual Soil

The value of annual average soil loss rate for each group was determined in ton/ha/year, and then the values were converted to $m^3/km^2/year$. The sediment yield is determined by multiplying the annual average soil loss rate with the area of the group analysis. The total sediment yield was calculated by summing the sediment yield of all the group of study area surrounding the reservoir of Sultan Abu Bakar Dam. The total rate of sediment filling increased from 4,715.50 m^3/ year in 2013 to 6,510.61 m^3/year in 2014 by 38% increasing rates. By referring to the Table 3, Group C and Group F gives the higher rates of sedimentation which are 1,352.94m^3/year and 1,365.18m^3/year respectively. Meanwhile, in 2014 as in Table 4, both groups constantly give the higher rates of sedimentation towards the dam which are 1,868.18 m^3/year and 1,884.63 m^3/year each. By referring to the study conducted by Teh (2011), the value of sediment yield is increasing by 278% in 2 years period of time for 2013. Teh (2011) predicted, the amount of sediment yield is 1,251.23 m^3/year for Reservoir area. [10]

Table 3: Annual Sediment yield for 2013

GROUP	Area (km^2)	Soil loss (ton/ha/yr)	Soil loss ($m^3/km^2/yr$)	Sediment Yield (m^3/yr)
A	0.691	0.78	96.33	66.56
B	0.904	6.81	841.04	760.30
C	0.700	15.65	1932.78	1352.94
D	0.298	22.50	2778.75	828.07
E	0.237	11.70	1444.95	342.45
F	0.128	86.36	10665.46	1365.18
Total sediment yield (m^3/year)				4715.50

Table 4: Annual Sediment yield for 2014

GROUP	Area (km^2)	Soil loss (ton/ha/yr)	Soil loss ($m^3/km^2/yr$)	Sediment Yield (m^3/yr)
A	0.691	1.08	133.38	92.17
B	0.904	9.40	1160.90	1049.45
C	0.700	21.61	2668.84	1868.18
D	0.298	31.07	3837.15	1143.47
E	0.237	16.15	1994.53	472.70
F	0.128	119.22	14723.67	1884.63
Total sediment yield (m^3/year)				6510.61

Group C and Group F contributes more sediment yield generation towards the dam which is about 29% each as shown in Figure 4. The sediment yield is relating to the soil loss rates that have been measured before. This means, both areas is in critical state of soil loss and giving high contribution of sedimentation to the dam

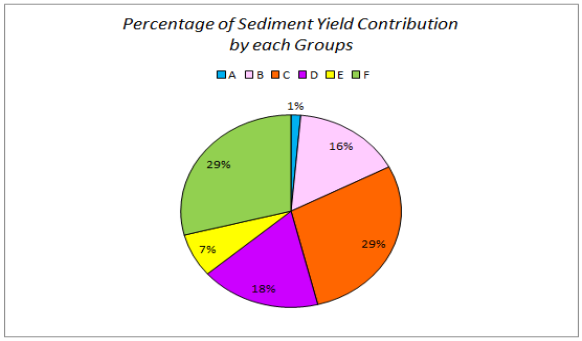


Figure 4: Percentage of sediment yield contribution by each group of study area

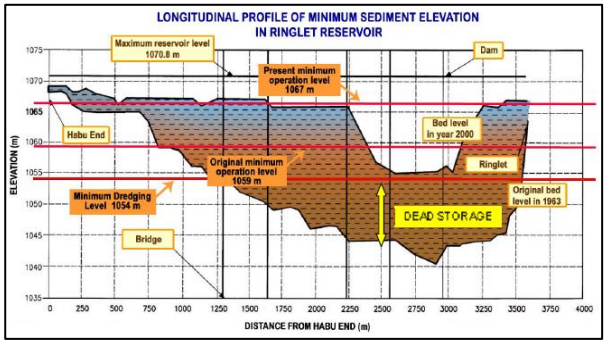


Figure 5: Profile of Sediment Elevation in Ringlet Reservoir

The drastic situation in Ringlet Reservoir shows that though Tenaga Nasional Berhad as an authorized management of the dam has taken the mitigation action to rehabilitate the dam, the sedimentation yield keep increasing. By the records, the dam used to be shutting down in 2005 for de-silting work that takes about two and a half year to be finish. [11]. The silting problem was brought to light at a seminar entitled A Study on Pollution Prevention and Water Quality Improvement Programs of Rivers in Cameron Highlands; where the Consultant Engineer, Alias Hashim, who presented his paper of Formulation of Integrated Sediment and Erosion Control Measures for Pollution Prevention and Water Quality Improvement of Rivers in Cameron Highlands, said agricultural activities topped the list of river polluters, followed by development and road construction especially around the Upper Telom and Upper Bertam catchments that contribute to high percentage of eroded top soil flowing and settling into mountain streams.

When constructed in 1963, Sultan Abu Bakar Dam was designed with the gross storage of reservoir about 6.7 million m^3 with 4.7 million m^3 for live storage and 2.0 million m^3 for dead storage. The dam design life approximately 80 years since 1963 with no special provisions to cope with sedimentation. [3] However the storage capacity of the dam was decreased tremendously because of the high sediment yield accumulation compared to the design life expectancy of the dead storage. Figure 5 shown the dead storage has been fully occupied by the sediments and the live storage is almost completely filled with sediments. The minimum operation level of the reservoir has been increased from 1059m to 1067m due to the sedimentation problem. [10]

CONCLUSION

There are three factors towards the geo-hazard events being studied, which is lineament pattern, soil loss rate and sedimentation in Sultan Abu Bakar Dam. Such factors including the rainfall intensity contributes to the rapid rise of the dam sedimentation that causes the flooding event in the Bertam Valley. Soil erosion is the major concern of problem since the occurrence in the study area keeps increasing. Deforestation and land clearing for the purpose of agricultural, urbanization and infrastructure development in surrounding area of the dam caused the widespread of soil erosion over the land surface. Excessive sediment deposited in the Ringlet Reservoir affects the storage and service life of the reservoir.

From the analysis, the area in the direction of South-East of the dam recorded the high rates of soil loss and sedimentation. Moreover, the area towards North of the dam, near Habu Catchment, also recorded the critical potential of soil loss and sedimentation to the dam. Since the area is in the critical potential of soil loss, any other development shall be avoided to reduce the rate of sedimentation generation in the reservoir. The rate of sediment yield increased from 4,715.50 m3/ year in 2013 to 6,510.61 m3/year in 2014 with the 38% of increase rates. This number is expected to increase for time being as agriculture activities and deforestation actively occurred. The result compared to the research conducted by Teh (2011) resulting the total sedimentation yield in reservoir dam increased by 278% in just 2 years period of time for 2013 while in 2011, the predicted sediment yield is 1,251.23 m3/year. [10]

By looking at the trends of the sedimentation accumulation, if there are no mitigations actions to be taken, the probability of the dam to be closed is high since the dam is constructed for the purpose of hydroelectric generation dam. The high sedimentation rate causes problem to the hydro power plant since sediment always rise up to the intake level and loss its gross storage and need to be remove every year to deepen the intake area. [12] Tenaga Nasional Berhad (TNB) has spent over RM180 million over the past five years to cleaning up the Ringlet reservoir and the Sultan Abu Bakar Hydroelectric Dam from sediment, silt and garbage. Since the cost for the maintenance of the dam rapidly rising, the operation of the dam could be handy with the limited output gained. The silting event of Ringlet Reservoir suggests that the reservoirs always operate at full supply level with no storage capacity in the future. The absence of storage for flood control may oblige the authorities to keep the Sultan Abu Bakar dam spillway gates open. It is known that the flooding is likely to increase due to intense deforestation in the watershed. [13]. The high level of sediment accumulation in the dam will also raise the concern for the stability of the dam while it is uncertain that the dam could resist the forces exerted by a combination of high sediment load and high intensity of flood level.

Sultan Abu Bakar Dam used to be a popular recreational attraction in Cameron Highland with the recreational and tourism activities purposes. However, recently those attraction is not in the state it used to have because of the sedimentation and silting problem cause the scenery of the lake become gloomy. With the addition of the rising activities of deforestation, the temperature of the highlands keep increasing causing the tourist attraction of the land is in downpour state. For this approach, the most practical and effective sedimentation concentration and removal points along the streams are identified in the Ringlet End and Habu End of the Ringlet Reservoir, where inactive flow conditions encourage sediments to settle naturally. The natural sedimentation will be enhanced by the check dams to concentrate the sediments and increase the natural trap efficiency. The concentrated sediments would have to be dredged and removed periodically where this would reduce the sediment loads into the Ringlet Reservoir. In the long term practical, a control source strategy should be implemented, based on modifications to the current land use practices especially in illegal deforestation, to encourage soil conservation and minimize soil loss from the contributing catchments, reducing sediment loads into the streams and reservoir. [13]

REFERENCES

[1] Norshamirra, H. *et al*. (2016). *Formulation of an Integrated Community Based Disaster Management for Hydroelectric facilities : The Malaysia Case. International Conference on Advances in Renewable Energy and Technologies (ICARET 2016)*, 12032(June 2013). https://doi.org/10.1088/1755-1315/32/1/012032

[2] Mustafa, D. and Wrathall, D. (2011). *Indus Basin Floods of 2010: Souring of a Faustian Bargain?* Water Alternative, 4(1), 72-85.

[3] Nor, M., Mohamed, B., & Julien, P. Y. (2012). *Challenge in Running Hydropower as Source of Clean Energy : Ringlet Reservoir, Cameron Highlands Case Study*, 2012(June 2016), 8–10.

[4] Huggett, R. J. (2007). *Fundamentals of Geomorphology*. United States of America: Taylor & Francis.

[5] Tirén, S. (2010). *Lineament Interpretation: Short Review and Methodology*, 1–42.

[6] Shahzad, F., Mahmood, S.A. & Gloaguen, R. (2009). *Drainage network and lineament analysis: An approach for Potwar Plateau (Northern Pakistan)*. Journal of Mountain Science.

[7] DID. (2010). *Guideline For Erosion And Sediment Control Plan*. Ministry of Natural Resources and Environment Malaysia.

[8] Gregory, L. Morris & Jiahua, Fan (1998). Reservoir Sediment Handbook. United States of America: McGraw Hill.

[9] Wischmeier, W.a. (1978). *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning*. United States of America: Department of Agriculture.

[10] Teh, S. H. (2011). *Soil Erosion Modeling using Rusle and Gis on Cameron Highlands, Malaysia for Hydropower Development*. Iceland: RES-The School for Renewable Energy Science.
[11] The Star Online. (2005) Retrieved from http://www.thestar.com.my on March, 9 2017.
[12] Zaini, H., Seh, D.R. & Ahmad, S. (2011) Vertical Profile of C, N, P, K and Radionuclides in Soil Collected from Highland Tea Plantation Areas. Selangor: Universiti Teknologi MARA.
[13] Tenaga National Berhad Research. (2009). *A Study on the Effectiveness of Check Dams to Reduce River Sedimentation in Cameron Highlands*.

Plastic Waste Aggregate for Partial Replacement of Natural Aggregate in Asphaltic Concrete Wearing 20 (ACW20) in Hot Mix Asphalt (HMA)

Ahmad Kamal Akram Md Uzir, Md. Maniruzzaman A. Aziz

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

mzaman@utm.my

Keywords: Plastic bottle (PET), bitumen, plastic coating, environment, replacement, recycle.

ABSTRACT. One of the thrust areas of today's research is disposal of plastic waste and pavement defects are running almost parallel. In order to solve the problem of pot holes, rutting, stripping and other defects of pavements which are time consuming, costly for paving roads and flow of traffic become disruption; an overlay of asphaltic concrete mix is the method to resolve it. It will not only strengthen the construction of road work but also improve the road life span as well as will help to enhance the environment by utilizing the use of the innovative technology. Generally, bitumen is used as binder in road construction due to its viscoelastic behavior. Waste plastic pieces can modify the binding properties of bitumen by blending both which it can be applied for construction purpose. Waste plastic coated conventional aggregate can improve road strength and life span. It enhances the binding properties, stability, density and more resistant to water through this modifying bitumen mix and plastic aggregates. Thus, durability of roads is increasing with increased resistance to wear and tear of road. It can pass through 2-3mm sieve when the clean plastic waste is cut into a size that required. By using an inexpensive polymer such as waste polymers, it can reduce the cost of constructions and more convenient as one of the way on using it. Determining the effect of incorporating waste plastic bottles (Polyethylene Terephthalate (PET)) on the engineering properties of Hot Mix Asphalt (HMA) mixture is the main purpose of this research. Various percentages of PET (0, 5, 10, 15 and 20%) being used as partial replacement of natural aggregate.The softening point waste plastic which is mainly used for packing are made up of polyethylene (PE), polypropylene (PP) and polystyrene (PS), varies between 110 and 140 degree Celsius and no toxic gases creates during softening. However, when it is spraying over the hot aggregate at 160 degree Celsius, the softening plastics have a tendency to create film-like structure over the aggregate. In this study, the result obtained from the Marshall Test shows the maximum PET aggregate can be added was 15% replacement of natural aggregates. The finding also indicates the Resilient Modulus Test of PET aggregate modified mixture tend to decrease compared to the natural aggregate.

INTRODUCTION

There a number of different points of view for the re-use of wastes. The re-use of waste will save and maintain the natural resources and will decrease the pollutant to our environment. Poly-ethylene Terephthalate (PET) wastes was one of the important issues. One of the method to reduce of utilization landfills and pollution is to re-use it in other industries. Hence, the use of PET in partial replacement of natural aggregate in HMA have been investigated and compared with control samples.

Problem Statement

Nowadays, plastic waste including the various waste materials, plastic, and municipal solid waste are the issues of global environment. The proper use of disposed plastics is needed to find in the short time. It means that the load bearing capacities of the roads need to increase simultaneously with the increasing of the road traffic volume[1].The disposing plastic wastes at the landfill are unsafe since toxic chemicals leach out into the soil, and underground water and pollute the water bodies as plastic is non-biodegradable in nature which it remains in environment for several years [2].

Instead of primary (virgin), the used of secondary (recycled) materials help to ease landfill pressure and the demand of extraction being reduced. The sustainable construction is being practiced through this way of getting the road industry. Therefore, the partial replacement to bitumen in the flexible pavement by using plastic waste is considered in the present work on dealing with this problem [3].

Objectives

The objectives of this study are:

1. To determine the Marshall Properties incorporating PET aggregate in HMA.

2. To determine the optimum percentage of PET aggregate as partial replacement in ACW20 with 60-70 bitumen grade for better performance in HMA.

Scope of Study

This research is carried out to study the utilizing of plastic waste (PET) as partial replacement of the natural aggregate so that the PET can be implemented in road construction. The ACW20 aggregate has been selected as the gradation limit for partial replacement of natural aggregate in HMA. The sample is preparing and mixing based on the percentage of PET used 0, 5, 10, 15 and 20% by weight of natural aggregate. The blending sample is loaded in Marshall Compaction equipment and tested in Marshall Apparatus. Resilient Modulus test also being tested by applying compressive loads with haversine waveform. The load was applied in the vertical diametric plane of a cylindrical specimen. The experimental result have shown in Figure 2.

LITERATURE REVIEW

The soft-drink container or plastic bottle was selected as PET material because this material is tough (so that it can withstand when it drops), cheap, clarity, durability, excellent odor resistance and low permeability to carbon dioxide. It also is used as high performance films such as photographic, magnetic tape, electrical insulation and decorative film laminates. In concrete technology, the performance of PET as an aggregate replacement had been done in. For example, in Algeria, Boutemeur et al., the usage of PET have been investigated as aggregate for concrete[4].

The comparison of stiffness and fatigue properties of PET modified mixes with conventional asphalt has been studied by Moghaddam et al. in 2012. The fatigue life of modified mix containing 1% PET (by weight of aggregate) was twice than that of unmodified mix based on their report but the stiffness of modified mix was lower compared to conventional mix. Especially the results of stiffness test warranted the proper deformation characteristics of modified mixes at heavy loading conditions[5].

METHODOLOGY

The main objective of the research is to determine the Marshall Properties incorporating PET aggregate in HMA and to determine the optimum percentage of PET aggregate as partial replacement in ACW20 with 60-70 bitumen grade for better performance in HMA. This research methodology consists of: sample preparation, ACW20 mix, Marshall Test and Resilient Modulus Test. Those are needed in order to get the parameter for analysis.

Material Used

The materials used in this study include the use of bitumen grade 60-70, aggregate and PET aggregate. The ACW20 aggregate used is from the quarry of Malaysia Rock Product (MRP) Ulu Choh, Johor Bahru Malaysia. For the PET aggregate, the PET bottle is collected and cooked it with oil to change its shape into the size of conventional aggregate. Table 1 shows the properties of 60-70 bitumen grade.

Table 1: Properties of the 60-70 bitumen grade

Properties	*60-70 penetration grade*
Penetration at 25^{0}C (0.1mm)	62.70
Softening point (^{0}C)	53.00
Specific gravity (g/cc)	1.03

Sample Preparation

In this study, a total of fifteen (15) samples for each bitumen content 4.5, 5.0, 5.5, 6.0 and 6.5 were prepared to determine the optimum bitumen content (OBC) using Marshall Method. Three control samples of ACW20 mixture for verification of optimum bitumen content. The total weight of aggregate for each sample was about 1200g. PET aggregate (size 14mm, 10mm, and 5mm) were formed by melting it in a pan with oil to shape it. About nine samples of ACW20 with different content of PET aggregate (5, 10, 15 and 20%) were added directly using OBC. Three samples of ACW20 also being packed for the verification of maximum PET aggregate that can be added. The temperature for mixing and compacting was at 160^{0}C and 130^{0}C. All samples were compacted using Marshall Compactor for 75 blows per side. After that, the conventional samples and modified samples with added PET aggregate were tested for determine Marshall Properties and the optimum percentage of PET aggregate need to be used

Marshall Test

The properties of the mix include stability and flow were carried out by using Marshall Test according to ASTM D 1559 and also as a method of mix design according to the specifications that were stated in the Asphalt Institute Manual (1979) and the American Association of State Highway and Transportation Officials (AASHTO). The main purpose of this test is to find the optimum bitumen content based on the parameters provided. Table 2 shows the testing and analysis of the parameters according to JKR (JKR/SPJ/1988) for Marshall Test.

Table 2: Marshall Test Parameter (JKR/SPJ/1988)

Parameter	*Wearing Course*	*Binder Course*
Stability, S	> 500 kg = 4905 N	>450 kg= 4414.5 N
Flow, F	>2.0 mm	>2.0 mm
Stiffness, S/F	>250 kg/mm= 2452.5 N/mm	>225 kg/mm=2207.25 N/mm
Air voids in total mix (VTM)	3.0-5.0 %	3.0-7.0 %
Voids in aggregate filled with bitumen	75-85 %	65-80 %

Resilient Modulus Test

This test was conducted to determine the performance of the modified samples with PET aggregate when subjected to a load. This modulus value will determine the strength of the modified samples when subjected to such load as a load applied by the vehicle on it. Other parameters also being considered as to control the variables of this test such as temperature, load pulse, the number of pulses, pulse repetition period, maximum stress and the Poisson ratio standardized for all samples. The samples that need to be tested must be conditioning for 3 hours in the chamber at a temperature of 25^0C and 40^0C as to obtain a uniform temperature of the sample. The Resilient Modulus test procedure is according to the ASTM D 4123.

RESULTS AND DISCUSSION

The results obtained were to analyze the characteristics of ACW20 according to the laboratory test which has been carried out. Based on Marshall Test, the data analysis and the result was compared to the specification stated by the JKR. A comparison of the characteristics of ACW20 between conventional mixture and modified mixture were analyzed based on the density, stability, flow, stiffness, voids in the total mix, and voids filled with bitumen. In addition, Resilient Modulus test was conducted to determine the stiffness modulus of natural aggregate and PET aggregate.

Aggregate Gradation of ACW20

The aggregate was sieved accordance to the JKR specification. The following table shows the gradation limit and selected gradation for ACW20 mixture. Table 4 shows the grading and the calculation of aggregates used in this study.

Table 3: Aggregate Gradation for ACW20 JKR/SPJ/1988

Sieve Size (mm)	% Passing	% Average	% Retained	Mass Passing (g)	Mass Retained (g)
28.0	100	100	0	1200	0
20.0	76-100	88	12	1056	144
14.0	64-89	76.5	11.5	918	138
10.0	56-81	68.5	8	822	96
5.0	46-71	58.5	10	702	120
3.35	32-58	45	13.5	540	162
1.18	20-42	31	14	372	168
0.425	12-28	20	11	240	132
0.150	6-16	11	9	132	108
0.075	4-8	6	5	72	60
Pan	0	0	6	0	72

Determination of Optimum Bitumen Content (OBC).

The test results for Marshall Test were summarized in Table 5 in determining the optimum bitumen content. Based on the data obtained, the graph of the Marshall parameter such as density, stability, flow, voids total mix (VTM), and voids filled with bitumen (VFB) were plotted to obtain the optimum bitumen content of the ACW20 mixtures. The optimum bitumen content was determined by averaging the value of maximum bulk density, 4% of voids in the total mix (VTM), 75% for voids filled with bitumen (VFB), and the value of a maximum of stability. Based on the calculation, the optimum bitumen content obtained is 5.16%. After getting the OBC, three samples were prepared by using the bitumen content of OBC for the verification of the specification. Table 6 shows the results data for sample verification. According to the Table 6, the verification samples met the specifications stated in JKR/SPJ/1988. Thus, the bitumen content of 5.16% was used for modified samples added with PET aggregate. Table 5 and Table 6 shows the summary of Marshall Test for obtaining the Optimum Bitumen Content (OBC) and the results for OBC verification sample of ACW20.

Table 5: Summary for Marshall Properties

Bitumen Content (%)	Density(g/cc)	VFB (%)	VTM (%)	Stability (N)	Flow (mm)	Stiffness (N/mm)
4.5	2.303	64.5	5.5	22 257	3.92	5673.1
5.0	2.352	80.1	2.8	19 751	4.54	4347.3
5.5	2.355	86.1	2.0	17 403	6.19	2810.0
6.0	2.371	95.4	0.7	13 289	6.80	1955.3
6.5	2.365	98.4	0.2	10 676	7.50	1424.1

Table 6: Result for control sample of ACW20

Marshall Properties	JKR/SPJ/ 1988 Requirements	Control Sample
Stability	>500 kg= 4905 N	13533 N
Flow	>2.0 mm	4.67 mm
Stiffness	>250 kg/mm =2452.5 N/mm	2897.80 N/mm
VTM	3.0-5.0%	3.08 %
VFB	75-85%	82.66 %
Density	-	2.219 g/cc

Determination of ACW20 Added with PET Aggregate Using OBC

PET aggregates samples were prepared based on the optimum bitumen content 5.16% which are obtained from the analysis of 15 controlled samples. The Marshall Mix design was conducted by adding the PET aggregate of 5, 10, 15 and 20% by weight of natural aggregate. Table 7 shows the summary results for Marshall Test. From the result, there were only 5 and 10% of PET aggregate replacement were fulfilled the JKR/SPJ/1988 requirements. Meanwhile, 15% plastic aggregate replacement didn't fulfill the specifications and 20% was failed to design due to over-added PET which makes the sample failed to fully compact.Table 7 shows the summary of Marshall Test for added plastic content by percentage. Figure 1 shows the Marshall Properties results when PET aggregate was used as partial replacement of natural aggregate.

Table 7: Summary of Marshall Test result for added PET aggregate by percentage.

Marshall Properties	JKR/SPJ/1988 Requirements	PET Aggregate Samples					
		5%	Result	10%	Result	15%	Result
Stability	>500kg=4905 N	13 475 N	Passed	10456 N	Passed	6791 N	Passed
Flow	>2.0 mm	4.54 mm	Passed	5.61 mm	Passed	5.77 mm	Passed
Stiffness	>250 kg/mm= 2452.5 N/mm	2784.1 N/mm	Passed	2647.2 N/mm	Passed	1177.9 N/mm	Failed
VTM	3.0-5.0%	4.8 %	Passed	5.0 %	Passed	10.8 %	Failed
VFB	75-85%	77.6 %	Passed	75.2 %	Passed	57.5 %	Failed
Density	-	2.193 g/cc	Passed	2.058 g/cc	Passed	1.946 g/cc	Passed

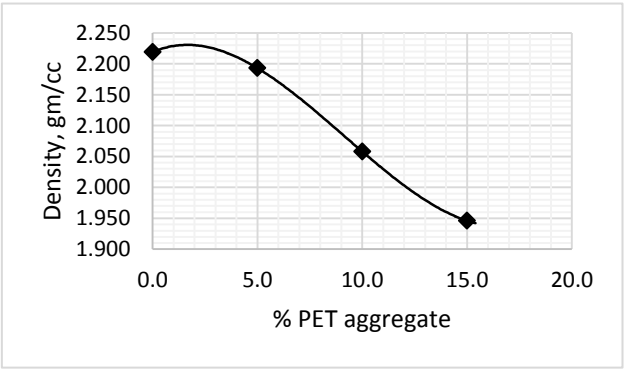


Figure 1(a): Density vs % PET aggregate

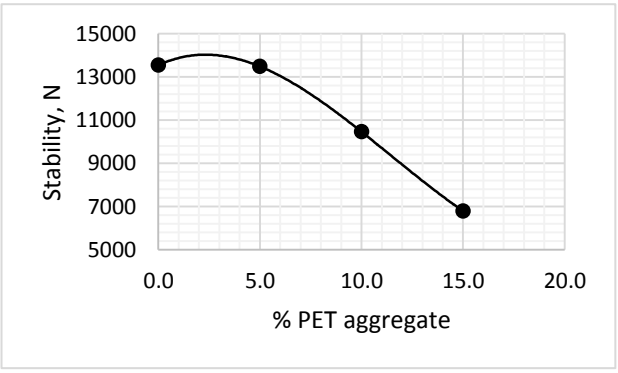


Figure 1(b): Stability vs % PET aggregate

Figure 1(c): VFB vs % PET aggregate

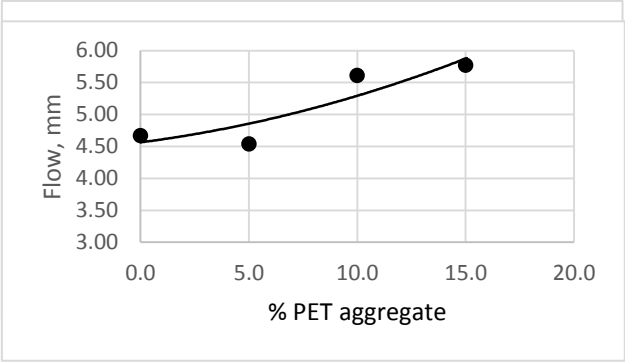


Figure 1(d): VTM vs % PET aggregate

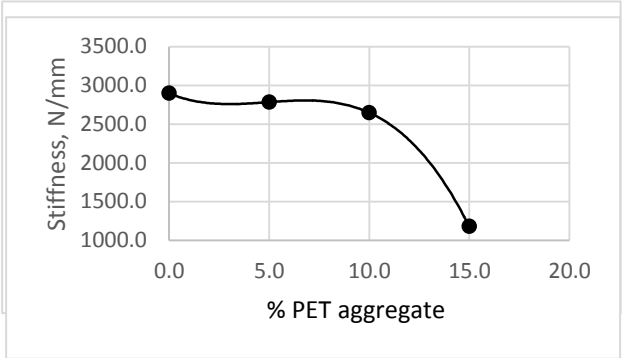


Figure 1(e): Flow vs % PET aggregate

Figure 1(f): Stiffness vs % PET aggregate

Figure 1: Marshall Properties

Density. The density of the modified sample mixes was lower than the controlled sample when PET aggregate was added. The replacement of various percentage PET aggregate by weight shows the results in a reduction in the bulk density of the compacted mixes.

Stability. The stability of the sample is decreased when the percentage PET aggregate increases. The maximum stability obtained for modified sample mixes with 15% PET aggregate and lower than the control mixes. With increasing PET aggregate, the stability becomes decrease due to low friction between the PET granules.

Flow. The flow of modified sample is increased when the percentage of PET aggregate is increased. In mixes with higher PET, the effect of lower friction between PET granules exceeds the good adhesion between the bitumen and PET granules.

Resilient Modulus Analysis

Resilient modulus test was conducted for 5 and 10% added PET aggregate replacement under the temperature of 25^{0}C and 40^{0}C as to show how the replacement of PET aggregate influence traffic loading. Based on the results of these tests clearly, shows the modulus value decreased simultaneously with the increasing of the PET aggregate. It shows the sample with PET aggregate has lower elasticity compared to the controlled samples. When the PET aggregate increased, it will result the bitumen film thickness becomes reduce, reducing of aggregate-bitumen adhesion and the tensile strength of the modified sample. At 25^{0}C, the Resilient Modulus results show the sample with added 5% PET aggregate has a low value of stiffness modulus (1508 MPa) compared to the control sample (1848 MPa) which was the modulus decreased by 18% from the control sample. Meanwhile at 40^{0}C, the modulus decreased by 18% from the control sample. This has shown that the use of PET aggregate will decrease the stiffness of the sample. Figure 2 shows the result of Resilient Modulus Test at temperature 25^{0}C and 40^{0}C.

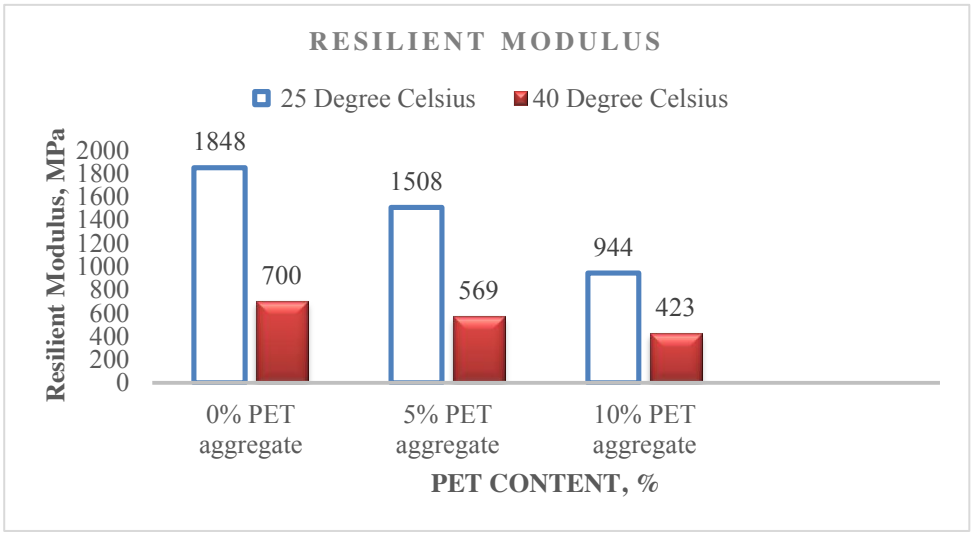


Figure 2: Resilient Modulus Result for 25^{0}C and 40^{0}C

CONCLUSION

From the analysis and discussion, there are some conclusions as follows:

1. The Marshall properties only can incorporate with 5% and 10% of PET aggregate as partial replacement of natural aggregate in HMA, and 15% PET have mixed results.

2. The Resilient Modulus for PET blended mix is decreasing with the increase in PET aggregates, and has the lower stiffness than control sample.

REFERENCES

[1] Rajasekaran, S., Vasudevan, R., & Paulraj, S. (2013). Reuse of Waste Plastics Coated Aggregates-Bitumen Mix Composite for Road Application—Green Method. *American Journal of Engineering and Research*, *2*, 1-13.

[2] Chavan, A. J. (2013). Use of plastic waste in flexible pavements. *International Journal of Application or Innovation in Engineering and Management*, *2*(4), 540-552.

[3] Huang, Y., Bird, R. N., & Heidrich, O. (2007). A review of the use of recycled solid waste materials in asphalt pavements. *Resources, Conservation and Recycling*, *52*(1), 58-73.

[4] Rahman, W. M. N. W. A., & Wahab, A. F. A. (2013). Green pavement using recycled polyethylene terephthalate (PET) as partial fine aggregate replacement in modified asphalt. *Procedia Engineering*, *53*, 124-128.

[5] Modarres, A., & Hamedi, H. (2014). Effect of waste plastic bottles on the stiffness and fatigue properties of modified asphalt mixes. *Materials & Design*, *61*, 8-15.

Physical Properties of Modified Bitumen Using Palm Oil Fuel Ash (POFA)

Amira Maryam binti Md Sukaimi, Haryati binti Yaacob

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

haryatiyaacob@utm.my

Keywords: POFA; POFA Modified Bitumen; Penetration Test; Softening Point Test.

ABSTRACT. Malaysia is having rapid economic development in recent years, and this has placed high performance demand on its highway infrastructure. The increased in number of traffic has led to severe pavement deterioration. Due to this, better and stronger pavement materials are needed in order to cater the increasing number of axle loading. Palm oil fuel ash (POFA) has been used as a modifier to improve the properties of bitumen. POFA is a biomass that had pozzolanic properties (siliceous material). POFA is the ash from burning mesocarp of the fruitlet of the palm oil fruits. By using POFA in bitumen, it will promote sustainability and lesser landfill to dump this waste. The objective of this research is to evaluate the effect of grinding time of POFA and to evaluate the effect of different percentage of POFA towards physical properties in POFA modified bitumen. A few sets of samples of POFA modified bitumen at different grinding time and POFA content have been prepared and tested with penetration test and softening point test. From the result, it shows that grinding time and POFA content does not influence the physical performance of the bitumen.

INTRODUCTION

Deterioration of road structure happened more these days due to the increased of traffic volume and low efficiency on the road maintenance process. To increase on the long term durability of the pavement, the bituminous layers should be improved with regard to performance properties, such as resistance to permanent deformation, fatigue, and aging. The application and usage of bitumen modifier in order to increase the quality of the bitumen, hence to increase the pavement performance could be the solution.

Problem Statement

POFA is by-product of palm oil mills in the form of ash resulting from the burning of fibers and shell of palm fruits in boiler mills. These has been disposed as waste thus polluting the environment and affecting the health of surrounding community. POFA when properly processed has shown to be effective as construction materials and readily meet the design specifications in concrete [1]. Roads reach the terminal end of their service life earlier than their design life [2]. According to Road Transport Department this is due to increasing vehicle at road year-on-year. Increasing number relate to heavier commercial vehicles [2] and heavier vehicular loads [3].

Objectives

The objectives of this study are:

1. To evaluate the effect of grinding time of POFA in POFA modified bitumen.

2. To evaluate the effect of different percentage of POFA towards physical properties in POFA modified bitumen.

Scope of Study

This study only focused on the physical properties of POFA modified bitumen, which does not involved any mixture performance. Several laboratory physical testing on binder performance were conducted at different grinding time and different percentage of POFA.

LITERATURE REVIEW

The American Society for Testing and Materials (ASTM) defines bitumen as a class of black color (solid, semisolid or viscous) cementatious substance which occurs in nature or obtains in petroleum processing, composed principally of high molecular weight hydrocarbons of which bitumen. Bitumen has certain weaknesses whereby it can ‘flow’ at high temperature, leading to pavement rutting, and it can fracture at low temperature, leading to pavement cracking, the adhesion between bitumen and aggregate breaks down under a combination of ageing and water attack. The inherent weaknesses of bitumen cause highway maintenance works quite difficult and expensive. Bitumen is shear-sensitive and hence making it prone to shove and rut at higher temperatures. On the other hand, at low temperatures it becomes brittle and tends to undergo fracture cracking and potholing. Cracking is generally reduced by making the asphalt binder either less viscous or less temperature susceptible. Reducing low temperature viscosity leads to soft bitumen and the

mechanical properties of mixture deteriorate. According to [4], modified bitumen is produced for the purpose of altering and improving the properties of the bitumen to enhance the long term performance of pavements. While the modifier may affect many properties, the majority of modifiers are used in an attempt to reduce temperature dependency, oxidative hardening of bitumen, and the moisture susceptibility of asphalt mixtures.

The National Centre for Asphalt Technology (NCAT), as quoted by King et. al. has published reasons for the use of bitumen modification which are it can soften binders and mixtures at high temperature to minimize rutting and reduce the detrimental effects of load induced moisture damages, improve fatigue resistance, particularly in environments where higher strains are imposed on the asphalt concrete mixture, improve bitumen-aggregate bonding to reduce stripping, improve pavement durability with an accompanying net reduction in life cycle costs, and improve overall performance as viewed by the highway user. POFA content is most feasible to be used as bitumen modifier and based on thepenetration test result of 5% OPFA-MB (Oil Palm Fuel Ash bitumen modifier) can be graded as binder penetration 60-70 PEN [6] because it is resistant to high temperature rutting and resistant to low temperature thermal cracking.

METHODOLOGY

The purpose of this study was to observe the effect of adding palm oil fuel ash in bitumen and act as bitumen modifier by using different percentages of POFA. The process and procedures on how this study was carried out will be explained in detail. Flowchart of the study is shown as in Figure 1 below.

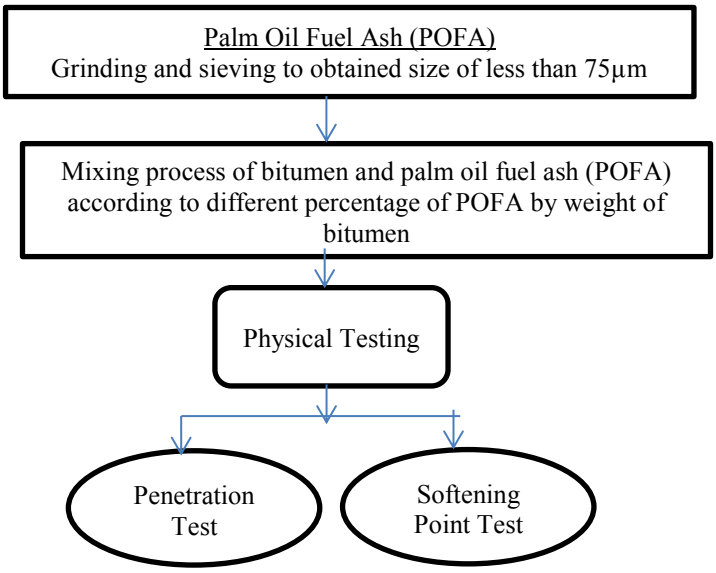


Figure 1: Flowchart of research plan

The testing procedures were based on The American Society for Testing and Material (ASTM) standard guide for laboratory works. POFA had been grinded by using Los Angeles Abbrasion machine at different griding hours (1, 2, 3, and 4 hours). POFA modified bitumen were prepared by mixing different percentage of POFA (at different grinding hour) into the bitumen of 80-100 PEN. Physical tests, namely Penetration tests (ASTM D5/D5M-2013 standard) and softening point test (ASTM D36/D36M-2014 standard) had been conducted on each samples.

Sieve Analysis

Sieve analysis had been carried out in order to get the POFA that passing 75µm size. These POFA were then grinded at different grinding hours (1, 2, 3, and 4 hours).

Process of mixing Bitumen and POFA

Four different percentages of POFA has been choosed based on previous findings by [7], namely 0% (control), 5%, 6%, and 7% by the total weight of the bitumen content. POFA has been mixed with bitumen at a mixing temperature of 160ºC, for about of 60 minutes and stirring speed of 800rpm. This mixing process was based on [7]. This procedure was conducted so that POFA was thoroughly mixed with bitumen. POFA was poured into 400g of bitumen at room temperature before mixing. For every 10 g of bitumen, an equal amount of POFA was added then the mixtures of bitumen-POFA were heated in the oven just to make it as liquid later then place it to above of hot plate under the drive shaft rotor propeller of the mixer at the speed of 800rpm.

Physical Test on POFA as bitumen modifier

Penetration Test

Penetration test is an empirical test used to measure the consistency (hardness) of bitumen. The penetration of a bituminous material may be defined as the distance in tenths of millimeter that a standard needle vertically penetrates a sample of the material under known conditions of loading, time, and temperature. The penetration test is used for evaluating the consistency of a bituminous material. The grade of semisolid and solid bituminous material is usually designated by the penetration.

Softening Point

Softening point test is an empirical test used to measure the consistency of bitumen. Softening point is the temperature at which a substance attains a particular degree of softness under specified conditions of test. As temperature increases, bitumen changes from solid to liquid, and the stiffness of bitumen will reduce accordingly. Before mixing with aggregate to form road pavement, bitumen must be soft enough in order for it to be handled easily during pavement work. The most common method to soften the bitumen is by heating it. Higher grade bitumen has higher softening temperature compare to lower grade bitumen. The ring and ball test is commonly used to determine the softening temperature of bitumen.

Penetration Index

The penetration index represents a quantitative measure of the response bitumen to variation in temperature. Knowing the penetration index of particular bitumen, it is possible to predict its behavior in an application. Therefore, bitumen with high penetration numbers (called "soft") are used for cold climtes while binders with low penetration numbers (called "hard") are used for warm climates. All bitumen display thermoplastic properties i.e. they become softer when heated and harden when cooled. This method can be used to predict high-temperature shear resistance of the paving mixture.

RESULTS AND DISCUSSION

Penetration Test

Figure 2 shows the results of penetration test for different percentages of POFA which are 5%, 6% and 7%. On each percentage, the effect of grinding time has been further looked. Generally from this Figure 2, it can be seen that by grinding the POFA from 1-4 hour, the penetration values has decreased slightly showing that the specimens has become harder. However for 5% and 6 % of POFA, with the increased of grinding period from 1 to 3 hour the penetration has shown an increment from 7.24 to 8.20 and 7.01 to 8.37 respectively. When the grinding time increased to 4 hours, the penetration has reduced back to 7.21 and 7.43 respectively. In addition, Anova test has been run in order to determine the significant of effect of grinding time towards penetration value. Table 1 shows ANOVA of Penetration Value by different percentage of POFA to grinding hour, the P value are higher than the P critical which is 0.05

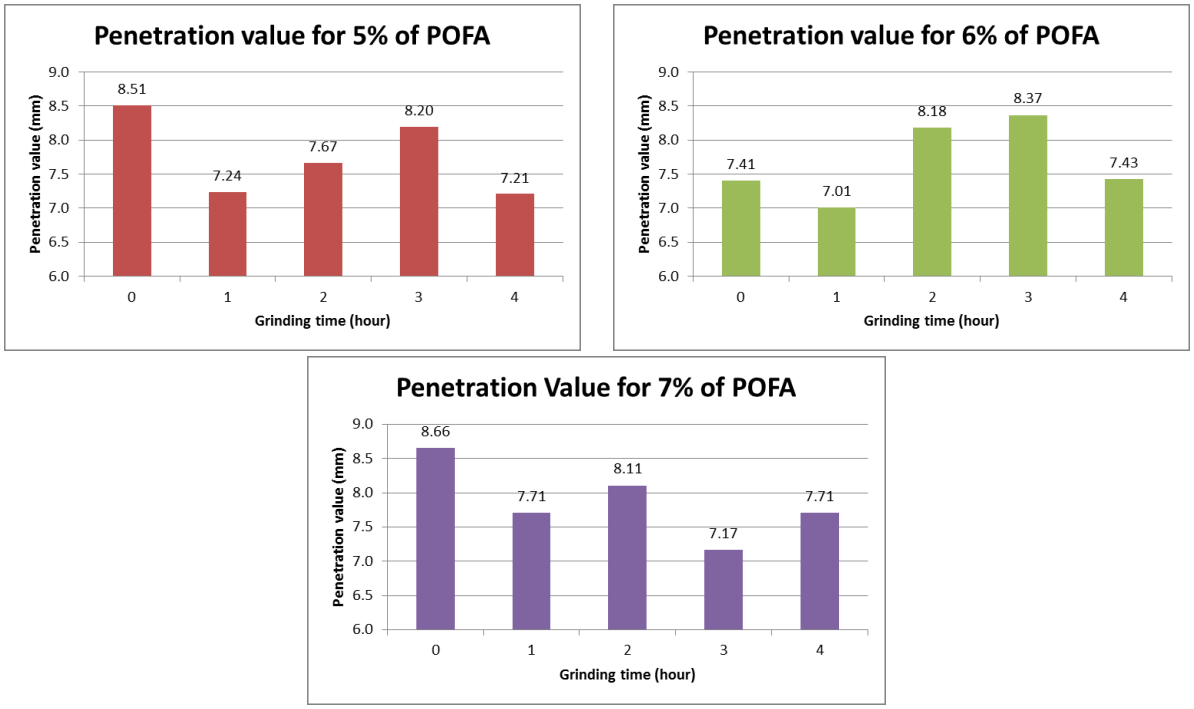


Figure 2: Graph of penetration value based on different percentage of POFA

Table 1: ANOVA of Penetration Value by different percentage of POFA to grinding hour

Variables	Pvalue	Pcrit	Condition	Significant	Remarks
5% of POFA	0.36	0.05	P>Pcrit	No	Reject the hypothesis
6% of POFA	0.68	0.05	P>Pcrit	No	Reject the hypothesis
7% of POFA	0.19	0.05	P>Pcrit	No	Reject the hypothesis

Figure 3 shows the results of the penetration test for different grinding times which are 0 hour, 1 hour, 2 hours, 3 hours and 4 hours. At each grinding time, the effect of different percentage of POFA has been further looked and compared with control sample (without POFA). In general, the graphs show inconsistent result with some samples of POFA modified bitumen having higher penetration value compared to the control sample. Further analysis has been done by using POFA, where from Table 2 it shows that ANOVA results of each percentages of POFA at certain grinding hour are not having the significant change with each other. The hypothesis is rejected because the samples with different percentages of POFA modified bitumen are not having significant effect with the controlled sample.

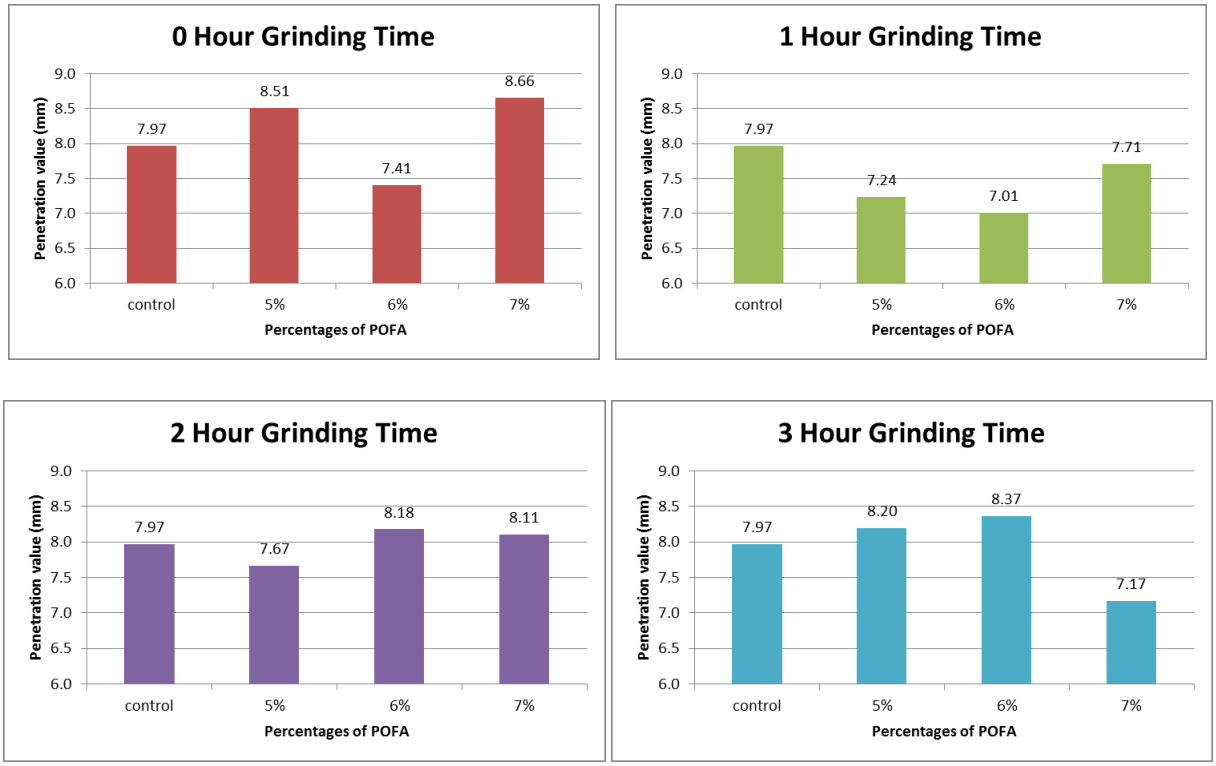


Figure 3: Graph of penetration value based on different grinding time on POFA

Table 2: ANOVA of Penetration Value by grinding period to different percentage of POFA

Variables	Pvalue	Pcrit	Condition	Significant	Remarks
5% of POFA	0.36	0.05	P>Pcrit	No	Reject the hypothesis
6% of POFA	0.68	0.05	P>Pcrit	No	Reject the hypothesis
7% of POFA	0.19	0.05	P>Pcrit	No	Reject the hypothesis

Softening Point Test

Figure 4 shows the results of softening point for different percentages of POFA which are 5%, 6% and 7%. For each percentage of POFA the effect of grinding time (0, 1, 2, 3 and 4 hours) towards softening point value has been further looked. At 5% POFA, it was recorded that softening point value increased from 39^{0}C to 41.5^{0}C with and increased of grinding time from 0 to 3 hours. When the grinding time increased to 4 hours, the softening point has reduced back to 40^{0}C. However, for 6% of POFA, the temperature maintains at 40^{0}C except at 3 hours grinding time, the value increased to 42^{0}C and reduced back to 40^{0}C at 4 hours grinding time. For 7% POFA, inconsistent value has been recorded. Further investifation has been done by conducting the ANOVA test analysis. Based on Table 3 ANOVA of Softening Point Value by different percentage of POFA to grinding hour it shows all of the grinding times are not have the significant change. The hypothesis on the different grinding time will give higher temperature on softening point test is rejected because it has no significance value at every temperature.

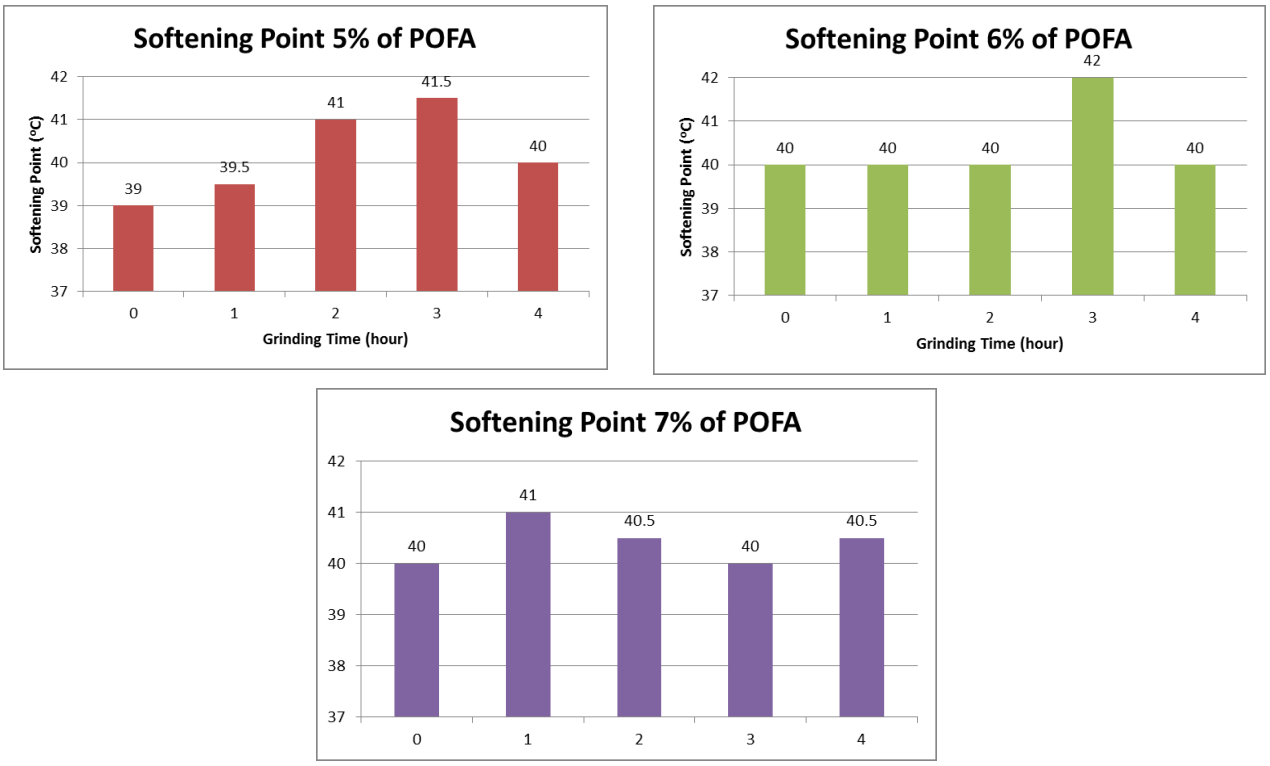
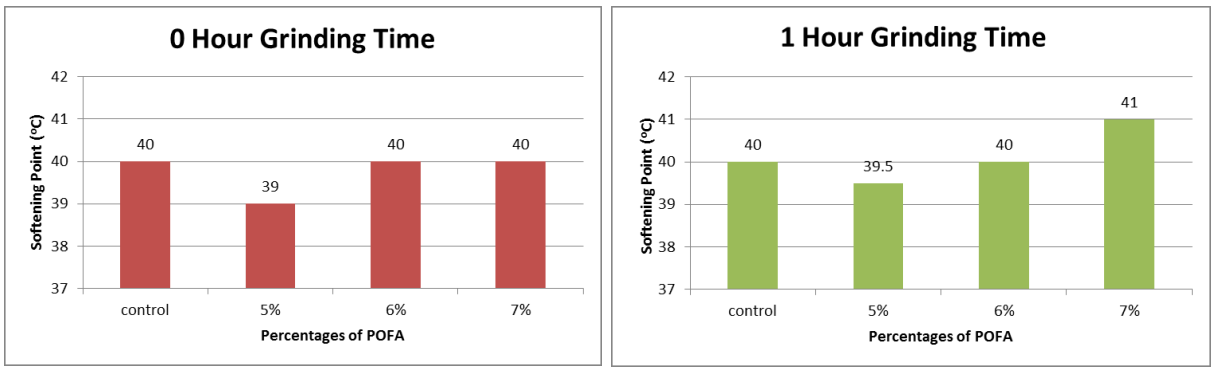


Figure 4: Graph of softening point value based on different percentage of POFA

Table 3: ANOVA of Softening Point Value by different percentage of POFA to grinding hour

Variables	Pvalue	Pcrit	Condition	Significant	Remarks
0 hour of grinding	0.89	0.05	P>Pcrit	No	Reject the hypothesis
1 hour of grinding	0.62	0.05	P>Pcrit	No	Reject the hypothesis
2 hour of grinding	0.61	0.05	P>Pcrit	No	Reject the hypothesis
3 hour of grinding	0.61	0.05	P>Pcrit	No	Reject the hypothesis

Figure 4 shows the results of the softening point test at different percentage of POFA. For 1, 3 and 4 hours grinding time, there is a slight increased of softening point values with an increased of POFA content, compared to control sample. However, similar to penetration test, inconsistent results were found in softening point values in certain cases. Therefore ANOVA test has been done in order to summarize the significant of POFA towards softening point value. From Table 4 ANOVA of Softening Point Value by grinding period to different percentage of it can be seen that all of the percentages have P value that are bigger than the P critical so that shows it has no significant effect. Therefore, the hypothesis was rejected because each of the percentages of POFA was not significance to controlled sample.



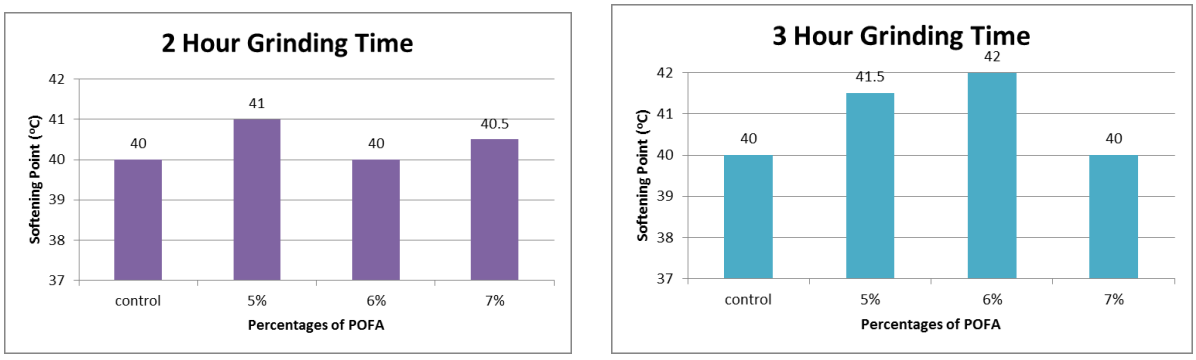


Figure 5: Graph of softening point value based on different grinding time on POFA

Table 4: ANOVA of Softening Point Value by grinding period to different percentage of POFA

Variables	Pvalue	Pcrit	Condition	Significant	Remarks
5% of POFA	0.24	0.05	P>Pcrit	No	Reject the hypothesis
6% of POFA	0.43	0.05	P>Pcrit	No	Reject the hypothesis
7% of POFA	0.70	0.05	P>Pcrit	No	Reject the hypothesis

Penetration Index

Based on Table 5, the penetration index value was found to be within the range of -3.1 to -2. Penetration index less than -2, means that the bitumen has high temperature susectibility . Asphalt mixture with this high temperature susceptibility bitumen will face with permananet deformation at high temperature, and it will easily crack at low temperature.

Table 4: ANOVA of Softening Point Value by grinding period to different percentage of POFA

Penetration Index	Grinding time (hour)					
	Control sample	0	1	2	3	4
5%	-2.6	-3.1	-3	-2.5	-2.20	-3
6%		-3.00	-2.97	-2.50	-2.00	-3.05
7%		-2.50	-3.00	-2.8	-3.00	-3.00

CONCLUSION

From the results obtained from the analysis in this study, the following conclusions can be drawn:

(i) Based on ANOVA analysis, for all conditions the p value was found to be more than 0.05. It can be concluding here that the grinding time doesn't contribute to any siginificant effect towards penetration and softening point result.

(ii) Based on ANOVA analysis, for all conditions the p value was also found to be more than 0.05. These results explain that by adding POFA it does not improve the properties of POFA modified bitumen compared to control sample (80-100 PEN). This result is contradicted with findings by [9]. This might be due to the uneven mix between POFA and bitumen at mixing stage. The POFA might not be fully dissolved during the mixing stage.

REFERENCES

[1] Mannan, M. A., & Ganapathy, C. (2004). Concrete from an agricultural waste-oil palm shell (OPS). *Building and Environment*, *39*(4), 441-448.

[2] Judin AK (2011) Road Infrastructure development in Malaysia. Public Work Department Malaysia, Kuala Lumpur.

[3] Abdullah, A. S., Karim, M. R., & Yamanaka, H. (2010). Prospect of using weigh-in-motion based system for enhancing vehicle weight enforcement-A case study of Malaysian roads. In *17th ITS World CongressITS JapanITS AmericaERTICO*.

[4] McGennis, R. B., Shuler, S., & Bahia, H. U. (1994). *BACKGROUND OF SUPERPAVE ASPHALT BINDER TEST METHODS. FINAL REPORT* (No. FHWA-SA-94-069).

[5] Department of Environtmental, Ministry of Science, Technology and the Environment Malaysia, (1999). Industrial Process and the Environment of Crude Palm Oil Industry. Printed by Aslita Sdn. Bhd. Kuala Lumpur, December 1999.

[6] King, G., King, H., Pavlovich, R.D.,Epps, A.L., and Kandhal, P.S. (1999).Additives in Asphalt. *Journal of Association of Asphalt Paving Technology*. Vol. 68, pp 32-69.Salihuddin Radin Sumadi (1993). *Relationship between Engineering Properties and Microstructural Characteristics of Mortar containing Agricultural Ash*. Doctor Philosophy, Universiti Teknologi Malaysia

[7] Rusbintardjo, G. (2011). *Bitumen modification using oil palm fruit ash for stone mastic asphalt* (Doctoral dissertation, Universiti Teknologi Malaysia).

Trip Attraction Rate of Secondary Schools in Taman Universiti

Aqilah binti Ahmad Sedek, Che Ros bin Ismail

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

cheros@utm.my

Keywords: Trip ttraction Rate, Macroscopic Model, Microscopic Model, Regression Analysis

ABSTRACT. Trip attraction was used to describe trips generated by activities at the non-home end of trips. In this study, secondary school enrolment was considered as the non-home end of trips for the trip attraction rate. The objectives of the study were to identify the parameters that affect the rate of the trip attraction of the secondary schools and to establish the relationship between the school trip rate of secondary schools and the selected parameters of the school. Microscopic and macroscopic approaches were used in this study and regression analysis was applied to determine the relationship of all the selected parameters. The parameters or the independent variables used for regression analysis were number of employees, total floor area of the schools, and the average distance to school. The outcome of this study showed that the number of employees was the strong parameters that affected the trip attraction rate of secondary schools in Taman Universiti, Skudai.

INTRODUCTION

Trip generation is the first stage in the classical first generation aggregate demand models. Trip generation aims at predicting the total number of trips generated and attracted to each zone of the study area. Travel demand forecasting remained significant tools in the analysis of transportation planning and policies. The results from the analysis were very useful for decision making in transportation planning for any design of system and facility to develop the plan. The main factors affecting personal trip production included income, vehicle ownership, house hold structure and family size. The personal trip attraction, on the other hand, was influenced by factors such as roofed space available for industrial, commercial and other services.

Problem Statement

Over time, the changes of land use affects the travel demand in an area. These relationships were the basis for trip generation and must be reviewed, if necessary, in the continuing process of travel demand forecasting. School travel demand trends often follow a synchronized rise and fall graphs during term and off-term times, favorable and ambient conditions [1]. Through careful studies of data on students' travel behaviour, relationship can be developed to predict how many trips students will make. These relationships are the basis for trip generation and must be reviewed, if necessary, in the continuing process of travel demand forecasting. As the first step in the travel demand forecasting, trip generation was very important to ensure that the transportation plan will respond to the area's transportation needs.

Objectives

The objectives of this study were:

1. To identify the independent variables that significantly affects the trip attraction rate of secondary schools in Taman Universiti;

2. To establish the relationship between the school trip rates of secondary schools (Y), number of employees (X_1), average distance to school (X_2) and total floor space area (X_3) by using regression analysis in macroscopic model.

Scope of Study

The main focus of the study was to determine the trip attraction rate of two secondary schools in Taman Universiti. Taman Universiti has two secondary schools which are Sekolah Menengah Kebangsaan Taman Universiti (SMKTU) and Sekolah Menengah Kebangsaan Taman Universiti 2 (SMKTU 2). The elements in the scope of study included the rate of trip attraction, microscopic and macroscopic models, and some physical feature of the secondary schools.

Microscopic and macroscopic models were used to determine the trip attraction rate of the secondary schools in Taman Universiti. Microscopic approach concerned on the individual parts or units from a whole system where these individual parts were used to determine the equation for the whole system as one. Whereas the macroscopic model approaches the system as one unit with some variables which included dependent and independent variables. In this study the physical features of each secondary which was of the regression analysis where they were treated as independent variables to determine the trip attraction rate of the secondary schools by using macroscopic approach.

LITERATURE REVIEW

Trip generation was an idea and a concept of observing the behavior of travel in an area of interest. Basically, it perceived the travels made by people or delivering goods to a certain places and location. This also involved what type of activities were done in that place of a certain time. The results from the analysis were very useful for decision making in transportation planning for any design of system and facility to develop the plan. Since trip generation was the first step of the "four-step modeling process" errors made here may be carried through the entire process. Trip generation models were used to predict the number of trip ends generated by an individual household or a traffic analysis zone for a specified time period such as a 24-hour day or a peak period. There were two types of trip ends associated with each trip, productions and attractions, and separate models typically are used to predict each of these types.

Trip generation was the process by which the measure of activity on a land was converted into number of trips. The number of trips generated by a school was actually quite different from the trips generated by a supermarket eventhough both the school and supermarket uses the same amount of space on the land. The relationship between land use and activity was important as it will be used in the future to analyze the pattern of the land use and traffic produced for future development planning. According to [4], the main factors affecting personal trip production included income, vehicle ownership, house hold structure and family size. In addition factors like value of land, residential density and accessibility were also considered for modeling at zonal levels. The personal trip attraction, on the other hand, was influenced by factors such as roofed space available for industrial, commercial and other services. At the zonal level zonal employment and accessibility were also used. The number of trips produced by a household was highly dependent on family size and household structure.

Trip attraction was basically used to describe trips generated by activities at the non-home end of trips and it was made by analyzing the urban activities that attracted a journey or a trip. Trip attraction models served primarily to scale the subsequent destination choice (trip distribution) problem. Essentially, these models provided a measure of relative attractiveness for various trip purposes as a function of socio-economic and demographic (and sometimes land use) variables [5]. These attractions of various locations depended on the character of location and amount of activities taking place in a zone. Attractions were typically a function of socioeconomic activity - households, employment by type, school enrollment - but can also be land-use based (e.g. gross floor area for manufacturing, retail, government, open space, etc.).

Early trip generation models were commonly developed by regression analysis because of its power and simplicity. The independent variables in such models were usually zonal averages of the various factors of influence. Trip generation equations developed by regression are still used by some planning agencies, more commonly for attraction models than for production models. This was because only zonal averages of trip attracting characteristics were usually available since most travel surveys did not survey at trip destinations. Obtaining more detailed data for individual attraction zones required a survey of trip attractors, such as a workplace survey.

[7] stated that an historical overview of the development of traffic flow models was proposed in the form of a model tree where the model tree showed the genealogy of four families which were the fundamental relation, microscopic, mesoscopic and macroscopic models. The modern traffic model research was known by two types which were macroscopic and microscopic models. A study of trip generation which came from an overall perspective was called macroscopic models whereas microscopic models took into account the details in the overall perspective and its interaction within it. Both type of models have active research and modern, state-of-art equations and traffic phenomenon (such as traffic jams) can be studied with both types of models [6].

METHODOLOGY

In order to achieve the objectives of the study, the population data of the students are obtained. The data collection methodology consisted of site selection, a process for collecting context variables, and a strategy that captured total trip attraction rate.

The first phase was the initial study about the basics and fundamental of trip generation and regression analysis. The basic concept of these fundamental knowledge was obtained and understood for applying them in the study. Literature review was done for better understanding of the trip attraction definition and the use of regression analysis to discuss the outcome of the study. Problem statement was also identified to determine the objectives of the study and also the scope of the study. The first phase was crucial in order to use them in analyzing data.

Phase two of the study included surveying and collecting data of Taman Universiti population, land use, and others and data for secondary schools in Taman Universiti. This was done by site visit or comparing the data with local plan or authority to obtain the condition of the schools. Data collection included the data of students and employees entering each school during peak hour for every 15 minute interval.

The data was analyzed in the third phase by using the multiple regression analysis in macroscopic model. The regression analysis was done by using Microsoft Excel in which the relationship between each parameter was determined. Hence, trip attraction rate of school trip generation was determined for Taman Universiti by expressing it in an equation.

Microscopic Model Analysis
The model was based on the equation below where the rate of trip attraction of the whole school was expressed in terms of the weighted sum of the trip attraction rate of each form in the school.

$$Y_T = w_1 a_1 + w_2 a_2 + \ldots + w_n a_n$$

Where:
w_1, w_2, w_n – Weights of each form in the school
a_1, a_2, a_n – School trip per day of each form in the school

As for estimation of the weights, weighted sum was the product of trip attraction rate for each form in the school and its weight. It was assumed that the weights for those trip attraction rates have to be assigned such that the weighted sum was equal to the trip attraction rate of the whole school [3]. The sum of the weights gave an indication of the amount of trip chaining [3]. Trip chaining means that there was an overlapping of attraction to each form. Since each students were assigned to their individual form, there was no overlapping attraction among them. If there was no overlapping, then the total trip attraction rate of the school was equal to the sum of each form's rate of trip attraction. This means that the value of w_i was equals to one (1). Whereas the trip attraction rate of each form were obtained from the students' attendance or enrollment from each school for individual form.

Macroscopic Model Analysis
The macroscopic approach determined the trip attraction rate of the school by evaluating the school as a whole or as one unit of analysis. The macroscopic model that was proposed here have the considered variables of total area of each secondary school, total number of students and total number of employees. These factors were chosen based on the literature review.

$$Y = A_1X_1 + A_2X_2 + A_3X_3$$

Y - Trip attraction rate of secondary school
A_n - Coefficients of the regression model

The total floor area of the schools influenced the number of students enrolled which affected the total trip attraction rate of each secondary school. In this study, regression analysis was used to determine the trip attraction rate and the relationship between the parameters and the trip attraction. The regression model considered the number of employees, average distance from home to each secondary school and total floor area of secondary schools.

Regression Analysis
Regression analysis gave the functional relationship between two or more variables. The coefficients of the regression equation were obtained by doing regression analysis by using Microsoft Excel. In this study, the trip attraction rate was the dependent variable, Y and the independent variables were the attributes and features of the secondary schools. According to [2], in order to attain a more significant and valid outcome of the study, the constant in the regression equation was eliminated where sometimes the value will turn out to be too big or too small and has a negative value. The value can be eliminated before applying the data in regression analysis. The coefficient of determination which also known as the R-squared (R^2) measured the goodness of fit of the regression model. In other words, it measured the relationship between the dependent variable and the independent variables. The R-squared values ranged between 0 and 1 where values that were near to 1 are considered as good fit whereas values closer to 0 was a poor fit. In transportation planning, R^2 score over 0.3 is often acceptable [2].

ANALYSIS AND FINDINGS
This chapter discusses the results of the analysis and the discussion. The main objectives of this study were to determine the secondary school trip attraction rate in Taman Universiti, Skudai using microscopic and macroscopic approach and also to determine the relationship between the numbers of attraction to the secondary schools and the physical features of the schools through regression analysis in the macroscopic model.

Microscopic Model
The average percentage of attendance per day in each school was also collected to calculate the average daily number of students and employees who attended the school was then applied to the equation of microscopic model. The data of number of students and employees obtained were used alongside the percentage value to get the actual number which was shown in Table 1 below. The general equation that was generated from regression analysis was as follows:

$$Y_T = a_1w_1 + a_2w_2 + a_3w_3 + \ldots + a_nw_n$$

Where:
Y_T – Total school trip per day
w_1, w_2, w_n – Weights of each form in the school
a_1, a_2, a_n – School trip per day of each form in the school

Table 1: Average Attendance per day of Secondary Schools in Taman Universiti

	SMKTU		SMKTU 2		Average School Trip (a_n)
	Percentage (%)	No. of Attendance	Percentage (%)	No. of Attendance	
Peralihan	90.41	45	90.54	22	34
Form 1	92.01	374	94.30	260	504
Form 2	88.89	402	93.74	226	314
Form 3	93.48	430	93.78	161	296
Form 4	94.96	508	90.80	213	361
Form 5	95.82	486	91.93	197	342
Employees	98.53	186	96.21	107	147

The percentage of the students and employees' attendance were obtained from the school administration and the number of the attendance was calculated by using the total number of the school occupants and the attendance percentage. The school trip was determined by taking the average value between the two schools. Using the data tabulated in Table 1 above, the average school trip is used in the equation for macroscopic model. The equation obtained is the following.

$$Y_T = 34w_1 + 504w_2 + 314w_3 + 296w_4 + 361w_5 + 342w_6 + 147w_7$$

It was discussed that the sum of the weights gives an indication of the amount of trip chaining (Kikuchi *et al*, 2004). Trip chaining means that there was an overlapping of attraction to each form. Since each students and employees were assigned to their individual category, there was no overlapping attraction among them. If there was no overlapping, then the total trip attraction rate of the school was equal to the sum of each form's rate of trip attraction. This means that the value of w_i was equal to one (1).

Macroscopic Model

The trip attraction rate of the secondary school was estimated from the macroscopic model. Unlike microscopic model, it was based in the features of the whole secondary school. The independent variables, which were the physical features of the school, were the number of employees (X_1), average distance to school (X_2) and total floor area of the school (X_3). The dependent variable in the macroscopic model was the trip attraction rate for the secondary school (Y).

While table 2 below shows the trip attraction rate of secondary school and the values of the variables stated to be used in the regression analysis for the two secondary schools in Taman Universiti. The worksheet from ITE provided space to record the number of people which includes students and staff entered the school during each 15-minute interval. While the area of the school was collected from the school administration itself.

Table 2: Trip Attraction Rate (15-minute interval)

		Trip Attraction Rate (15min), Y	Employees, X_1	Average Distance to School (m), X_2	Total Floor Area (m^2), X_3
SMKTU	A.M	301	117	1313	14167
	P.M	197	72	1313	14167
SMKTU 2	A.M	130	59	1425	11376
	P.M	111	52	1425	11376

The trip attraction rate was calculated based on the recorded school trip done during peak hour. One in the morning and the other one was in the evening. The average school trip for every 15-minute interval was calculated as shown in Table 2 above. The general equation that will be generated from regression analysis is as follows:

$$Y = A_1X_1 + A_2X_2 + A_3X_3$$

Where:

Y - School trip per day

A_n - Coefficients of the regression model

X_n - Independent variables

The independent variables included the number of employees in the secondary school, average distance from the nearest area in Taman Universiti to respective secondary school, and the total floor area of the school.

Regression Analysis

In this study, two forms of equations were generated from the regression analysis in the macroscopic model. The first one, the trip attraction rate was generated with the average distance of the closest areas in Taman Universiti to the schools and number of staff as independent variables while the second one, the trip attraction was generated with the

school total floor area as the independent variable. Table 3 and Table 4 below summarized the important regression results for the estimated trip generation model.

Table 3: Regression Coefficient and Test Result of Every Parameter (First Form)

	Coefficient	Standard Error	t Stat	P-value
A_1	2.894	0.294	9.861	0.010
A_2	-0.024	0.017	-1.418	0.292
Multiple R			0.99833	
R Square			0.99666	
Significance F			0.04092	

Based on the data tabulated in Table 3 above, the coefficient for the first form of equation was highlighted in the first column. The equation obtained using the regression analysis was the following.

$$Y = 2.894X_1 - 0.024X_2 \qquad R^2 = 0.99666$$

The coefficient of X_1 and X_2 (the number of staff and employees in the secondary school and the average distance to school, respectively) have positive values. This meant that these two variables positively affected the number of trip attraction rate. The goodness of fit. The R^2 value is about 0.99666 or 99.67% indicated a very strong relationship and correlation, and this meant that as the number of employees increases, the trip attraction rate also increases since the trip attraction to a school was mandatory.

The significance F value indicates the probability that the regression output could have been obtained by chance, which in other words, smaller value of significance F confirmed the validity of the regression output. Based on Table 3, the significance F value is 0.04092, so there is a small chance of 4.09% that the output was a chance occurrence.

From this equation, the number of employees (or teachers) was found to be the most significant in determining the number of trip attraction rate. In other words, the number of employees was essential for school enrollment. It was logical to predict the school enrollment based on the number of employees since parents are most likely look for the quality of teaching and service.

In the second form of model, the result of the regression analysis was as tabulated in Table 4 below. The coefficients of the second form equation were also highlighted in the first column. The equation obtained using the regression analysis was the following.

Table 4: Regression Coefficient and Test Result of Every Parameter (Second Form)

	Coefficient	Standard Error	t Stat	P-value
A_3	0.0148	0.0026	5.7144	0.0106
Multiple R			0.95701	
R Square			0.91586	
Significance F			0.02929	

$$Y = 0.0462X_3 \qquad R^2 = 0.91586$$

The coefficient of X_3 which was the total floor area of the secondary school has a positive value. This meant that the variable affected positively on the dependent variable which was the school trip per day. It explained that as the total floor area of the school increases, the school trip per day also increases. This made sense because the larger the space, the more room there was to be occupied by the employees and other staff and also for the classrooms. This can also be further supported by the first form of model where the number of employees affected positively on the dependent variable.

The R^2 value of the model of 0.91586 indicated that the independent variable entered into the model gave about 91.57% of the variation in the dependent variable. It was concluded that it has quite strong relationship and correlation. Based on Table 4, the significance F value is 0.02929, so there is a chance of 2.93% that the output was a chance occurrence. However, when all the independent variables were put together into one form of equation, the result was the following.

$$Y = 2.315X_1 - 0.088X_2 + 0.010X_3 \qquad R^2 = 0.99999$$

As shown in the equation above, the R^2 value was 0.9999 which was almost too unrealistic. The results obtained will most unlikely be a reliable model because a too unrealistic value affected the significance and accuracy of the outcome. Thus, it was more suitable to do a separate form of equation in the macroscopic model.

CONCLUSION

In this study, trip attraction was used to estimate the school trip of secondary schools in Taman Universiti. Taman Universiti in Skudai was chosen because of its continuously increasing demand in properties. The objectives were to identify the independent variables that significantly affected the trip attraction rate of secondary schools in Taman Universiti and to establish the relationship between the school trip rate of secondary schools and the selected independent variables.The chosen independent variables were number of employees (X_1), average distance to school (X_2) and total floor area of the school (X_3).

Two forms of equation was formed separately to avoid multi-collinearity between the selected independent variables. In the first form which included the number of employees and average distance to school, it showed a high value of R^2. The R^2 value of indicated there was a strong relationship between the parameters and school trip rate. While the second form of equation included the total floor area of school and from the equation, it showed that the R^2 gave strong relationship and correlation with a positive value of coefficient. However, when all the independent variables were essembled together into one equation, the value of R^2 was too unrealistic because the value was almost one (1). Thus, it was only fitting that two separate forms were applied to avoid unsignificance and low accuracy in the results.

In this study, only three independent variables were used to predict the school trip in Taman Universiti. However, in further studies, other variables can be considered such as household income and school accessibility. To make sure the model used is valid, a new set of data should be collected to ensure a more accurate trip attraction result. A similar study can also be conducted but with different land use, for example, trip attraction for shopping complex or polyclinics. Other than that, instead of using Microsoft Excel for regression analysis, SPSS can be considered for future studies.

REFERENCES

[1] Ben-Edigbe, J., & Rahman, R. (2010). Multivariate school travel demand regression based on trip attractions. *World Acad. Sci. Engg. Technol*, *66*, 1695-1699.

[2] Hassan Moussa & Essam H. Almasri. (2013). *Development of a Trip Generation Model for Gaza City*. Islamic University, Gaza.

[3] Kikuchi, S., Felsen, M., Mangalpally, S., & Gupta, A. (2004). Trip Attraction Rates of Shopping Centers in Northern New Castle County, Delaware. *Delaware Center for Transportation*.

[4] Mathew, T. V., & Rao, K. V. K. (2007). Introduction to transportation engineering (pp. 3–8).

[5] Mcnally, M. G. (2007). The Four Step Model. In *Handbook of Transport Modeling* (2nd ed.). California, Irvine

[6] Miller, S. (2011). Traffic Modeling. Falthead Valley Community College, Montana.Mathew T. V., & Krishna Rao K. V. (2007). *Introduction to Transportation Engineering*. National Programme on Technology Enhanced Learning.

[7] Wageningen-kessels, F. Van, Lint, H. Van, Vuik, K., & Hoogendoorn, S. (2015). Genealogy of Traffic Flow Models. *EURO Journal on Transportation and Logistics*, 445–473. https://doi.org/10.1007/s13676-014-0045-5

Analysis of Road Traffic Accident: A Case Study at Senai-Desaru Expressway

Fatin Sakinah Binti Mohd Mahali, Nordiana Binti Mashrof

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

mnordiana@utm.my

Keywords: Accident Trends, Road Accident, Traffic Safety Management, Expressway, Countermeasure

Abstract. This paper present the case study of accident analysis at Senai-Desaru Expressway in Malaysia based on two years period data which consists year 2014 and 2015. General, accident is an unfortunate incident that happens unexpectedly and unintentionally, typically resulting in damage or injury. The statistic of road accident in Malaysia is increase throught the year. As the number of population increase, the number of accidents also increase. The main objective of case study is to identify the crash pattern at Senai-Desaru Expressway and determine the hazardous location at Senai-Desaru Expressway. This is because Senai-Desaru Expressway can categories as non busy road but accidents still occured at this expressway. Futhermore, the case study is to determine the contributor factor of the accident and select the suitable countermeasure to reduce the number of accident. This case study is focused at Ulu Tiram Interchange to Cahaya Baru Interchange. The total length of the segment is 20.7 km. The traffic accident data were stored into Microsoft Excel Spreadsheet for checking process to ensure no redundant data. All these data were used to develop collision diagram using AutoCAD. Then, in selection of hazardous location the segment was divided into small segment by using blackspot treatment which is 400m length. Then for ranked segment, Average Crash Frequency and Equivalent Property Damage Only (EPDO) was used. The data is ranked in descending order to identify hazardous segment to further the analysis. As result, the most hazardous segment from Ulu Tiram Interchange until Cahaya Baru Interchange are segment 64 and segment 83 which in the Average Crash Frequency and EPDO are in top of five. In addition, the contributor factor was identified and countermeasure have been selected.

Introduction

According to National Institute of Statistic and Economic Studies, a road accident refers to any accident involving at least one road vehicle, occurring on a road open to public circulation and in which at least one person is injured or killed. Road accidents occur for various reasons. The causes of road traffic accidents are multi-factorial and can be divided broadly into three major factors including driver, vehicle and roadway factors [1]. Among the factors that contribute to road traffic accidents are the influences of alcohol, drive over the speed limit, gender, the age of the car, weather condition and so on. Those factors can cause death and the chances to continue living is less. Furthermore, road accidents can effect to the community and national which are it can loss of productivity, damage to public properties, loss of family income and so on [2]. Due to tremendous losses in both economically and socially, associated with traffic accidents, which has led researchers to seek effective measures that aim to reduce accidents [3][4][5][6]. In order to predict and prevent road accident, accident analyses and prediction are the most important issues in terms of traffic safety management. Predicting the risk factors that contribute to road traffic accidents is important in identifying interventions that can reduce the risk associated with those factors.

Problem Statement

Road accident is a real dilemma in these days because it can causes much killing and great loss in souls. The statistic of road accident is increase throughout the year. The number of population in Malaysia is increased with 7.89% in 5 years as well as the number of vehicles registered with 30.28% in 5 years. The number of road crashes is increase from 476,196 to 489,606 in year 2104 and 2015 respectively. Moreover, the number of road death is increased by 0.48% in year 2014 to 2015. Beside that, the total number of slight injury is decreasing from year 2010 until 2013 but rise in year 2014 [7]. By 2030, crashes that happen in highway are projected to be the 5th leading cause of death in the world. Therefore, Malaysian Government should be worry because road accident will impact to the country such as destroy public property, decrease productivity and so on. The solution must be produce to overcome this problem and make the user feel ease when they use the roads.

Objectives

The objectives of the study are:

1. To identify crash pattern and to recognize the site condition that related to the pattern at Senai-Desaru Expressway.

2. To determine the rank site and identify the factor that can cause the accident at the Senai-Desaru Expressway.

3. To suggest the countermeasure based on several site that have identified as the most likely to benefit from safety improvement.

Scope of Study

Generally, Malaysia have two categories of roads which are federal roads and state roads. Senai-Desaru Expressway is included in federal roads and was chosen as a location for accident analysis. The total length of Senai Desaru is 77 km, however only the road length of 20.7 km was considered in this study which from Ulu Tiram Interchange to Cahaya Baru Interchange. Two years traffic accident data for both directions were used for developing collision diagram and other analysis such as crash pattern and site condition. In order to understand and prevent crashes, the road length of 20.7 km was divided into 52 segment. These segments were ranked from most likely to least likely using two methods. Only most likely sites were assessed. Suitable countermeasures were suggested to reduce the number of accident. Bearing in mind that condition diagram was not considered in this study due to difficulty in observing real condition at selected sites.

Previous Study

Type Of Crash Road traffic accident also known as traffic collision where a vehicles are collided with other vehicles, pedestrian, animal and other stationary obstruction such as tree, divider and so on. The collision can cause fatal, serious injury, slightly injury or maybe property damage only. There are several common types of road accidents. Among the most type of accidents is run-off-road crash. Run-off-the-road crashes are defined as those involving vehicles that leave the travel lane and encroach onto the shoulder and beyond, and overcorrect, overturn, or hit one or more of any number of fixed or non-fixed objects, or that otherwise result in a harmful event to the vehicle occupants or other persons. Run-off-road crashes in recent times have become a major cause of serious injuries and fatalities in the United States [8]. A study of fatal crashes in the state of Florida primarily in the year 2000 showed that about one-third of the crashes involved running off the road as the first event, and more than 25% of the run-off-the-road crashes involved overcorrection [9]. While, in 2010, rear-end crashes, accounted for 32.2% of all road crashes, lead to 1694 deaths and 476,000 injuries in the US [10]. In the same year, 2691 people died in China because of highway rear-end crashes which account for 40.4% of all highway crashes [11].

Factor of Accident According to the World Health Organization, in year 2020 the road injuries will increase more that 60% and 95% of those victim will be from the low and medium income countries. There are several factors that can increase the risk if someone involved in accident. There are individual factor and contextual factor Some of these factor related to individual level such as excessive speed, consume alcohol and so on. The consumption of alcohol can effect the rick of crash. The effect of alcohol consumotion can be noticed within 10 minutes [12] which can reduce awareness and concentration, slower reaction times and increase their confident. In addition, drink driving is the main contributor factor or road fatal in South Australia [13]. Speed is a contributing factor in up to 30% of all fatal crashes [14]. Most of driver love to drive with high speed. It is because they like to challenge their self and also they want to arrive destination faster. However, the impact of high speed is greater. When the speed is higher, the risk of crash become greater and the probability of serious injury is higher. In contextual factors, there are factors that can cause road accident which are road condition, weather condition and also age of vehicle. For the road conditions, engineer has an important role to reducing the crash risk for motor vehicles, due both to the inclusion of safety features such as median barriers, and also the messages that roads send to drivers about their environment through signage and traffic control. Beside the road condition, weather condition can be one of importance factor to cause accident happen which are rain, snow, ice, poor lighting condition, and strong winds [2]. Poor weather can increase the lost of control of vehicles as well as potentially increasing stopping distance and visibility. The weather can effect their resistance of the vehicle and they need to lower the speed to make sure the vehicles is under control.

Collision Diagram The purpose of collision diagrams is to graphically represent crashes and identify similar accident patterns at a particular location. They provide information on the type and number of accidents including conditions such as time of day, day of week, climatic conditions, pavement conditions and other information. There are several important parts in collision diagram which are construction of collision diagram, symbols and accident pattern. The collision diagram is sketched for either an intersection or roadway section using standard form such as the sketch need not be to scale, show the path each vehicle involved in the accident with adequate room for information, place a north arrow for orientation and sketch the path of each vehicle to show vehicle maneuver, type of collision and accident severity, light condition, pavement condition and so on. Next is symbols which representing the nature of operation, vehicle or object involved and severity of the accident. Last but not least accident pattern. The visual trends identified in a collision diagram may not reflect a quantitative or statistically reliable assessment of site trends but however they do provide an indication of whether or not patterns exist. If there have multiple sites under consideration, it can be more efficient to develop the collision diagrams with software. In addition, there is one of tools that can used to help develop a better understanding of the areas that may need to be looked at for a particular location.

Impact of Accident Road accident is one of cause death in Malaysia. Road accident can give huge impact to individual, social and national. The most tragic is when the victim is death at the accident location and their part of body is separated. It will give goose bump if other peoples is at the location. Car accident are connected with the psychological effects inspire of ignoring or keeping it hidden. The effect of road accidents are the materialist losses, pain and physical disabilities. But psychological might be effected after the individual experience or being exposed to road accidents [15]. When the violation and car accident increase, the anxiety, fear and tension also increase. Furthermore, person who exposed to car accident, they might suffer from great difficulties in coping with their new style life. Their personality will be changed and their tension will increase and become more depressed. If they continued for a month or more, they need to treat psychologically. Beside that, accident can give impact to the economic. The cost of motor crash that occurred in 2010 is $242 billion and it is equivalent to 1.6 percent of the U.S. Gross Domestic Product [16]. Based on the study before, it show that South Africa needed R32 billion per annum to keep the roads in good condition which is far less than the cost of traffic crashes. This study also show that the effect of road accident not only impacts on the lives of family and friends of those involved, but also affect the cost of proper, adequate health care provision. A study case about roads phobia was conducted in Saudi Arabia. From the study it show that the economic estimated expense for the road injuries was between 1% and 2% of the total annual national income for such countries. This represents a great loss estimated by 65% billion dollars every year which is equal to dual development donation the developing countries take [17]

Methodology

This study was focuses on E22 Senai-Desaru Expressway. E22 Senai-Desaru Expressway is divided into 3 Packages, however the study only focuses on Package 2 which is from Ulu Tiram Interchange until Cahaya Baru Interchange. For the purpose of analyzing, two years period data were obtained which consists of year 2014 and 2015 and any accident occur were recorded for 24 hours.

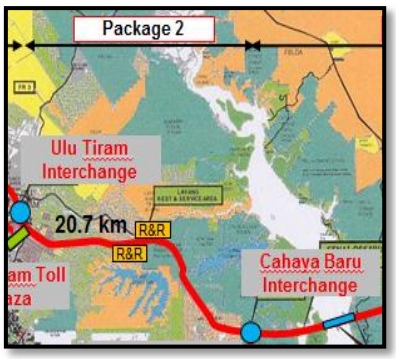


Figure 1: Study lcation of E22 Senai-Desar Expressway

Overall Crash Pattern and Site Condition Traffic accident data which obtained from Senai-Desaru Expressway Berhad were stored into Microsoft Excel Spreadsheet. The data were carefully checked in order to ensure no redundant data and were used to develop collision diagram using AutoCAD. The purpose of collision diagram is to get clear view of accident pattern, type of accident, time of collision and weather condition at Package 2. The length of the segment is about 20.7 km. The data were used to determine crash severity, crash type, pavement condition and light condition and all the results were presented in graphical method for a better understanding.

Selection Hazardous Location Determining hazardous location or high risk location for vehicles crash is very important to reduce risk in these area and the basic strategies for accident reduction through the use of countermeasure is single site/blackspots area.This study was focuses on the 20.7 km segment and it was divided into small segment by 400m of length. In general, there are many methods to determine high risk accident location. However, this study were used average crash frequency method and equivalent property damage only (EPDO) average crash frequency method. These two methods are used to rank segments from most likely to least likely. The most likely segment was considered for further analysis.

Average Crash Frequency. Average crash frequency method is generally to produces a simple ranking of sites according total crashes and according to crash severity. This method was used to select an initial group of sites with high crash frequency for further analysis. There are several steps in order to get simple ranking. Firstly, the crashes for each segment were sum up. Next is rank the location. The segments were ranked in descending order by the number of one or more for an example total crash, fatal, injury and PDO crash.

Equivalent Property Damage Only (EPDO) Average Crash Frequency. The equivalent property damage only (EPDO) average crash frequency method assigns weighting factors to crashes by severity to develop a single combine frequency and severity score per segment. The weighting factor was calculated relative to Property Damage Only (PDO) crashes.

Then, based on the calculated value, segments were ranked from highest to lowest. Monetary cost of accidents is important in calculation of EPDO weights. At present the only available accident costing used in Malaysia is produced in 1985. The categories of accident monetary cost are classified into 3 which are fatal, injury and damage only. Table 3.6 is projected monetary cost of accidents in 1995 and it was used in this study for calculation of EPDO.

Table 1: Monetary cost of accident

Accident Class	1995 ESCAP Costs (RM)
Fatal	207,300
Injury	22,800
Damage-only	390

It begin with calculation of EPDO weights for fatal, injury and PDO crashes. The fatal, injury PDO weight are calculated using Equation 1.0 where the cost of fatal, injury or PDO crash is divided by the cost of PDO crash, respectively

$$Weigthing\ factor\ based\ on\ crash\ severity = \frac{Crash\ cost\ for\ crash\ severity}{Crash\ cost\ for\ PDO\ severity} \qquad \textbf{Eq. 1.0}$$

Then for each segment, the EPDO weight is multiplying with number of fatal, injury and PDO crashes and sum up all the value to get total EPDO score as shown in Equation 2.0

$$Total\ EPDO\ score = (Fatal\ crash\ weight * Number\ of\ fatal\ crashes\ per\ segment) + (Injury\ crash\ weight * Number\ of\ injury\ carsh\ per\ segment) + (PDO\ crash\ weight * Number\ of\ PDO\ crash\ per\ segment) \quad \ldots\ldots \textbf{Eq 2.0}$$

After that, the intersection is ranked in descending order by EPDO score.

Assessment of Hazardous Locations and Selection of Countermeasure Then, after the segments were rank based on the potential for reducing accident frequency by using method above, those segments higher on the list were considered most likely to benefit from countermeasures intended to reduce crash frequency. Segment that higher on the list was selected for further analysis and was evaluated to identify the pattern in crash type, crash severity, the pattern, weather condition or driver behavior were also identified. For crash location can be summarized by using 3 tools which are collision diagram, condition diagrams and crash mapping. However in this study, only collision diagram as a visual tool was used to show the pattern related to crash location. Lastly is countermeasure selection. This step is essential to reduce crash frequency or severity at specific segments. Countermeasure can be defined as a roadway strategy intended to decrease crash frequency or severity or both at the site. Thus, factors contributing to the cause of crashes at the subject segment were identified and countermeasures were selected to address the respective contributing factor.

Results and Discussion

Overall crash pattern and site condition Figure 2.0 shows crash severity in year 2014 and 2015 at E22 Senai-Desaru Expressway. The figure represent the percentages of crash severities which include fatal, injury and PDO. The injury and PDO formed a huge portion of the total number of crash severity. Crash injury contributed the highest number of accidents with 55% of the total crash severities, followed by PDO crash 41% and fatal with 4% of crash. Figure 3.0 shows the type of crash in year 2014 and 2015. The highest rank is runoff with 53 number of vehicle involved and followed by hit-and-animal with 20 accidents. The number of accident for hit objects and sideswipe is equal with 3 accidents and the lowest number of accident is head-on with 1 accident. The highest percentage of pavement condition dry with 72% and for wet pavement is 28%. The day light condition performed huge portion which 73% and followed by night light with 26%.

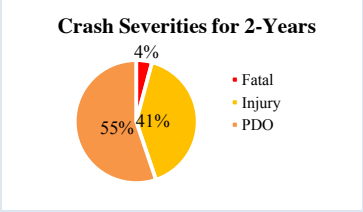


Figure 2: Crash Severity in 2 Year

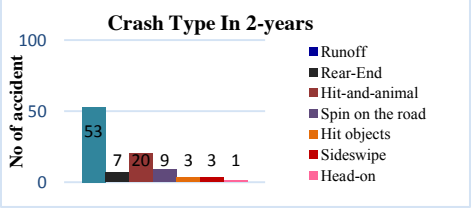


Figure 3: Crash Type in 2 Years

Rank Segment This study has utilized two methods in order to rank 52 segments at Package 2. There are Average Crash Frequency and Equivalent Property Damage Only (EPDO) average crash frequency.

Rank Segment Based on Average Crash Frequency . For ranking segment in Average Crash Frequency, it can be classified into 3 where is ranking by total crashes, fatal and injury and property damage only crash (PDO) The ranking of the segment is ranked in descending order. The result shows the highest of total crash is at segment 64 and 65 with total of 6 accidents for each segment and followed by segment 83 with 5 accidents. For segment 59 and 60 is 4 number of total crash. The highest number of PDO crash is at Segment 64 and 65 with 4 accidents and followed by others segment such as 59, 73 and 99 with 3 accidents. However, the highest number fatal and injury is at Segment 61 and 83 which is 4.

Rank Segment based on EPDO Average Crash Frequency. The result shows the highest of EPDO score is at segment 83 with 707 score. It is because of in the segment 83 have 1 fatal, 3 injury and 1 property damage only (PDO). Then, followed by segment 95 and 97 with 532 EPDO score. The lowest score from the top 5 is segment 64 which is 120 of EPDO score.

Segment Assessment and Countermeasure. The assessment in this study was only considered segment 64 and 83 due to segments that can be deemed *high risk due* to the presence of higher number of accident.

Segment 64. Segment 64 is located at km 25.2 until km 25.6 with a distance is 400 m. The number of total crash in the segment 64 is 6 included injury and property damage only. Figure 4.0 indicated the collision diagram at the segment 64 where it is included the type of crash, type of vehicle, the crash severity, crash time and weather conditions. There are 3 type of crashes happen at segment 64. There are runoff, rear-end and hit-and-animal. It shows that the percentage of runoff in 67% which is highest compare to other crash types as shown in Figure 5. About 75 % of runoff happen in wet condition. The drivers was effected by wet condition which it reduce visibility to see object in front of vehicles and reduced vehicles traction and mobility. In addition, one of factors accident could happen is the driver behavior which drive over speed limit. Most of the collision occurs during at day time as showed in Figure 4.0 and about 80% of it involved runoff collision. Thus there are several countermeasure in order to reduce the number of accident based on the contributed factors. In order to overcome the wet pavement, road drainage need to maintenance and adding more signage such as slippery road. Next is produce more signage which included the speed limit sign and caution dangerous road and so on. In addition, to reduce number of accident at night is improve roadway lighting

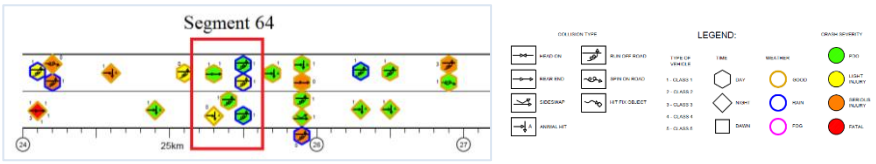


Figure 4: Collision diagram and the legend for Segment 64

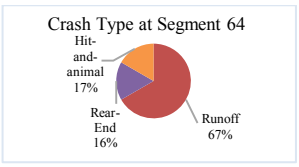


Figure 5: Percentage of crash type

Segment 83.Segment 83 is located at km 32.8 until km 33.2. Figure 6.0 shows the collision diagram at segment 83. The total number of crash involve in the segment is 5 which included runoff and hit-and animals. The highest percentage for type of crash is runoff with 60%.All the runoff crash happen at day time and about 66.67% happen in good condition (dry) and the percentage of injury severity that involved runoff crash is 66.67%. It might due to excessive speed where the driver drive over the speed limit. In addition the stopping distance for a vehicles to react and brakes is longer with greater speed. Based on Figure 6.0, the percentage of hit-and animal is 40% which included fatal and injury only. It might due to lack of light which can reduce the visibility of driver and lack of signage. Thus there are several countermeasure in order to reduce accidents in this segment which is improved the road lighting. The way to improve the road lighting is put it at standard distance which 29 m. In addition, the signage need to improve to makesure the road user be more carefull and more alert.

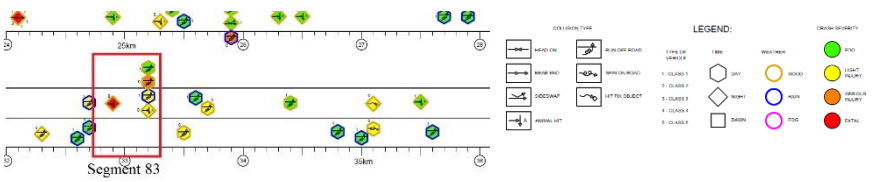


Figure 6: Collision diagram and the legend for Segment 83

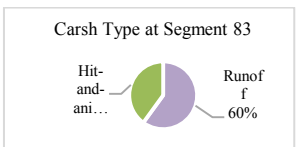


Figure 7: Crash type at Segment 83

CONCLUSION

This case study presents the accident analysis at E22 Senai-Desaru Expressway which from Ulu Tiram Interchange until Cahaya Baru Interchange. The case study are conclude as below:

.

1. Based on the 2 years accident data, the highest type of crash happen is runoff with 55% and followed with hit- and animal. For crash severity, the percentage of fatal is 4% which is lowest compare to injury and PDO. The highest percentage of crash severity is injury with 55%. Most of the accident occurred during good weather (dry) with 72% and about 73% of total number of accident occur during day light condition.
2. Based on the ranked, there are 2 segments that can be identified as blackspot area. There are segment 64 and 83. For segment 64, the contributor factor of accident are excessive speed, less of signage, and less of drainage maintenance. But for segment 83, the contributor factor of the accident is less of signage, excessive speed and poor roadway lighting. During night light condition, the sign visibility is poor and might due to poor lighting.

3. Countermeasure is selected base on contributor factor at segment 64 and segment 83. There are several countermeasure that can apply at those segment which are improving roadway lighting, increase the signage such speed limit signage, animal crossing sign and adequate drainage maintenance.

REFERENCES

[1] Olusina, Jo; Ajanaku, Wa. Spatial Analysis of Accident Spots Using Weighted Severity Index (WSI) and Density-Based Clustering Algorithm. J. Appl. Sci. Environ. Manage. April. 2017 Vol. 21 (2) 397-403

[2] Goodman, Thomas. "Killers On Our Roads: *A Study Aimed At Reducing New Zealand's Road-Toll*". (2010): n. page.

[3] Polat, K., Durduran, S. S. (2012) Automatic determination of traffic accidents based on KMC-based attribute weighting. Neural Computing and Applications. 21 (6). pp. 1271-1279.

[4] Sokolovskij, E., Prentkovskis, O. (2013) Investigating traffic accidents: *the interaction between a motor vehicle and a pedestrian*. *Transport*. 28 (3). pp. 302-312.

[5] Çelik, S., Senger, O. (2014). Risk Factors Affecting Fatal Versus Non-Fatal Road Traffic Accidents: The Case Of Kars Province, Turkey. *International Journal for Traffic and Transport Engineering*. 4 (3). pp. 339-351.

[6] Török, Á. (2015) Analysing the Connection of Hungarian Economy and Traffic Safety. *Periodica Polytechnica Transportation Engineering*. 43 (2). pp. 106-110.

[7] MIROS (Malaysia Institute of Road Safety Research). (2017). *MIROS (Malaysia Institute of Road Safety Research)*.

[8] Uttara Roy and Sunanda Dissanayake (2011). Comparison of Factors Associated with Run-OffRoad and Non-Run-Off Road Crashes in Kansas. *Journal of the Transportation Research Forum*, Vol. 50, No. 2, pp. 69-86.

[9] Spainhour, L. K., D. Brill, J. O. Sobanjo, J. Wekezer, and P. V. Mtenga. Evaluation of Traffic Crash Fatality Causes and Effects: *A Study of Fatal Traffic Crashes in Florida from 1998–2000 Focusing on Heavy Truck Crashes*. *Final Report*. Project No. BD-050. Florida Department of Transportation, Tallahassee, Oct. 2005.

[10] National Highway Traffic Safely Administation, "Traffic Safety Facts 2010: *a compilation of motor vehicle crash data from the Fatality Analysis Reporting System and the General Estimates System*," Tech. Rep.

[11] Ministry of Public Security Traffic Management Bureau, *White Paper on Road Traffic Accidents in China 2010*, P.R.C. Ministry of Public Security, Traffic Management Bureau, Beijing, China, 2011 (Chinese).

[12] Raymond Peck, Michael Gebers, Robert Voas, Eduardo Romano (2008). 'The relationship between blood alcohol concentration (BAC), age, and crash risk'. *Journal of Safety Research, 39:* 311-319

[13] Mylicence.sa.gov.au. (2017). *My Licence - Safe driving tips - Alcohol and drugs*.

[14] Margie Peden, Richard Scurfield, David Sleet, Dinesh Mohan, Adnan A. Hyder, Eva Jarawan and Colin Mathers (2004). *World Report on Road Traffic Injury Prevention*. Geneva, World Health Organisation

[15] Hauschildt ,E. (2002), Acute Stress Disorder Seen in Children, Parents After Traffic Injury. Pediatrics Electronic Pages.

[16] The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)1. (2015). *Annals of Emergency Medicine*, 66(2), pp.194-196.

[17] M. Jabali, Dr. Safia et al. "The Social, Psychological And Economic Impact Of Car Accidents On The Victims' Families". *Journal of Education and Practice* 4.4 (2013): n. pag

Marshall Properties of Asphalt Mixture containing Bottom Ash for Wearing Course

Mira Azmina Mohamad Azan, Norhidayah Abdul Hassan

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

hnorhidayah@utm.my

Keywords: Bottom ash; Wearing course; Asphalt Mixture

Abstract: The use of bottom ash as aggregate replacement can potentially help to strengthen the asphalt concrete pavement to improve the durability and the quality of the surface layer particularly for wearing course. This study investigates the possibility of using bottom ash as fine aggregate replacement based on Marshall Properties of asphalt concrete mix (AC10) compared to conventional mix. In this study, a total of 60 samples were prepared to determine the Marshall properties and optimum bitumen content (OBC) using Marshall Mix design Method. The bottom ash and granite aggregates were blended according to AC10 as specified in JKR specification. Bottom ash was sieved and used to replace 25% (1.18mm), 37% (1.18mm + 0.425mm) and 46% (1.18mm +0.425mm + 0.150 mm) by volume of the aggregate. The laboratory results on Marshall Properties show the increment of bottom ash content has increased the optimum bitumen content and the stability of the mix.

INTRODUCTION

Pavement construction involves consumption of large quantity of construction materials. Some of these materials are available in natural form and some are manufactured. Due to rapid growth of infrastructure, natural construction material such as granite is insufficient and will decrease over time. Therefore, there is a need to find alternative materials particularly for the road constructions. Nowadays, Hot Mix Asphalt (HMA) is commonly used in the asphalt road construction and aggregate is the major component in the HMA. Construction of asphalt pavement uses a lot of aggregate and asphalt as a binder. The way to get the aggregate is either from the blasting or mining process that will disturb the ecosystem. Mining activities may lead to the degradation of land and vegetation [1]. The deforestation that has come from surface mining has long-term effects even when the soil is replaced and trees are planted after mine decommissioning. Therefore, there is a need to find alternative way to replace this conventional aggregate with other material. Bottom ash is seen suitable to be used for the aggregate replacement in order to solve the landfill problems due to lots of these waste produced nowadays in the power plant. Bottom ash is part of the non-combustible residue of combustion in a furnace or incinerator for the generation of electricity. The clinkers fall by themselves into the bottom hopper of coal-burning furnace is referred to bottom ash [2]. Therefore, generating innovation in asphalt pavement by using the bottom ash will introduce alternative construction materials in road construction. This study investigates the characteristics of bottom ash as fine aggregate replacement in asphalt concrete mixture (AC10) as well as performance comparisons between the modified mixture and conventional mixture. This study covers the Marshall Mix design, where the mix was tested based on Marshall Properties requirements for hot mix asphalt as specified in JKR specification. Bitumen that was used in the mix is a penetration grade of 60/70 PEN. Four types of samples were prepared according to the different percentages of bottom ash i.e. 0, 25, 37 and 46% from the total weight of aggregate.

LITERATURE REVIEW

Municipal solid waste incineration (MSWI) ashes have been receiving a growing attention around the world [3]. A study has been conducted on utilization of power plant bottom ash as aggregate in fiber-reinforced cellular concrete (FRCC) [4]. It was found that the bottom ash can be applied as construction material that will improve the compressive strength of FRCC significantly and also reduce the environmental problems related to unused of bottom ash waste. Besides that, bottom ash is also suitable for aggregate replacement either fine or coarse aggregate in concrete mixing [5]. However, it was found that the slump flow of fresh concrete that contain coarse aggregate of bottom ash is slightly decrease and could be because of the characteristic of the bottom ash itself which is porous and high water absorption. Moreover, both fine and coarse bottom ash aggregate had more influence on the flexure strength than compressive strength. Bottom ash also can be used in road-base layer for road construction. Nevertheless, the practice of bottom ash both in gravel-cement bases and in concrete pavements able to do if the particle size distribution was refined and if the resistance towards abrasion was increased. Both could be achieved by mixing the bottom ash with a fraction of natural aggregate. Bottom ash also can be used for the road sub-bases, soil and embankment levelling, landfilling and restoration of the degraded zones [6]. Other than that, Gunalaan (2013) has conducted a study with replacement of 0, 1, 2, 3, 4, 5, and 6% of bottom ash as filler in AC14 [7]. The study concluded that the stability of the samples with coal

bottom ash is higher than conventional. This study also found that, the increase in bottom ash has increased the sample's density, strength and stiffness. Other than that, the result of Marshall Stability indicates that the best replacement of the bottom ash is at 20% in order to get high stability of the asphalt mix [8]. However, it was noticed that the mix with bottom ash requires greater amount of binder content. They concluded that the coal bottom ash can be efficiently used as fine aggregates in asphalt mixture [9].

METHODOLOGY

Figure 1 shows the flowchart of the study. The laboratory works were undertaken as follows:

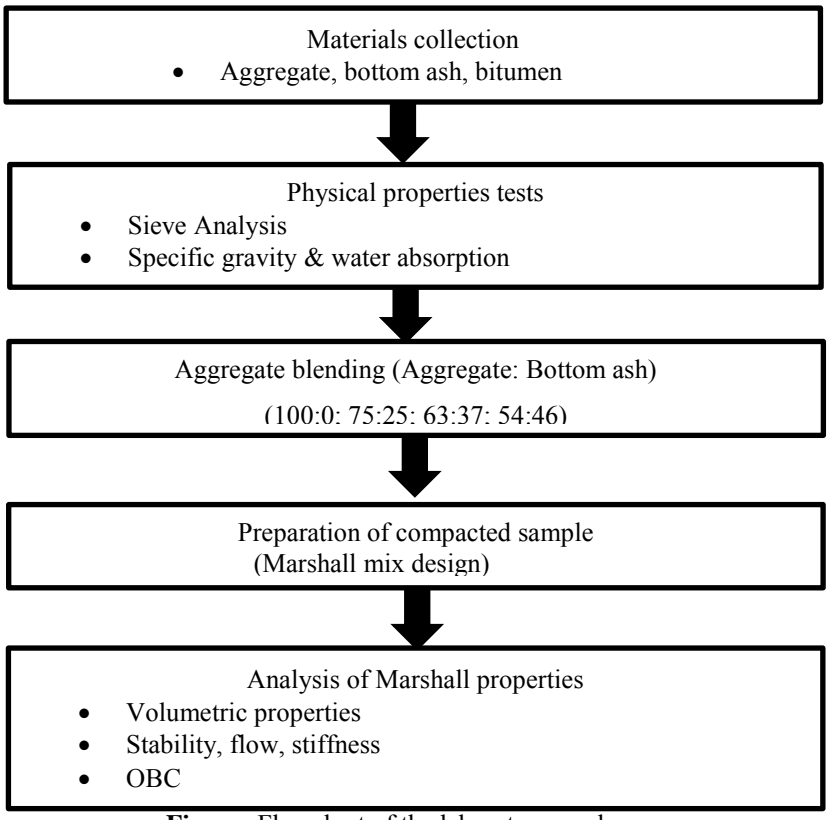


Figure: Flowchart of the laboratory work

Materials

The materials used in this study include aggregate, bottom ash, hydrated lime and bitumen. Aggregate was supplied from Hanson quarry while bottom ash was obtained from Tanjung Bin power plant and the bitumen used was 60/70 PEN. Details of the aggregate and bottom ash characteristics are given in Table 1.

Table 1 Properties of Bottom Ash and Aggregate

	Aggregate	Bottom ash
Specific gravity	2.22	2.18
Water absorbtion (%)	0.81	1.51
Aggregate impact value (%)	42.3	23.4

Sample Preparation

In this study, 15 samples were prepared for each mix type (control and modified mixes) with 3 samples for each bitumen content using Marshall mix design method. The samples were prepared for AC10 gradation as shown in Table 2 as per JKR specifications. The total weight of aggregate for each sample was about 1200 g. Bottom ash were first sieved to obtain the size for aggregate replacement which in the size of 1.18 mm, 0.425 mm and 0.15 mm. The bottom ash was added at different percentages of bottom ash i.e. 0, 25, 37 and 46%. The temperature for mixing and compaction was at 160°C and 130°C respectively. All samples were compacted using Marshall compactor for 75 blows per side.

Table 2 Aggregate Gradation Limit for AC10

Sieve Size (mm)	Percentage Passing (%)
20.0	100
14.0	100
10.0	90 – 100
5.0	58 – 72
3.35	48 – 64
1.18	22 – 40
0.425	12 – 26
0.150	6 – 14
0.075	4 – 8

Test Methods

Marshall Test

Marshall Test was conducted to determine the properties of the mix including stability and flow according to ASTM D 1559 and also as a method of mix design according to the specifications stated in the Asphalt Institute Manual (1979), American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO). The main purpose of this test is to get the optimum bitumen content and some other parameters. Table 3 shows the testing and analysis of the parameters set by the Public Works Department (JKR/SPJ/2008) for Marshall Test [10].

Table 3: Marshall Test Parameters according to JKR/SPJ/2008-S4

Parameter	Wearing Course	Binder Course
Stability, S	> 8000 N	> 8000 N
Flow, F	2.0 – 4.0 mm	2.0 – 4.0 mm
Stiffness, S/F	> 2000 N/mm	> 2000 N/mm
Air voids in mix (VIM)	3.0 – 5.0 %	3.0 – 7.0 %
Voids in aggregate filled with bitumen (VFA)	70 – 80 %	65 – 75 %

RESULT AND DISCUSSION

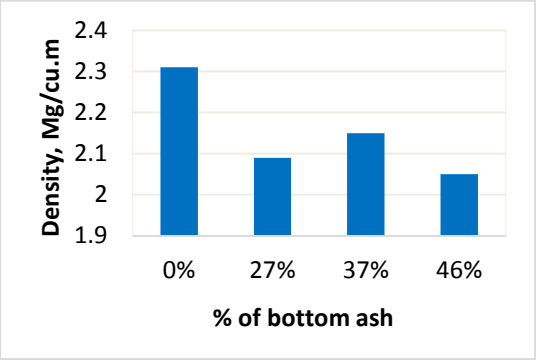
According to the laboratory test which has been carried out, the results and data obtained were used to characterise AC10 with bottom ash. Table 4 summarizes the Marshall Properties of optimum bitumen (OBC) content for the different mixes. Based on the data obtained, the graph of the Marshall properties such as stability, flow, stiffness, voids in total mix (VTM), voids filled with bitumen (VFA), and density were plotted in order to see the trend according to the different percentages of bottom ash added to the mix. The plots are given in Figure 2.

From the results, it can be seen that the increase in the bottom ash content has led to the increase in bitumen content. It happened because of the properties of the bottom ash itself. The porosity of the bottom ash particles is very high, and it tends to absorb more bitumen compared to conventional granite aggregate. Figure 2a shows the density decrease with the increase in bottom ash content. According to the stability graph, the trend shows that the increase in bottom ash content of 37 to 46% has increased the stability of the mix according to the JKR specification compared to the conventional mix. However, the trend of flow graph shows the decrease in flow with the increase in bottom ash content. Moreover, result for stiffness shows an increase of 30% at 37% bottom ash compared to the conventional mix. On the other hand, the VTM result for modified mixes shows higher void content compared to the control mix. This could be due to the high porosity of the bottom ash within the mix. Besides, the trend of VFA shows the increment of bottom ash content from 25% to 37% as well as 46% have increased the VFA to 76%. However, the value complies with the specification for AC10.

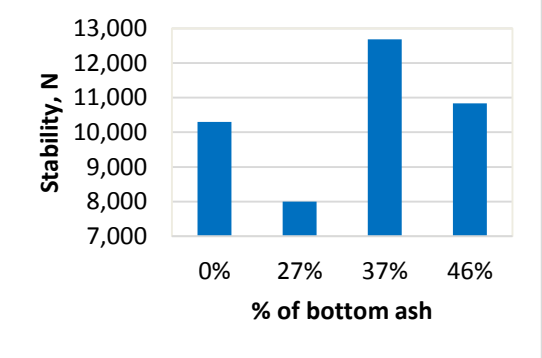
Table 4: Optimum Bitumen Content and Marshall Properties for control and modified mixes

Marshall Parameter	JKR/SPJ/2008 Specification	0%	25%	37%	46%
OBC		6	8.1	8.4	10.2
Stability	> 13000 N	10,300	8,000	12,686	10,831
Flow	2.0 – 4.0 mm	4.25	4.55	4.4	3.6
Stiffness	> 2600 N/mm	2400	1630	3147	2986

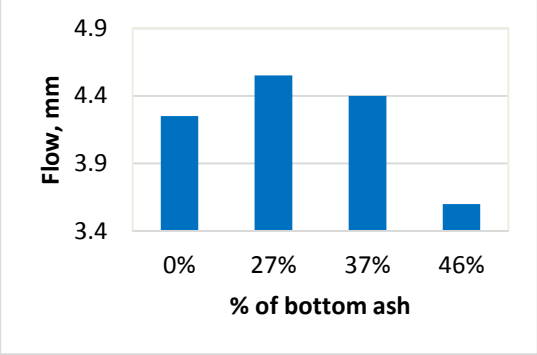
VTM	3.0 – 5.0 %	4.4	7.1	5.1	6.5
VFA	70 – 80 %	75	70	76	76
Density	-	2.31	2.09	2.15	2.05



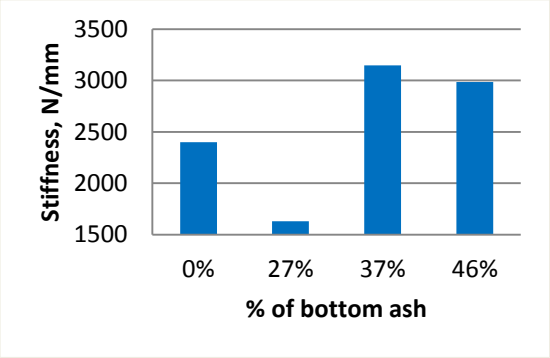
(a) Density vs Bottom Ash



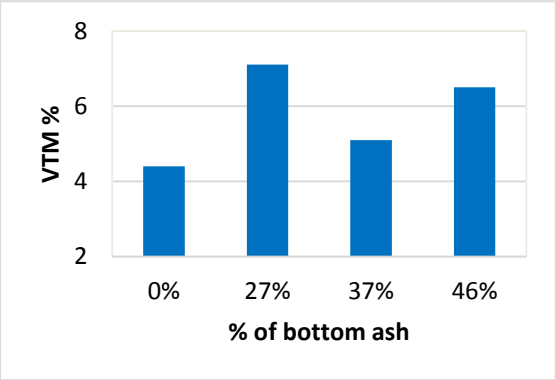
(b) Stability vs Bottom Ash



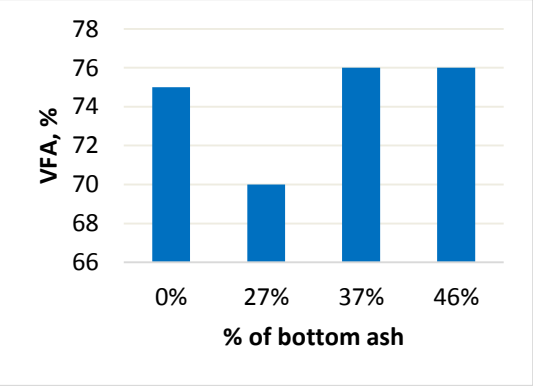
(c) Flow vs Bottom Ash



(d) Stiffness vs Bottom Ash



(e) VTM vs Bottom Ash



(f) VFA vs Bottom Ash

Figure 2: Marshall Properties according to OBC for control and modified mixes

CONCLUSION

The optimum bitumen content was obtained for different bottom ash replacement. The more consumption of bottom ash, the more bitumen content needed for the mix. Besides, the use of bottom ash as fine aggregate in AC10 provides greater stability to the asphalt mix. Overall, the stability and stiffness of the mix increase with the increase of the bottom ash content.

References

[1]Joseph, Y. Y. (2008). Environmental and Health Impact of Mining on Surrounding Communities: *A Case Study of Anglogold Ashanti in Obuasi*, Hons thesis, Kwame Nkrumah University of Science and Technology.

[2] Birgisdóttir, H., & Christensen, T. H. (2005). *Life cycle assessment model for road construction and use of residues from waste incineration* (Doctoral dissertation, Technical University of DenmarkDanmarks Tekniske Universitet, Department of Environmental Science and EngineeringInstitut for Miljøteknologi).
[3]Lee, H. K., Kim, H. K., & Hwang, E. A. (2010). Utilization of power plant bottom ash as aggregates in fiber reinforced cellular concrete. *Waste Management*, *30*(2), 274-284.
[4]Kim, H. K., & Lee, H. K. (2011). Use of power plant bottom ash as fine and coarse aggregates in high strength concrete. *Construction and Building Materials*, *25*(2), 1115-1122.
[5] Muhammad, M. A. (2010). *The Potential of Bottom Ash as Fine Aggregate Replacement in Concrete* (Doctoral dissertation, UMP)..
[6]Forteza, R., Far, M., Seguı, C., & Cerda, V. (2004). Characterization of bottom ash in municipal solid waste incinerators for its use in road base. *Waste management*, *24*(9), 899-909.
[7] Vasudevan, G. (2013). Performance on coal bottom ash in hot mix asphalt. *Int. J. Res. Eng. Technol*, *2*(8), 24-33.
[8]An, J., Kim, J., Golestani, B., Tasneem, K. M., Al Muhit, B. A., Nam, B. H., & Behzadan, A. H. (2014). Evaluating the use of waste-to-energy bottom ash as road construction materials.
[9]Yoo, B. S., Park, D. W., & Vo, H. V. (2016). Evaluation of asphalt mixture containing coal ash. *Transportation Research Procedia*, *14*, 797-803..
[10] Malaysia, P. W. D. (2008). Standard specification for road works, section 4, flexible pavement. *Jabatan. Kerja Raya Malaysia, Kuala Lumpur*.

Effect of Fineness Kaolin Clay on the Properties of Asphaltic Concrete AC14

Mohamad Hasimim Rafsanjani, Ramadhansyah Putra Jaya

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

simin.jani94@gmail.com

Keywords: Asphaltic concrete, kaolin clay, fineness, creep, stiffness

ABSTRACT. Nowadays natural recourses are scarce, which is used in highway construction, therefore they need to be replaced with recycled products. Kaolin clay is one product of waste material that has numerous applications in the construction of highways. Road damage is a phenomenon of great practical importance in highway engineering design and construction. The objective of this study was to investigate the effect of Fineness Kaolin Clay (FKC) as substitute filler on the properties of asphaltic concrete mixture at various percentages of 0%, 2%, 4%, 6% and 8% by weight of the bitumen. Marshall Tests conducted to assess the suitability of kaolin clay as mineral filler for normal conditions and modified bitumen. Resilient modulus test was conducted to measure the stiffness of the asphalt mixtures. The test was conducted in two different temperature 25ºC and 40ºC. Dynamic creep test was conducted to measure the permanent deformation and the strain of the asphalt mixtures. The results of the tests were compared between control samples and samples with FKC. It was found that Marshall Parameters can be improved by adding FKC as filler replacement when compared to normal filler. It is worth noting that there is a definite increase in the Marshall stability and reduces the flow. Modified asphalt mixture with 4% kaolin clay replacement is the highest resilient modulus for 25ºC and 40ºC temperatures which is 7090 MPa and 1400 MPa respectively. The highest creep modulus is 32.30 MPa which is when 4% of kaolin clay is replaced in the asphalt mixture. Since 4% kaolin clay replacement gives the highest value for tests, it can be conclude that 4% kaolin clay replacement is the optimum value that should be replaced to the asphalt mixture.

INTRODUCTION

Asphalt-concrete mixture is composed of aggregates and asphalt, and is widely used in the surface layer of flexible road-pavement [1]. The presence of filler in the asphaltic concrete mixture is more important because of possible interactions with asphalt. During the mixing process, when the asphalt and aggregate are mixed together, the mastic asphalt filler formed due to the fineness of the filler. There is interaction between the asphalt and fillers that cause certain properties of mastic, thereby affecting the performance of this mixture. Because of the greater surface area, the filler can absorb more asphalt and asphalt interaction can lead to different performance of asphaltic concrete mixtures [2].

Problem Statement

Kaolin clay is a waste product after cleansing china clay from their ores, which is one of the main waste materials. To produce one ton of pure kaolin clay eight to nine tonnes of waste generated. Kaolin clay is an important raw material in various industrial sectors. However, kaolin clay mining and processing industry generates large amounts of waste. So, the good alternative to make the kaolin clay waste is useable by use it as modifier in the preparation of road wearing course [3]. Kaolin waste studies can determine whether it is suitable for use in asphalt mixtures. In addition, it can reduce the cost of road construction, addition, this study will raise awareness of environmental problems caused by industrial waste disposal.

Objectives

The objectives of this study are:

4. To investigate the effect of Fineness Kaolin Clay as a filler replacement on the engineering properties of asphaltic concrete mixture at various percentages (0%, 2%, 4%, 6% and 8%) by weight of bitumen.
5. To determine the optimum kaolin clay content replacement in asphaltic concrete mix.

Scope of Study

In order to investigate the effect of FKC on asphaltic concrete mixture properties, the scope of the study was included preparation of AC14 Marshall samples with bitumen content without additive as control sample and with additives of FKC. The Marshall Test was conducted to determine Marshall properties of the asphalt mixtures. In addition, content of FKC used were 0%, 2%, 4%, 6%, and 8% as mineral filler into the mixture. The optimum kaolin clay content will be determined using Marshall Test, resilient modulus test and dynamic creep test. The result on the density, stability, flow, voids in total mix, voids filled bitumen and stiffness from the modified sample and control sample were compared and analyzed according to specification stated in JKR/SPJ/2008.

LITERATURE REVIEW

Fillers can increase susceptibility and resistance temperature asphalt binder and asphalt concrete. Kaolin clay is one of the main mineral in the world and is also one of the most widely used minerals. Kaolin clay mainly formed after experiencing a completely weathered and rain washed. Pure kaolin has high whiteness, soft, easy to disperse, suspended in water, good plasticity and cohesiveness, low resistance and physical properties [4].There are other type of clay that is related to the clay such as nanoclay and organo-montmorillonite which has been used in the past studies [5]. So that it can be as the reference for this study.

Past study has shown that most of the nanoclays can be effectively used as a modifier to improve the mechanical properties of the asphalt binder. The nanoclays that are used in the study was improved shear complex moduli (G *) and viscosity. Direct tension tests showed that asphalt with nanoclay has better low temperature cracking resistance of conventional mixture. Finally, it is worth noting that the blending procedure is important in achieving distributed nanoclay asphalt [6].

Tests performed on samples of bitumen prove that nanoclay modification helps increase strength and aging resistance. Therefore, a low percentage of nanoclay in bitumen lead to changes in rheological parameters, reducing penetration and ductility and increase the softening point and resistance to aging [7]. [8] reported that addition of nanoclay to the mixture can gives a higher softening temperature than the base asphalt binders. It also decreases the penetration value and increase the Kinematic viscosity value.

The nanoclay also can increase the resistance of the asphalt mixes to thermal cracking and rutting. The modified asphalt binders with nanoclay could have good adhesion between aggregates. Therefore, modified asphalt binders could potentially be good at increasing the resistance of asphalt mixes to moisture-induced damage [9].

METHODOLOGY

According to the objectives of the study which is to investigate the effect of FKC on asphaltic concrete mixture properties and to determine the optimum of FKC content, there are three laboratory were conducted that is Marshall Stability and properties, resilient modulus test and dynamic creep test. All the material needed will be collected in the laboratory. The materials that will be tested during collecting the data is bitumen, aggregates and filler which is fineness kaolin clay. All the process needs to be done properly to get the correct value for all the data needed. The entire tests have been conducted based on the American Society for Testing and Materials (ASTM) and American Association of State Highway and Transportation Official (AASHTO).

Materials used in present stdudy;

Bitumen. 60/70 bitumen was used in preparation of samples. The amount of bitumen used for each sample was 5% by weight of aggregate. Bitumen was mixed with kaolin clay by wet process. The process was conducted within the temperature of 160ºC and blended at 2800 rpm for 60 minutes.

Fineness Kaolin clay. The FKC was grinded for two hours to make it finer. Then sieve it with 0.075 mm sieve. The FKC that just pass 0.0075 mm sieve will be used in mixing with bitumen.

Aggregate. Dry sieve analysis has be done in accordance to ASTM C 136 (1992). The selecting aggregate sizes will fall within the range of gradation limits for asphaltic concrete of AC14 JKR (2008) specified shown in Table 1.

Table 1: Aggregate grading AC14

Sieve Size (mm)	Percentage Passing By Weight (%)
20	100
14	90-100
10	76-86
5	50-52
3.35	40-54
1.18	18-34
0.425	12-24
0.150	6-14
0.075	4-8

Marshall Mix Design

The specimens were used in this study are Marshall Samples which have average height of 70 mm and average diameter of 100 mm. As much as 1200g aggregate and 63.16g modified bitumen (with kaolin clay) were mixed in the pan on the hot plate with temperature of 120ºC. Make sure the aggregate and bitumen was mixed thoroughly. The mix then was put in to the mould and compacted with the Marshall compactor for 75 blows. The mix was cooled at room temperature for 24 hours before tested.

Marshall Stability and Properties

The test was carried out in accordance with ASTM D6927 – 06. A minimum of three specimens for each percentage of kaolin clay of the given mixture shall be tested. Testing shall be completed within 24 hours after compaction. Specimens prepared with asphalt cement, tar, or tar-rubber was brought to the specified temperature by immersion in the water bath for 30 to 40 minutes. Maintain the bath temperature at 60 ± 1 ºC for asphalt cement. Then, specimen was removed from the water bath (in the case of after bath remove excess with a towel) and placed in the Marshall Stability Test Machine. The test was carrying on and the stability and flow value were recorded for analysis purpose. The value for density, VTM, VFA, stability, flow and stiffness were determined. The analysis shall be done according to the specification of JKR/SPJ/2008 for the parameters that shown in Table 2.

Table 2: Analysis Parameter for Asphaltic Concrete (JKR/SPJ/2008)

Parameter	Unit	Wearing Course
Stability,S	Newton,N	>8000
Flow,F	Millimeter,mm	2.0 mm-4.0 mm
StiffnessS/F	N/mm	>2000 N/mm
Air voids in mix,VTM	Percentage (%)	3.0% – 5.0%
Voids in aggregate filled with bitumen,VFB	Percentage (%)	70-80

Resilient Modulus Test

Indirect tensile test for resilient modulus of bituminous mixtures were performed in accordance with ASTM D4123 – 82. This test has been conducted in two different temperatures which is 25ºC and 40ºC. There are three samples for each percentage of kaolin clay which means there are15 samples including the conventional mixture for each temperature. So the total samples for this test are 30. The samples were in a control temperature cabinet and brought them to the specified test temperature at least 3 hours before testing. A sample was placed into the loading apparatus called Material Testing Appratus (MATTA) machine. The load was applied vertically in the vertical diametric plane of a cylindrical specimen. The resulting horizontal deformation of the specimen was measured. It provided a mean to analyse stiffness of materials under different conditions, such as moisture, density and stress level.

Dynamic Creep Test

Dynamic creep test is the simplest method of assessing the resistance to permanent deformation or rutting. The specimen that was used in dynamic creep test is Marshall samples which dimension is similar to that of specimen for indirect tensile resilient modulus test. Test was conducted in accordance BS EN 12697 – 25. The procedures for this test are quite similar with the resilient modulus test. But the test has been conducted just for a temperature which is 40ºC. So the total samples are 15. The specimen was placed in a controlled temperature chamber maintained at test temperature of 40 ºC for two to three hours. Then repeated load was applied for 3600 cycles for 40 to 45 minutes.

RESULTS AND DISCUSSION

Asphalt mixture that contained additives of fineness kaolin clay was undergoing Marshall Test, resilient modulus test and dynamic creep test. In Marshall Test, the comparison was observed in term of density, VTM, VFA, stability, flow, and stiffness. The samples properties were checked and compared to the specification stated on JKR/SPJ/2008. The objectives of carrying those entire tests were to determine the engineering properties of the asphalt mixtures with consist of fineness kaolin clay as well as to determine the optimum kaolin clay content replacement in asphaltic concrete mix.

Marshall Stability and Flow Test

***Density*.** Density is mass per unit volume. The densities of asphalt mixture at different percentage of kaolin clay are shown in Figure 1. The bar chart shows that the density of the asphalt mixture is peak at 4% of kaolin clay which is 2.316 g/cm^3. The density of asphalt mixture is drop suddenly after the mixture was replaced by 6% of kaolin clay. Conventional asphalt mixture has density as 2.283 g/cm^3. Asphalt mixture with 4% kaolin clay has density 6% higher than the conventional. The result shows that all the samples with kaolin clay have higher density than the conventional.

Voids in Total Mix (VTM). Figure 2 shows the effect of kaolin clay on voids in total mix. VTM for conventional asphalt mixture is 74.5%, while the VTM for kaolin clay modified asphalt mixture is varies from 3.1% up to 12.7%. According to JKR/SPJ/2008, range of VTM is from 3% to 5%. Based on the result presented in the bar chart below, all the VTM percentage for samples with kaolin clay were in the range except the 6% kaolin clay mixture. VTM is also known as voids and it is the ratio of the volume of voids in a compacted mixture to the total compacted mixture volume. Voids can be reduced by doing the compaction properly. The compactor machine need to be service according to the schedule in order to make sure it works well during compact the samples.

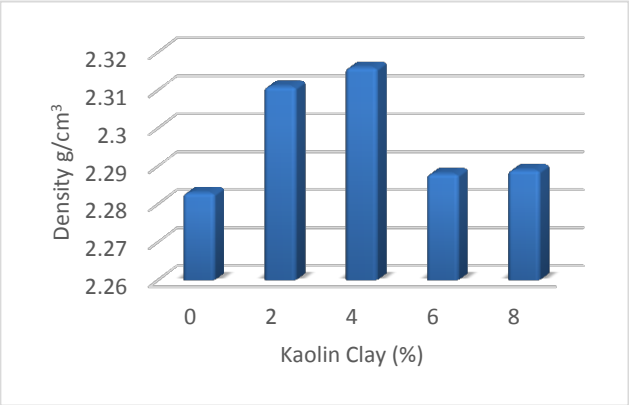


Figure 1 Effect of different percentage of kaolin VTM

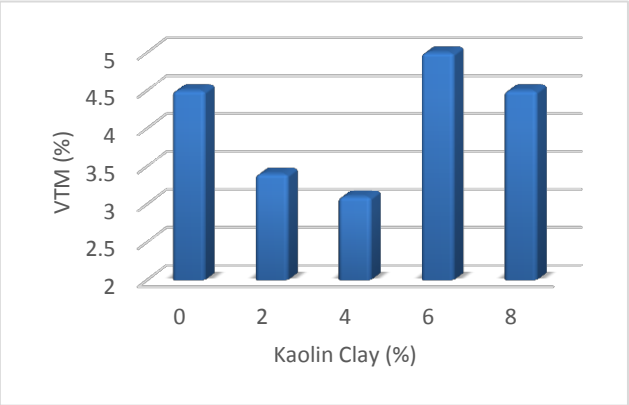


Figure 2 Effect of different percentage of kaolin clay to clay to density

Voids Filled with Asphalt Cement. The voids filled with asphalt binder (VFA) are plotted against percentage of kaolin clay added into the asphalt mixture in Figure 3. Voids filled with asphalt binder is the percent of voids in mineral aggregate (VMA) that is filled with asphalt cement. VFA for the conventional asphalt mixture shown in the bar chart below is 76.4 %. The pattern of the graph is slightly increased from 0% to 4% then drops a little bit for 6% and 8% of kaolin clay. The VFA for 6% and 8% kaolin clay is very close that is 77.1% and 77.7% respectively. The peak value for VFA is 4% kaolin clay which is 83.9%. The range of the JKR/SPJ/2008 specification for VFA is in between 70% to 80%. The conventional mixture, 6% and 8% kaolin clay were in the range.

Stability. Figure 4 shows relationship between stability and percentage of kaolin clay. The stability of 2% kaolin clay is the highest that is 11.88 kN while the conventional asphalt mixture has the stability of 9.72 kN. It shows the small gap between stability of the conventional asphalt mixture with the kaolin clay modified asphaltic concrete. The stability for 4%, 6% and 8% kaolin clay are very close which is from 11.08 kN, 11.04 kN and 10.75 kN respectively. Stability actually verifies the performance of the asphalt mixture under loading. From the result obtained, it shows that the kaolin clay can increase the stability of the asphalt mixture.

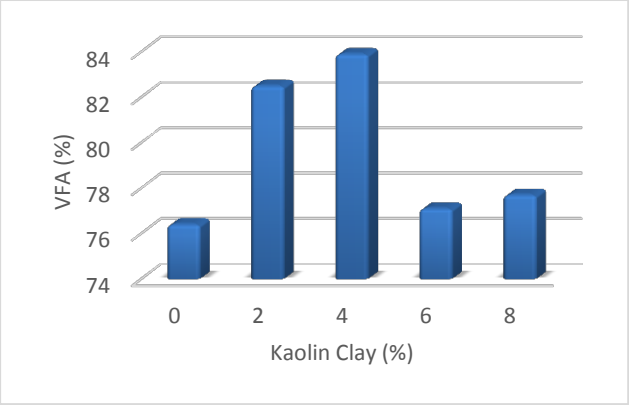


Figure 3 Effect of different percentage of kaolin clay to VFA

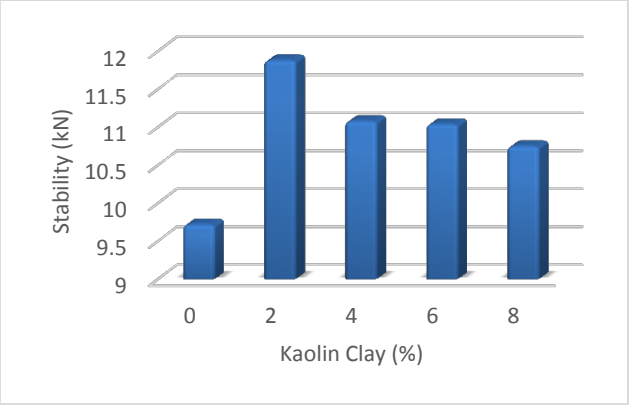


Figure 4 Effect of different percentage of kaolin clay to stability

Flow. Figure 5 shows the effects of flow with different percentage of kaolin clay in asphalt mixture. Flow is related to stability and shows the flexibility of the mix. The range of the JKR/SPJ/2008 specification for flow is in between 2.0 mm to 4.0 mm. Flow for the conventional asphalt mixture is 3.05 mm. The pattern of flow shows the decreasing from 2% to 6% kaolin clay then rise up for 8% kaolin clay. The sample with 6% kaolin clay has the lowest flow that is 2.65 mm. The highest flow is 3.22 mm when 2% of kaolin clay was replaced in the mixture. The results show that all the value of flow for the samples was in the range of JKR specification.

Stiffness. Figure 6 shows the effect of different percentage of kaolin clay to the stiffness. Stiffness is the important parameter to measure the rutting problem. It is good to have a higher stiffness pavement but it can be worst if it is too high because it can lead to fatigue cracking. The conventional asphalt mixture has the lowest stiffness which is 2.16 kN/mm. The stiffness for modified asphalt mixture is varies from 3.36 kN/mm to 4.17 kN/mm. The highest stiffness is 4.17 kN/mm which is when the asphalt mixture was modified with 6% kaolin clay.

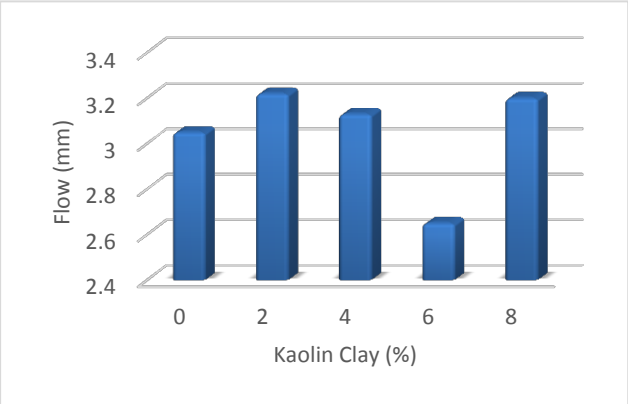


Figure 5 Effect of different percentage of kaolin to clay

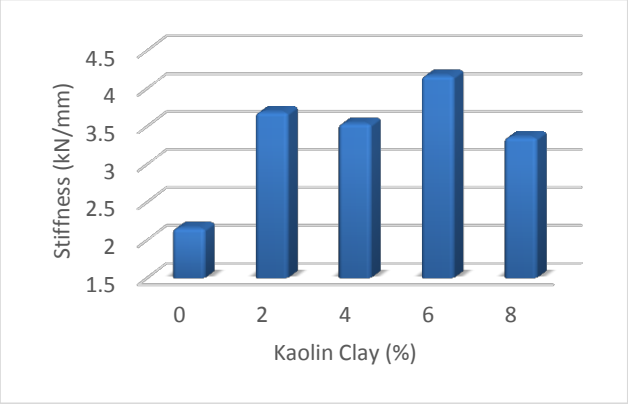


Figure 6 Effect of different percentage of kaolin clay to flow stiffness

Resilient Modulus

Figure 7 shows the results of different percentage of kaolin clay to resilient modulus at 25ºC temperature. The resilient modulus was increased as the percentage of kaolin clay increased until 4% kaolin clay. Then decreased again until 8% kaolin clay. The highest resilient modulus is 7090 MPa when 4% of kaolin clay was added. The 8% kaolin clay shows the lowest value of resilient modulus which was 6152 MPa. The conventional asphalt mixture has the resilient modulus of 6775 MPa which is in between of the highest and the lowest of resilient modulus value.

Figure 8 shows the results of different percentage of kaolin clay to resilient modulus at 40ºC temperature. The pattern of the graph almost the same to the graph of resilient modulus at 25ºC but it varies for the starting that is between the conventional asphalt mixtures to 4% kaolin clay. The conventional asphalt mixture has the resilient modulus of 1362 MPa while the 2% kaolin has the lowest resilient modulus that is 1217 MPa but increased again for 4% kaolin clay that is 1400 MPa. The resilient modulus for the mixture with 4% kaolin clay replacement was the highest. Then, it decreased again until 8% kaolin clay replacement.

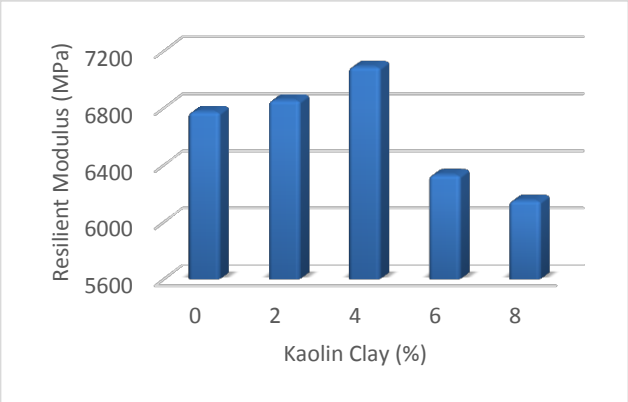


Figure 7 Effect of different percentage of kaolin clay to modulus at 40ºC

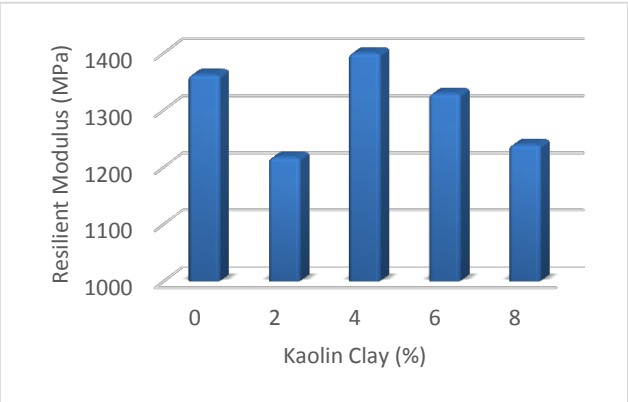


Figure 8 Effect of different of kaolin clay to resilient resilient modulus at 25ºC percentage

Dynamic Creep Test

The dynamic creep test result has been shown in figure 9. Dynamic creep test is repeated test load application to the asphaltic concrete and cause the development of rutting. From bar chart in figure 4.8, it shows that the creep modulus was increased with the increased or percentage of kaolin clay until 4% kaolin clay. Then, it decreased until 8% kaolin clay. There is very little different between 6% kaolin clay and 8% kaolin clay which is 19.8 MPa and 18.4 MPa respectively. The highest creep modulus is 32.3 MPa when 4% kaolin clay was replaced. While the lowest creep modulus has been shared by the conventional mixture and 8% kaolin clay which is 18.4 MPa.

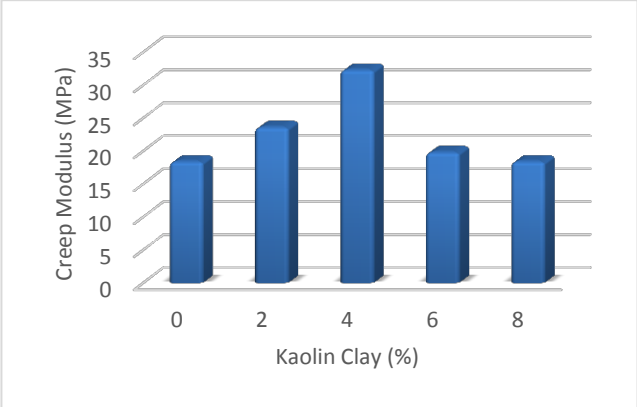


Figure 9: Effect of different percentage of kaolin clay to creep modulus

CONCLUSION

There are conclusion can be made based on the objectives of this study:

1. To investigate the effect of Fineness Kaolin Clay (FKC) as a filler replacement on the Marshall properties of asphalt-concrete mixture at various percentages 0%, 2%, 4%, 6% and 8% by weight of aggregate;
    i. From the Marshall result analysis, the highest density is 2.316 g/cm3 with 4% kaolin clay replacement, the lowest void in total mix (VTM) is 3.1% with 4% kaolin clay replacement, the highest void filled with asphalt binder (VFA) is 83.9% with 4% kaolin clay replacement, the highest stability is 11.88 kN with 2% kaolin clay replacement, the highest flow is 3.22 mm with 2% kaolin clay replacement, and the highest stiffness is 4.17 kN/mm with 6% kaolin clay replacement.
    ii. Modified asphalt mixture with 4% kaolin clay replacement is the highest resilient modulus for 25ºC and 40ºC temperatures which is 7090 MPa and 1400 MPa respectively.
    iii. The highest creep modulus is 32.30 MPa which is when 4% of kaolin clay is replaced in the asphalt mixture.
2. To determine the optimum FKC value that should be added into asphalt concrete mixture;
   Since 4% kaolin clay replacement give the highest value for tests, it can be conclude that 4% kaolin clay replacement is the optimum value that should be replaced to the asphalt mixture.

REFERENCES

[1] Zulkati, A., Diew, W. Y., & Delai, D. S. (2011). Effects of fillers on properties of asphalt-concrete mixture. *Journal of transportation engineering*, *138*(7), 902-910.

[2] Lee, D.-Y. 1964. The effect of filler on asphalt cement mastics.

[3] Megha Nema, Prof. R. Jain, Prof R.K.Grover 2014. Use of clay waste in semi dense bituminous concrete. *International journal of engineering & science* research, 8**,** 602-612.

[4] Lotfy, A., Karahan, O., Ozbay, E., Hossain, K. M., & Lachemi, M. (2015). Effect of kaolin waste content on the properties of normal-weight concretes. *Construction and Building Materials*, *83*, 102-107.

[5] Liu, G., van de Ven, M., Wu, S., Yu, J., & Molenaar, A. (2011). Influence of organo-montmorillonites on fatigue properties of bitumen and mortar. *International Journal of Fatigue*, *33*(12), 1574-1582.

[6] You, Z., Mills-Beale, J., Foley, J. M., Roy, S., Odegard, G. M., Dai, Q., & Goh, S. W. (2011). Nanoclay-modified asphalt materials: Preparation and characterization. *Construction and Building Materials*, *25*(2), 1072-1078.

[7] Polacco, G., Kříž, P., Filippi, S., Stastna, J., Biondi, D., & Zanzotto, L. (2008). Rheological properties of asphalt/SBS/clay blends. *European Polymer Journal*, *44*(11), 3512-3521.

[8] El-Shafie, M., Ibrahim, I. M., & El Rahman, A. A. (2012). The addition effects of macro and nano clay on the performance of asphalt binder. *Egyptian Journal of Petroleum*, *21*(2), 149-154.

[9] Abdullah, M. E., Zamhari, K. A., Hainin, M. R., Oluwasola, E. A., Yusoff, N. I. M., & Hassan, N. A. (2016). High temperature characteristics of warm mix asphalt mixtures with nanoclay and chemical warm mix asphalt modified binders. *Journal of Cleaner Production*, *122*, 326-334.

[10] Abukhettala, M. E. (2006). *The relationship between marshall stability, flow and rutting of the New Malaysian hot-mix asphalt mixtures* (Doctoral dissertation, Universiti Teknologi Malaysia).

Plastic Waste Aggregates for Road Construction as Partial Replacement of Natural Aggregates in Asphaltic Concrete Wearing 14 (ACW14) in Hot Mix Asphalt

Mohamad Shafiq bin Suhaimi, Md. Maniruzzaman A. Aziz

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

mzaman@utm.my

Keywords: Marshall Method; Plastiphalt; Plastic Waste; Flexible Pavements.

ABSTRACT. Nowadays, the increasing in population, urbanization, development activities and changes in life style produce higher quantity of municipal solid waste (MSW) and leads widespread littering on the landscape. For example, the water bodies can be polluted by unsafe plastic waste that have toxic chemical leaching out into the soil and under-ground water. To reduce this problem, developed techniques of using plastic waste for construction of roads and highways has reviewed in this paper. The top layer of flexible pavement can be modified with bituminous mix incorporating waste plastic pieces. This waste plastic modified bituminous mix show better binding property, stability, density and more resistant to water. The main purpose of this research is to determine the effect of incorporating waste plastic bottles (Polyethylene Terephthalate (PET). The moisture sensitivity and low temperature can be affected by using a modifier of low density polyethylene (LDPE) for asphalt paving materials. Based on investigation of Marshall Stability, the factors included such as physical properties, exposure time and environment temperature. The result shows temperature influenced the stability of the blended sample. It can be concluded that the natural aggregates can be replaced by recycled plastics aggregate which called (Plastiphalt) in dense graded bituminous mixes.

INTRODUCTION

Plastic waste replacement is eco-friendly system used at which structural components of flexible pavements in road and highway construction. This study aims to introduce PET aggregates as substitutes for raw materials in asphalting concrete. It can achieved the lowering of the cost of asphalt pavement used and better properties by replacement of waste materials. In asphalt construction, crushed stones, bitumen and stone dust are the main materials used. Municipal solid waste helps the construction of roads and can be reduce the number of landfill used. In the future challenges, futher researches and studies on plastic aggregates replacement shall be carried out in order to professionals as well as public develop level of confidence on implementation of this method in construction.

Problem Statement

The increasing in population, urbanization, development activities and changes in life style produce the higher quantity of plastic in municipal solid waste (MSW) and may lead widespread littering on the landscape. Thus, it becomes serious problem that can be occur by disposal of waste plastic that harmful to environment due to their non-biodegradability and unaesthetic view.

Legislation stated that the increasing volume of wastes generated and the procedures for their disposal are now restricted. The best environmental alternative for solving the problem of disposal by reusing of bulk wastes. Amount of mineral aggregates required in the road construction industry is large, the environmental benefits are not only related to the safe disposal of bulk waste but also to the reduction of environmental impacts arising from the extraction of aggregates which include the visual intrusion, heavy lorry traffic on unsuitable roads, noise, dust and blasting vibration. Further researches and studies on PET aggregates to achieve the using of plastic aggregates in flexible pavement design.

Objectives

The objectives of this study are:

6. To determine the Marshall properties incorporating PET aggregates in Hot Mix Asphalt.
7. To determine the optimum percentage of plastic waste to be added as partial replacement in ACW14 with 80-100 bitumen for better performance in Hot Mix Asphalt.

Scope of Study

This research is carried out to study the replacement aggregates in hot mix asphalt which is focused on the pavement layer concern were wearing course. A mechanism municipal solid waste used is PET aggregates which suitable material that can be used in replacement aggregate. Overall thirty nine (39) sample were prepared consist of control sample, verified sample, partial replacement aggregates and its verified samples. The sample for partial replacement packaging divided into 4 different percentage of plastic aggregates which are 5, 10, 15, and 20% by weight of the natural

aggregates. After the mixing process, the sample were compacted into Marshall Compactor Test. Then, proceed with Marshall Stability and Flow Test and Resilient Modulus Test. The result of natural aggregates and PET plastic aggregates were recorded and compared.

LITERATURE REVIEW

Marshall Method proposed partial replacement of coarse aggregates in hot mix asphaltic wearing course [1]. Plastics waste is coated over stone aggregates and mixed with bitumen to used for flexible pavement construction. In the range 10-15% of percentage of plastic waste, it can be used without separation [2].

It can say that volume of aggregates were replaced by recycled plastics aggregate which called (Plastiphalt) that used in dense graded bituminous mixes of asphalt. The results obtained in this investigation conclude that at the same air-void content, the conventional control mix has higher bulk density than compacted PET aggregates sample mix [3]. A durable structure of asphalt pavement can be achieved with consisting of aggregates. The voids between coarse and fine aggregates are filled by filler aggregates in bituminous mixture [4].

Polyethylene as one sort of polymers is used to investigate the potential prospects to enhance asphalt mixture properties. High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE) which are the two types of polyethylene were added to coat the aggregate. The results indicated that grinded HDPE polyethylene modifier provides better engineering properties. It is found to increase the stability, reduce the density and slightly increase the air voids and the voids of mineral aggregate [5].

METHODOLOGY

The main objective of the research is to determine the effect of PET aggregates as meterial in bituminous roads as partial replacement of the natural aggregates. In addition, the composition of plastic aggregates structure in asphalt layer pavement was compared with that of control sample pavement as well. This research methodology consisted of sample preparation of sample, Marshall Stability and Flow Test and Resilient Modulus Test. The purpose aggregate and bitumen used were ACW14 and 80-100 bitumen. After the thirty nine (39) sample were prepared, analysis were formed to compare the data between the control and modified sample.

Selection of Materials

The material selected in this study are ACW14 natural aggregates, 80-100 bitumen and PET aggregates. The source of the natural aggregates is from the quarry in Ulu Choh Pulai, Johor Bahru, Malaysia. The formation of PET aggregates is start from break down into the small pieces and frying in a pan until it become hard and compacted when freeze it. The shape of PET aggregates were formed look like a conventional aggregates.

Sample Preparation

The laboratory works were started with total all thirty nine (39) sample are formed by mixing the aggregate that divide into their weight by using ACW14 specifications from 14 mm sieve size until pan size aggregates. For purpose of plastic aggregates, the PET will be added as aggregate replacement in different percentages start from 5, 10, 15 and 20%. The PET bottles were collected from the dustbin of waste plastic bottles. The flow of the sample preparation were started from fifteen (15) control samples of ACW14 mixture to determine the optimum bitumen content. Then, three (3) control samples of ACW14 mixture for verification of optimum bitumen content. After that, nine (9) samples of ACW14 mixture with different content of PET plastic aggregates (5, 10, 15 and 20%). Then, three (3) samples of ACW14 for verification of maximum PET plastic aggregates content that can be added. Finally, three (3) control samples of ACW14 mixture for resilient modules test and three (3) samples of ACW14 mixture with PET plastic aggregates content for the same test. Table 1 shows the sieve analysis table of ACW14 design of pavement.

Table 1: Gradation Limit of ACW14 of JKR/SPJ/2008 requirements

Size (mm)	Range	Median (%)	Passing (%)	Retain (%)
14	90 - 100	95	95	5
10	76 - 86	81	86	14
5	50 - 62	56	75	25
3.35	40 - 54	47	91	9
1.18	18 - 34	26	79	21
0.425	12 - 24	18	92	8
0.15	6 - 14	10	92	8
0.075	4 - 8	6	96	4
Dust	-	4	96	4
Hydrated Lime	-	2	98	2

Marshall Stability and Flow Test

Marshall Test is applicable to hot mix design bitumen and aggregate. The stability is defined of the maximum load can be be carried by the spicemen at temperature of 60℃. The flow of the design defined as deformation between no load and maximum load carried by a spicemen during stability test. This test help to determine the optimum bitumen content (OBC) of the control sample before proceeding with the plastic mixture sample. All results of Voids in Mineral Aggregates (VMA), Voids Filled with Bitumen (VFB), Stiffness, Flow, Stability and Density analysis of graph. Below are the criteria that satisfied the JKR 2008 specifications. Table 2 explains the requirements need to be follow for each sample to satisfy the specifications.

Table 2: Marshall Mix Design Requirements of Specifications

Marshall properties	JKR/SPJ/2008 requirements
Stability	> 8000 N
Flow	2-4 mm
Stiffness	> 2600 N/mm
VTM	3%-5%
VFB	70%-80%
Density	-

Theoretical Maximum Density Test (TMD)

Theoretical maximum density is determine of the theoretical maximum relative density of paving mixtures containing aggregates of low-absorption as well as mixtures containing porous aggregates. The ACW14 sample of 1200g were broke down to formed of 1500g of TMD sample. Period time of 15 minutes using Asphalt Mixture Theoretical Maximum Specific Gravity and Density Tester. The weighed of the sample is recorded before and after the test in air and water.

Resilient Modulus Test

Resilient Modulus test is fundamental material property used to characterized bound pavement materials. It measured a stiffness and can be analysed by many factors such as moisture, stress level and density. A cylinder sample put into a cyclic axle load equipment called Material Testing Apparatus (MATTA) machine. The test divided into two different temperature which are 25℃ and 40℃. Resilient machine is turned on to achieve specific temperature and let 3 hours to keep the sample inside the machine.

RESULTS AND DISCUSSION

The result of ACW14 obtained were analysed according to the laboratory test. The obtained data was recorded and compared to the JKR specification. The comparison between verified samples also compared with the modified sample based on characteristics of voids filled with bitumen, voids in mineral aggregates, density, flow, stability and stiffness. Resilient Moduus Test were analysed to determine the stiffness modulus of controlled sample ACW14 and the compared with the modified sample. Below shows the table of gradation limit of ACW14 for control sample and modified sample. Table 3 shows weight of each grading limit for ACW14 for each sample. Table 4 shows weight of the mofified sample containing percent of PET aggregates.

Table 3: Gradation limit for control sample

Size (mm)	**Range**	**Weight (kg)**
14	90 - 100	0.06
10	76 - 86	0.168
5	50 - 62	0.3
3.35	40 - 54	0.108
1.18	18 - 34	0.252
0.425	12 - 24	0.096
0.15	6 - 14	0.096
0.075	4 - 8	0.048
Dust	-	0.048
Hydrated Lime	-	0.024

Table 4: Gradation limit for modified sample containing PET aggregates

Size (mm)	Weight (kg)				
	5% Plastic	10% Plastic	15% Plastic	20% Plastic	25% Plastic
14	0.057	0.054	0.051	0.048	0.045
10	0.1596	0.1512	0.1428	0.1344	0.126
5.0	0.285	0.27	0.255	0.24	0.225
3.35	0.1026	0.0972	0.0918	0.0864	0.081
1.18	0.2394	0.2268	0.2142	0.2016	0.189
0.425	0.0192	0.0864	0.0816	0.0768	0.072
0.15	0.0192	0.0864	0.0816	0.0768	0.072
0.075	0.0456	0.0432	0.0408	0.0384	0.036
Dust	0.0456	0.0432	0.0408	0.0384	0.036
Hydrated lime	0.0228	0.0216	0.0204	0.0192	0.018
Total	1.14kg	1.08kg	1.02kg	0.96kg	0.9kg

MARSHALL TEST ANALYSIS

Optimum Bitumen Content (OBC)

The results of material properties of verified and PET plastic sample were recorded into 5 characteristics which are voids in mineral aggregates, voids filled with bitumen, density, flow, stability and stiffness to obtain optimum bitumen content of ACW14 sample.The final result shows the percent bitumen used is 5.45% equal to 69.17 gram of bitumen. Then, 3 sample were prepared to categorize as verified sample of the specification. Below shows the result of control sample based on its characteristics and verified sample based on JKR specifications. Table 5 shows the average result for each bitumen for density, voids filled with bitumen, voids in total mix, stability, flow and stiffness.

Table 5: Marshall Test results for control samples

Bitumen content %	Density (g/cc)	VFB (%)	VTM (%)	Stability (N)	Flow (mm)	Stiffness N/mm
4.0	2.248	51.50	8.20	14123.0	3.29	4292.70
4.5	2.270	59.90	6.6	11500.0	3.02	3803.6
5.0	2.281	66.70	5.50	13525.00	3.64	3712.3
5.5	2.306	76.30	3.80	10469.0	3.72	2814.2
6.0	2.344	89.70	1.60	10275.0	4.66	2206.5

Table 6: Marshall Test results for verification samples of ACW14 mixture at 5.45% Optimum Bitumen Content

Marshall properties	JKR/SPJ/2008 requirements	Control sample	Result
Stability	> 8000 N	15443.0	Passed
Flow	2-4 mm	3.48	Passed
Stiffness	> 2600 N/mm	4442.0	Passed
VTM	3%-5%	3.1	Passed
VFB	70%-80%	79.2	Passes
Density	-	2.331	Passed

Determination of ACW14 Added with PET Plastic Aggregates of Optimum Bitumen Content 5.45%

Nine (9) sample with PET plastic aggregates were prepared based on the 5.45% bitumen content. The Marshall test was conducted by adding plastic aggregates percent of 5, 10, 15, 20 and 25%. Only the 5 and 10% have only passing the several specification of JKR/SPJ/2008 requirement. Start from 15% aggregate replacement, the mixing did not fulfill the purpose of the design because mixture of the conventional and plastic aggregates did not have mechanical bind during Marshall Compacting process. In addition, the sample were get a little 'bigger' than conventional aggregates that makes the compaction process not in suitable condition. Below shows the graph analysis for added plastic aggregates

and result characteristics of the added PET plastic aggregates by JKR specifications. Table 6 shows the result of verified sample using optimum bitumen content of the sample.

Analysis of the PET aggregates samples

The mixing of the PET aggregates with conventional are formed to proceed with the resilient modulus test. Five (5) characteristics were analysed from the Marshall test whether it met the specification stated in JKR/SPJ/2008 requirements. Table 7 shows Marshall Test results for added PET aggregates.

Table 7: Marshall test results for added PET aggregates

Marshall properties	JKR/SPJ/2008 requirements	PET plastic aggregates samples					
		5%	Result	10%	Result	15%	Result
Stability	> 8000 N	12167.0	Passed	9321.0	Passed	6476.0	Failed
Flow	2-4 mm	3.77	Passed	3.95	Passed	6.80	Failed
Stiffness	> 2600 N/mm	2659.40	Passed	2782.4	Passed	952.3	Failed
VTM	3%-5%	4.90	Passed	5.0	Passed	6.80	Failed
VFB	70%-80%	75.6	Passed	71.1	Passed	56.4	Failed
Density	-	2.189	Passed	2.061	Passed	1.931	Passed

Figure 1a, 1b, 1c, 1d, 1e and 1f shows the analysis of density, plastic content, stability, voids filled with bitumen, flow and stiffness when various percentage of PET aggregates were added respectively.

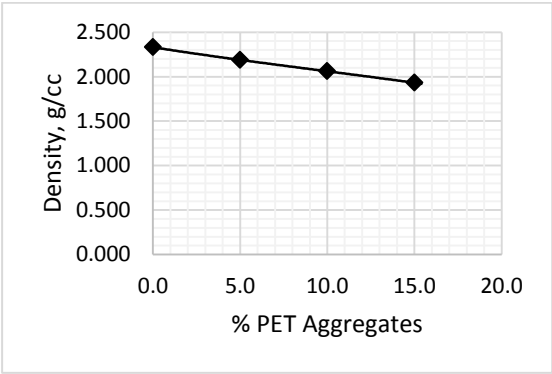


Figure 1a: Density vs % PET Aggregates

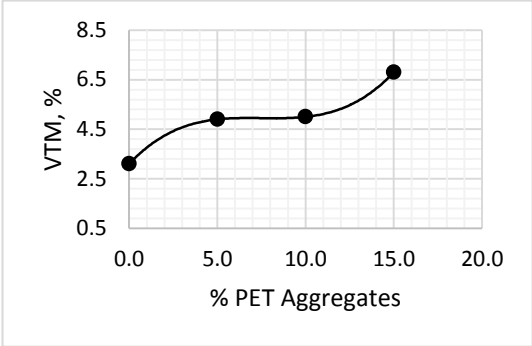


Figure 1b: VTM vs % PET Aggregates

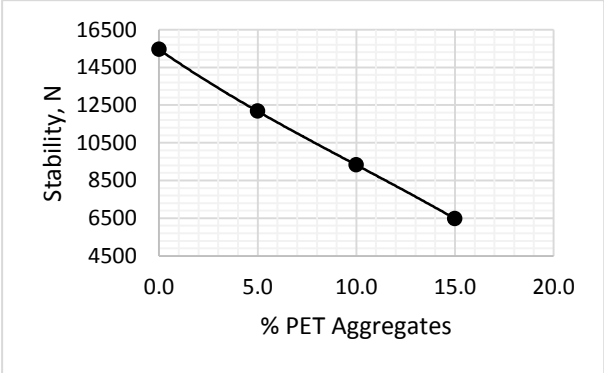


Figure 1c: Stability vs % PET Aggregates

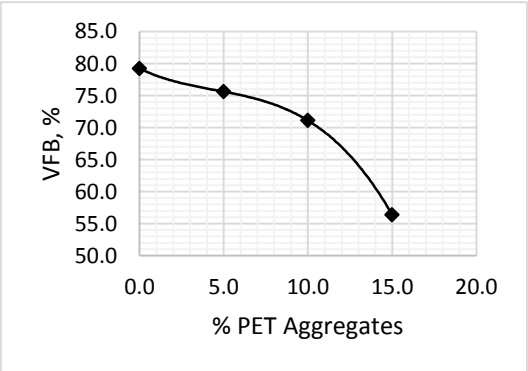


Figure 1d: VFB vs % PET Aggregates

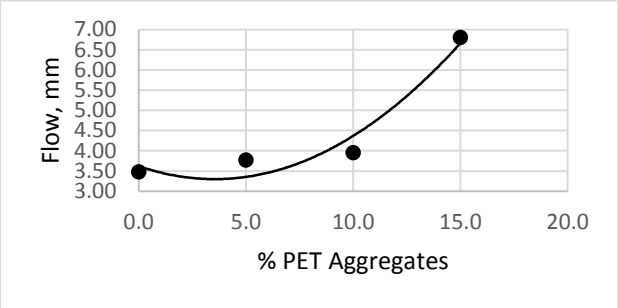


Figure 1e: Flow vs % PET Aggregates

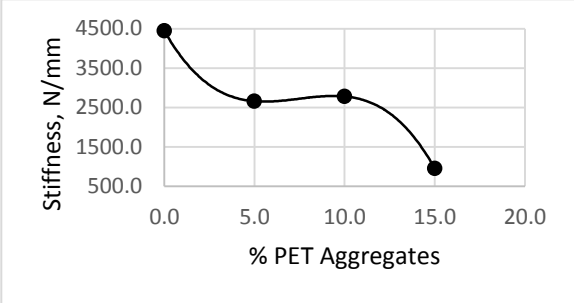


Figure 1f: Stiffness vs % PET Aggregates

Figure 1: Marshall Properties

Resilient Modulus Test

Resilient modulus test were conducted in two temperature which are 25℃ and 40℃. The purpose of the partial replacement aggregate is 5 and 10% because it has passing several characteristics of specifications. Comparison between the unplastic and plastic sample, modulus value decrease silmutenaoeusly with increasing PET plastic content. The increasing amount of PET plastic aggregate, it can increase the thickness of the sample between plastic and conventional aggregate less adhesion. At 25℃, the result shows for control sample, sample added with 5% and 10% are has stiffness value of 1894.5Mpa, 756.33Mpa and 580Mpa respectively. At 40℃, the result shows for control sample, sample added with 5% and 10% are has stiffness value of 1362.5Mpa, 394.67Mpa and 444.5Mpa respectively It can be conclude, the use of PET plastic aggregates in pavements can decreased the stiffness of the sample. Figure 1 shows the result for Resilient Moudulus test.

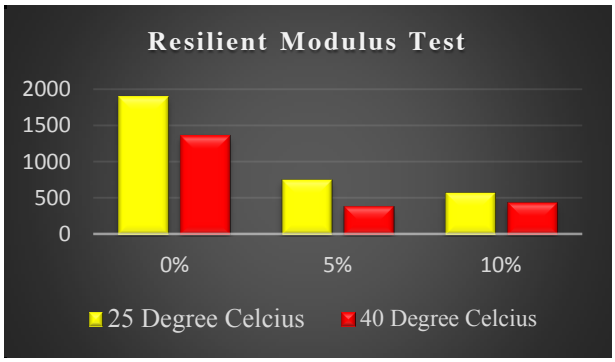


Figure 2: Resilient Modulus Test result for 25℃ and 40℃.

CONCLUSION

From the analysis and discussion:

1. There are only 5 and 10% PET aggregates can be replace into the sample due to met JKR specifications of all characteristics.
2. The Resilient Modulus for PET modified aggregates are lower than the control sample because of adhesion between the natural aggegates, PET aggregates and bitumen.

REFERENCES

[1] Olutaiwo, A. and A. Owolabi *Investigation of the Effects of Partial Replacement of Coarse Aggregate with Graded Palm Kernel Shell in Asphaltic Binder Course*.

[2] Rajasekaran, S., et al. (2013). Reuse of Waste Plastics Coated Aggregates-Bitumen Mix Composite For Road Application–Green Method. *American Journal of Engineering and Research, 2:* 1-13.

[3] Zoorob, S. and L. Suparma (2000). Laboratory design and investigation of the properties of continuously graded Asphaltic concrete containing recycled plastics aggregate replacement (Plastiphalt*). Cement and Concrete Composites 22*(4): 233-242.

[4] Kütük-Sert, T. and S. Kütük (2012). Physical and Marshall properties of borogypsum used as filler aggregate in asphalt concrete. *Journal of Materials in Civil Engineering 25*(2): 266-273.

[5] Rokade, S. (2012). Use of waste plastic and waste rubber tyres in flexible highway pavements. *International conference on future environment and energy, IPCBEE*.

Effect of Black Rice Husk Ash on Properties of Asphaltic Concrete 14

Muhammad Syahir, Ramadhansyah Putra Jaya

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

ramadhansyah@utm.my

Keywords: Black Rise Husk Ash; Hot Mix Asphalt; Bitumen.

ABSTRACT. There are many studies have been done to determine the waste material that can be used to improve resistance to rutting, fatigue cracking due to binder hardening and improve adhesion of binder to aggregate. In this study, the performance of Black Rice Husk Ash (BRHA) as bitumen modifier in asphalt concrete pavement will be investigated. This study focuses on the replacement with BRHA in following order 0% (control), 2%, 4% and 6% by weight of bitumen. The aim is to investigate the effect of BRHA on engineering properties of Asphaltic Concrete 14. The BRHA was grind using grinding ball mill for 120 minutes before sieving to get the size less than 0.075mm. Then, the different percentage of BRHA was mix with bitumen. Marshall Stability test shall carry out to determine the optimum bitumen content of the mixture. The performance of the samples was evaluated through to stability and volumetric properties, creep and resilient modulus.

INTRODUCTION

Problem Statement

Transportation infrastructure acts an important element in the growing up of every nation's economy. However, many roads reach the end of their service life earlier than design life [1]. The performance of road structure is decreased in recent years because of increased traffic volume, improper road surface drainage, improper design and poor maintenance.

Rice is a staple food in the diet for much of the world. The rice husk is available in larger quantity scale in rice producing countries like China, India, Indonesia, Bangladesh, Brazil and South East Asia [2]. Much of the husk produced from the processing of rice either burnt or dumped as a waste. The rice husk ash usually dumped into water streams and caused contamination of springs because there had no useful application [3].

Objectives

The objectives of this study are:

1. To determine the optimum percentage replacement of BRHA in Hot Mix Asphalt (HMA).

2. To evaluate the performance of asphalt mixture incorporating BRHA at a different percentage.

Scope of Study

This study focus on using BRHA as bitumen replacement in HMA where the size used is 0.075 mm. The mix used in this study is Asphaltic Concrete 14 that nominal maximum aggregates size is 14mm. The proportion BRHA replacements in a mix are 0%, 2%, 4% and 6% by weight of bitumen. Marshall, Resilient Modulus and Dynamic Creep are the tests conducted in this study to determine engineering properties in each mix.

LITERATURE REVIEW

Many products and waste materials can add to pavement construction in order to reduce disposal problem and reduce pollution [4]. Incorporating of waste or by-product materials in the construction industry such as the production of asphalt concrete mixtures give an advantage in term of environmental and economic view. Improve the quality of bitumen such as added material in asphalt will increase the stability, resolve problems of failing and reach the age of roads [5].

Hot mix asphalt concrete is a product from aggregate and asphalt cement. The aggregates are as the skeleton of the pavement and bitumen as the binder of the mixture [3]. Additive or filler materials have been used in bitumen to design or repair pavement due to surface defects, structural defects and cracking [6].

The physical and chemical properties of RHA are dependent on the soil chemistry, paddy variety, climatic conditions and fertilizers applied. Silica content is high in RHA (80-85%). The form of silica obtained depends on the temperature and duration of combustion rice husk. Table 1 shows the comparison of chemical properties of RHA from various locations [7].The best way to utilize the RHA is used as bitumen modifier than as filler in asphalt mixture [8].

The modified bitumen with 10% RHA for every percentage of bitumen (4.5%-6%) is giving much higher stability value as compared to the conventional mix. Addition of RHA by 1% as filler by partial replacement of stone dust giving

better stability [8]. The compressive strength of concrete with up to 20% RHA added achieve values equivalent to control concrete after 28 days present high carbon content [9]. There is a high increase in Marshall stability when the conventional mineral filler (OPC) has been replaced by RHA as percentage of increase is almost 65% and the same trend was observed in Marshall stiffness [10].

Table 1: Comparison of chemical properties of RHA from various locations [7]

	Weight (%)		
Constituents	Malaysia	Brazil	Netherlands
SiO2	93.1	92.9	86.9
Al2O3	0.21	0.18	0.84
Fe2O3	0.21	0.43	0.73
CaO	0.41	1.03	1.40
K2O	2.31	0.72	2.46
MgO	1.59	0.35	0.57
Na2O	*	0.02	0.11
SO3	*	0.1	*
LOI	2.36	*	5.14

Note: * not reported

METHODOLOGY

Rice husk is an agro based product that suitable used as a substitute of bitumen. In order to achieve objectives of this study, laboratory tests were conducted to acquire necessitate sets of data and results. All test conducted were based on JKR/SPS/2008-S4, American Society for Testing and Materials (ASTM) and American Association of State Highway and Transportation Officials (AASHTO) standard specification.

Materials Used

Bitumen. Bitumen is a component of asphalt binder that combines course aggregate, fine aggregate and mineral powder. Wet process was used to mix 2% to 6% BRHA with bitumen 60/70 PEN after heated at temperature of 160 °C. Bitumen and BRHA was blended at 800 rpm for 60 minutes to ensure dispersion of BRHA in bitumen. Properties of 60/70 PEN grade bitumen added with BRHA shown in Table 2 [11].

Aggregates. Referring by JKR/SPJ/2008-S4, aggregate for asphaltic concrete shall be a mixture of course and fine aggregates and mineral filler. The aggregate selected for the laboratory work was granite that was obtained from quarries around Johor. Sieve analysis was conducted to produce appropriate size using mechanical sieve shaker. Then, aggregates were collected and stored in individual bins according to the size of aggregates.

Black Rice Husk Ash. The BRHA used in this study is originated from factory in Muar. Rice husk ash is burned under uncontrolled temperature to produce a highly reactive BRHA that contain active carbon. BRHA was ground for 120 minutes to change the size into fine powder that passed 0.075 mm sieve.

Mix Design

Bitumen together with 14 mm nominal maximum aggregate size of granite was employed to prepare asphalt mixes. The mixture samples were designed to determine volumetric properties of Asphaltic Concrete 14 based on Marshall Mix design as outlined in JKR/SPJ/2008-S4. The mix used was 5% design bitumen content and three samples were prepared for each 0%, 2%, 4% and 6% of BRHA as bitumen replacement. Before mixing process, graded aggregates were dried in an oven at 110°C and bitumen was heated. The Marshall compacted at 75 blows per side according to heavy traffic conditions.

Marshall Stability and Flow

Marshall stability of an asphalt mixture is the maximum load that the material can carry when tested in the Marshall apparatus according to ASTM D6927 and Marshall flow is the deformation of the specimen when the load starts to decrease [12]. 12 cylindrical compacted samples, 100mm diameter by approximately 65mm height were prepared at the specified temperature by immersing in a water bath at temperature of 60°C for 30-40 minutes. Then, it was placed in Marshall stability machine and loaded at constant rate of until maximum load record under compression. Six parameters obtained from the test are density, stability, flow, stiffness, voids in total mix, voids in aggregates filled with bitumen and voids in mineral aggregate. HMA properties must comply with the specification range according to JKR/SPJ/2004-S4 as shown in Table 3 [13].

Resilient Modulus

The performance of pavement response to traffic loading was measured by used resilient modulus. After 4 hours conditioning, 12 samples were tested using Material Testing Apparatus (MATTA) at temperature 25°C and another 12 samples tested at temperature 40°C. The test was carried out in accordance with ASTM D 4123-82. Repeated haversine load of 1000 N was applied vertically subjected to 5 pulses. Each sample was tested twice which is 0° and 90° of rotation. The pulse repetition period was 1000 ms and loading pulse width was 100 ms.

Dynamic Creep

The dynamic creep is a test applies a repeated pulsed to estimate the rutting potential of mixes. Actual dynamic creep was conducted at temperature 40°C and 60°C, a cyclic loading stress of 300 kPa, seating stress 5kPa and loading with 3600 cycles or until the specimen is failed was applied. To ensure uniformity of temperature, the samples were stored in the temperature-controlled cabinet for at least 3 hours before testing.

Table 2: Basic properties of 60/70 PEN grade bitumen [11]

% BRHA	Penetration (mm)	Softening Point (°C)
0	69.0	52
2	67.8	52.5
4	65.3	53
6	59.6	54.3

Table 3: JKR Specification for Hot Mix Asphalt [13]

Test	Unit	Wearing Course
Stability, S	N	>8000
Flow, F	Mm	2.0 mm – 4.0 mm
Stiffness, S/F	N/mm	>2000
Voids in aggregate filled with bitumen (VFB)	%	70 – 80
Voids in total mixed (VTM)	%	3.0 – 5.0

RESULTS AND DISCUSSION

Marshall Stability Result

Stability. The relationship between stability and percentage replacement with BRHA are shown in Figure 1. From the bar graph, all modified samples have higher stability compared to control sample. The highest stability for modified sample was at 6% of BRHA replacement. The stability of modified sample is increase as the percentage replacement of BRHA increase. High stability is essential for the pavement to resist the deformation due to traffic load. Low in stability can result to brittle, easily crack and cannot resist high load.

Flow. Figure 2 shows the effect of BRHA on flow. Flow is related to stability and indicates the flexibility of the mix. The bar graphs show that the flows increase by increased of BRHA replacement. Control sample has lower flow value compared to other modified samples. Among modified samples, 2% BRHA content show lower flow value.

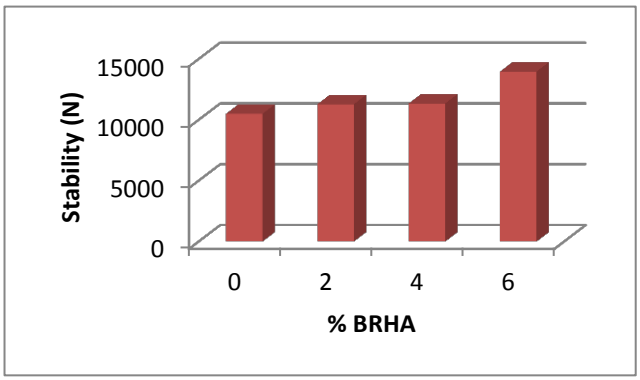


Figure 1: Stability against BRHA replaced

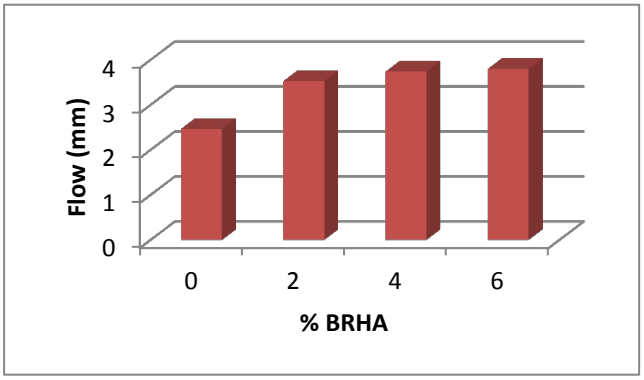


Figure 2: Flow against BRHA replaced

Stiffness. Stiffness is the stability over flow. It is used to measure rutting effects. High stiffness result a high strength of pavement but the stiffness should be up to the optimum point because brittle and cracking will happen if the pavement is too stiff. Figure 3 shows the relationship between stiffness and percentage replacement of BRHA. From the graph, all

modified samples have higher stiffness result compared to control sample. The stiffness is increasing as the percentage of BRHA is increasing. The sample with 6% replacement gives higher stability.

Voids filled with bitumen. VFB is the percentage of the volume of voids in mineral aggregate filled with bitumen. If the value of VFB exceeds JKR specification, the mix will bleed or exhibit plastic flow. Cracking and lower durability of bitumen mixture will occur when decreasing of VFB because it decreases effective bitumen film thickness between aggregates. Figure 4 shows effects of BRHA on VFB. The VFB values for 0% and 6% replacement only meet the standard specification and 2% and 4% replacement exceed the limit.

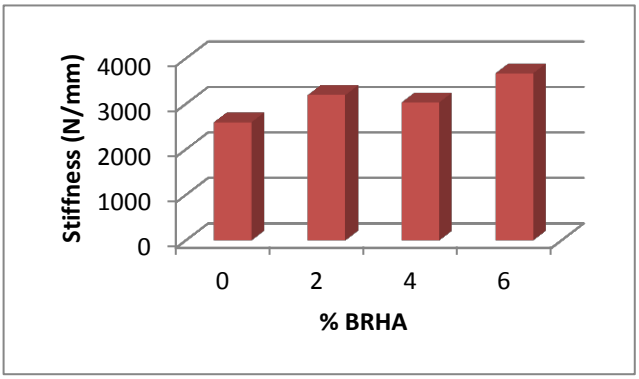


Figure 3: Stiffness against BRHA replaced

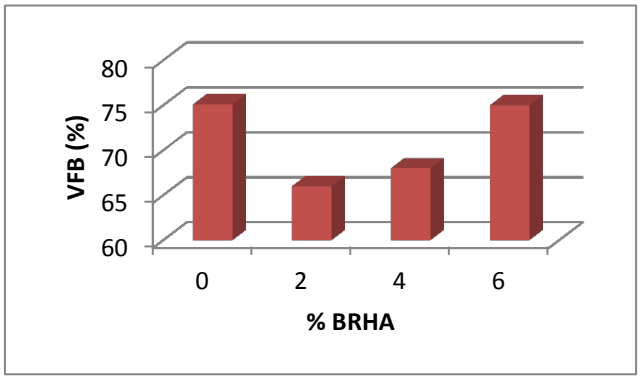


Figure 4: VFB against BRHA replaced

Voids in total mixed. VTM is also known as air voids or ratio of the volume of pockets of air voids between the aggregate particles of a compacted sample. By doing proper compaction with uniform temperature can avoid voids and causing the smaller particles to filled between aggregates. Figure 5 shows effects of BRHA on VTM. The 0% and 6% BRHA content follow the standard specification of road works.

Volume in mineral aggregate. VMA is the total volume of the voids spaces in between the aggregates in a compacted sample, part of which is filled with effective bitumen and part with air. High VMA value will cause low mixture stability. Based on Figure 6, the results with 6% BRHA content give lower value than others sample.

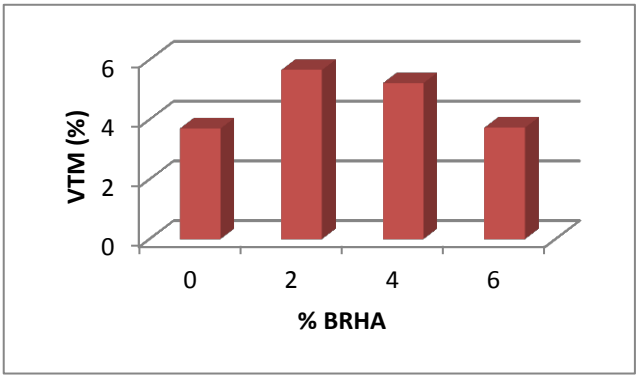


Figure 5: VTM against BRHA replaced

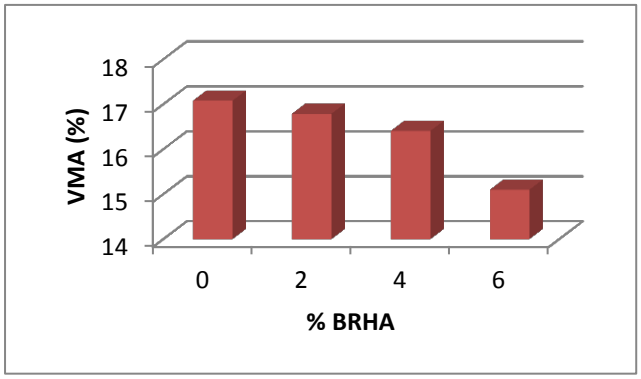
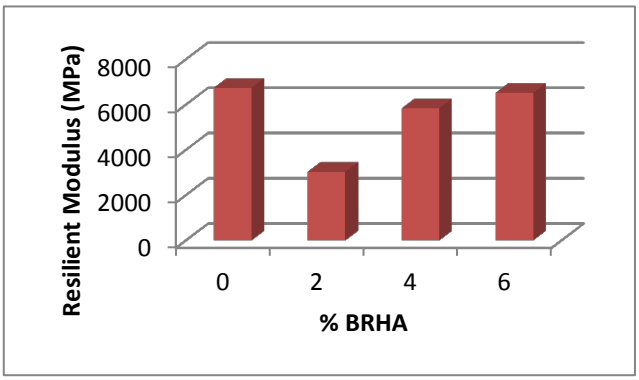


Figure 6: VMA against BRHA replaced

Resilient Modulus

The resilient modulus test results can be seen in Figure 6 and Figure 7. Resilient modulus is the most popular stress-strain measurement used to evaluate elastic properties. Then, it is used as input to the elastic theories model to generate an optimum thickness design [6]. For results of temperature 25°C in Figure 6, control samples have highest value compared to modified samples. Among modified samples, 6% replacement of BRHA has the highest resilient modulus value. Figure 7 shows the results at temperature 40°C. The results shown the temperature at 40°C have same trends with temperature 25°C but the values of resilient modulus are lower. According to the resilient modulus test, control sample has higher elasticity modulus at 25°C and 40°C. Cracking resistances for these samples are lowest and their stiffness is high.



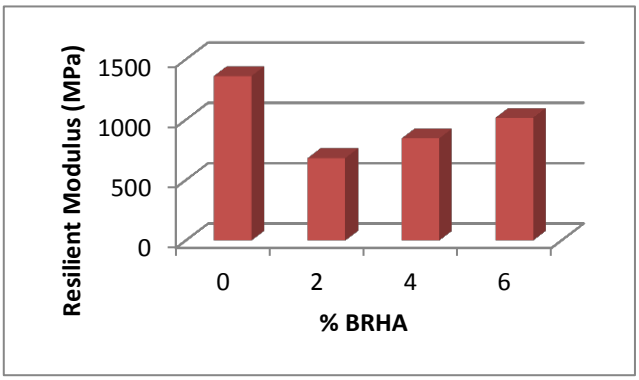
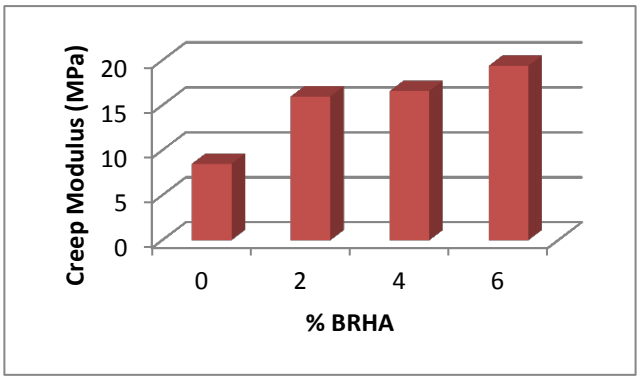


Figure 6: Resilient modulus at 25°C

Figure 7: Resilient modulus at 40°C

Dynamic Creep

This test is to determine resistance of mixture to rutting. Uniaxial creep test was performed at 40°C and 60°C test temperature. Higher creep modulus indicates higher mixture resistance to permanent deformation. Figure 8 shown 6% replacement by BRHA has highest creep modulus at temperature 40°C. For test at temperature 60°C, control sample has highest creep modulus compared to modified samples. The creep modulus for 6% BRHA content is higher than other modified samples.



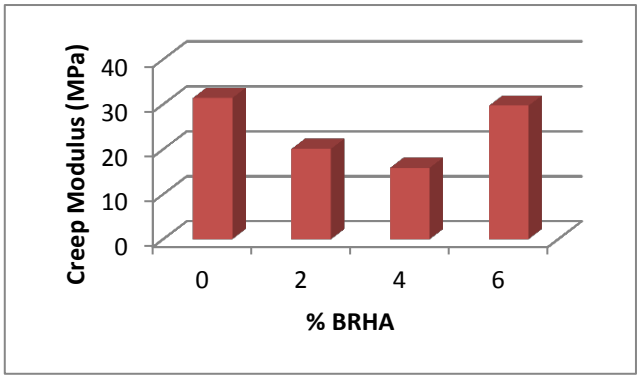


Figure 8: Creep modulus at 40°C

Figure 9: Creep modulus at 60°C

CONCLUSION

Summaries of the result based on analysis are:

1. The properties of BRHA as bitumen replacement differ on certain properties. Marshall stability and flow of hot mix asphalt increased by replacement BRHA with bitumen.

2. In generally, resilient modulus decrease with increased temperature due to softer mix. Sample added with 6% BRHA has better elastic properties other than modified samples and low elastic compared to control sample.

3. The creep modulus at temperature 40°C shown modified samples has higher value than control sample. At temperature 60°C, the control sample has higher value compared to modified samples. The higher creep value of the mixture indicates better rutting resistance.

4. The optimum percentage of BRHA replacement in hot mix asphalt obtained is 6% because of good in stability, stiffness, VFB, VTM, VMA and meets the road works specifications.

5. The performance of asphalt mixture incorporating BRHA at different percentage shown 6% BRHA has better performance compared to control sample. Replacing BRHA as bitumen for 6% shows remarkable effects where it can withstand the deformation from loading.

REFERENCES

[1] Shehu, Z., et al., Factors influencing road infrastructure damage in Malaysia. *Infrastructure Asset Management, 2014. 1*(2): p. 42-52.

[2] Anupam, A.K. and P. Kumar, Use of various agricultural and industrial waste materials in road construction. *Procedia-Social and Behavioral Sciences*, *2013. 104*: p. 264-273.

[3] Sargın, Ş., et al., Evaluation of rice husk ash as filler in hot mix asphalt concrete. *Construction and Building Materials, 2013. 48:* p. 390-397.

[4] Goh, B.H., et al. *Utilisation of Rice Husk Ash in Asphaltic Concrete Pavement*. in *Advanced Materials Research*. 2014. Trans Tech Publ.

[5] Widojoko, L. and P.E. Purnamasari, Study the use of cement and plastic bottle waste as ingredient added to the asphaltic concrete wearing course. *Procedia-Social and Behavioral Sciences, 2012. 43:* p. 832-841.

[6] Borhan, M.N., A. Ismail, and R.A. Rahmat, Evaluation of palm oil fuel ash (POFA) on asphalt mixtures. *Australian Journal of Basic and Applied Sciences, 2010. 4*(10): p. 5456-5463.

[7] Bakar, B.H.A., R. Putrajaya, and H. Abdulaziz, Malaysian rice husk ash–improving the durability and corrosion resistance of concrete: Pre-review. *Concrete Research Letters, 2010. 1*(1): p. 6-13.

[8] Banerjee, J., J.A. Barbhuiya, and P. Rajbongshi, *The Effective Ways of Utilization of Rice-Husk-Ash in Hot Mix Asphalt*.

[9] Chao-Lung, H., B. Le Anh-Tuan, and C. Chun-Tsun, Effect of rice husk ash on the strength and durability characteristics of concrete. *Construction and building materials, 2011. 25*(9)*:* p. 3768-3772.

[10] Al-Hdabi, A., Laboratory investigation on the properties of asphalt concrete mixture with Rice Husk Ash as filler. *Construction and Building Materials, 2016. 126*: p. 544-551.

[11] Romastarika, R. (2015). *The Effect of Black Rice Husk Ash on the Rheological Properties of Bitumen*.

[12] Nashruddina, T., et al., *Evaluation of Binder Absorption in Asphalt Mixture with Various Aging Conditions Using Rice Method*. 2014.

[13] Jabatan Kerja Raya, 2008. *Standard Specification for Road Works (JKR/SPJ/2008*). Malaysia.

Accident Analysis of Senai Desaru Expressway: A Case Study

Muzianis Nazira Binti Mahyidin, Nordiana Mashros

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

mnordiana@utm.my

Keywords: Accident Analysis; Road Accident; Expressway; Average Crash Frequency; EPDO Average Crash Frequency.

ABSTRACT. The problem of deaths and injury as a result of road accidents is now acknowledged to be a global phenomenon. In order to identify interventions that can reduce the risk of related to traffic injury, it is essential to know the contributing factors that lead to accident. The aim of this study is to analyze traffic accidents data at Senai-Desaru Expressway (SDE). This study utilized accident data on Senai-Desaru Expressway for the length of 21.2 km starting from Senai Utama Interchange until Ulu Tiram Interchange to identify crash pattern and recognize the site conditions that may relate to the pattern. 42 segments were analysed using Average Crash Frequency Method and Equivalent Property Damage Only (EPDO) Average Crash Frequency Method to identify and rank sites from most likely to least likely. Selected segments that identified as the most likely benefit from the safety improvement were assessed and suitable countermeasure was suggested. From the study, a predominant type of crash is run-off collision and PDO crashes were found higher than other fatal and injury. Approximately more than half of the crashes occurred during day condition for both segments. The potential countermeasure for run-off collision are increasing the lane or shoulder, install guardrail, reduced the speed limit by installing speed reducing signboard, improve the road surface and install or improve warning sign. Therefore, it can be concluded that road accident data are necessary to identify the causes of the accident and prevention strategies.

INTRODUCTION

Road traffic accident is uncertain and unpredictable events which can occur in any circumstances [1]. It can be defined by a set of variables which are mostly of discrete nature. Road traffic accident occurs when a vehicle that is moving along a roadway collides with another vehicle or object. According to the World Medical Association [2], serious injuries and mortality in road collisions are a public health problem with consequences similar to those of major diseases such as cancer and cardiovascular disease.

Road accidents that cause a lot of damages are occurring almost all over the place. It has been known that road accident results from a combination of factors related to the components of the system comprising roads, the environment, vehicles and road users, and the way they interact [3]. The exposure to potential road traffic injury has increased largely because of rapid motorization, coupled with poor road conditions, rapid population growth, lack of safety features in cars, crowded roads, poor road maintenance, and lack of police enforcement. The other problems that cause accidents are lack of attention, reckless driving, lack of proper protection, speeding, bad personal habits, social and behavioral misconduct and inconsiderate drivers of larger vehicles [4].

Problem Statement

Malaysia has witnessed an explosive rise in the demand for transport vehicles in recent decades in conjunction with its rapid economic growth [5]. An important challenge posed by the recent rapid motorization phenomenon in Malaysia is increasing road traffic accident. In the year 2015, the total number of road accidents was 489,606 with fatalities of 6,706 and injured 11,552.

A higher speed increases the likelihood of an accident and the risk is high especially at expressway due to higher speed limit because when speed increases the possibility of avoiding a crash decreases due to the increase in stopping distance at higher speeds. In addition, as speed increases the risk of fatality or injury increases due to the limits of the human body to tolerate physical force. For this reason systematic study of traffic accidents are required to be carried out. Proper investigation of the cause of accident will help to propose preventive measures in terms of design and control.

Objectives

The objectives of this study are:

8. To identify crash patterns and recognize the site conditions that may relate to the pattern.
9. To identify and rank sites from most likely to least likely to realize a reduction in crash frequency.
10. To assess segment that identified as the most likely benefit from the safety improvement and to suggest suitable countermeasure.

Scope of Study

This study was carried out for the Senai-Desaru Expressway by focusing on segment begins from kilometer 0.0 to kilometer 21.2 excluding ramp and others. Traffic accident data in 2014 and 2015 for both directions were obtained from Senai-Desaru Expressway Berhad. Overall crash pattern and the condition during the crash were investigated. Collision diagram was provided to display and identify similar accident patterns. In order to understand and prevent crashes, 42 segments with each of the segment has of 500m length were rank from most likely to least likely to realize a reduction in crash frequency. Only most likely sites were assessed and then suggested for suitable countermeasure. Condition diagram was not considered in this study due to difficulty in observing real condition at selected sites.

LITERATURE REVIEW

Road accident is a rare, random, multi-factor event always preceded by a situation in which one or more road users have failed to cope with their environment, resulting in a collision on the public highway which should be recorded by the police [6]. Road accidents are often caused by an accumulation of elements which belong largely to four major classes of conditions: the human factor, infrastructure, vehicles and weather conditions [7].

Human factors are described as that which the person did, or did not do at the same time of the accident.It includes speeding, inappropriate speed for circumstance, traffic violations, alcohol, drugs, negligence, driver error and age. Human factors such as human capabilities, limitations, physical conditions, and/or psychological states play a significant role in road accidents. In Saudi Arabia, the most common human factors contributing towards traffic accidents include speeding (in 65% of accidents), driver error (in 80% of accidents), violation of traffic signals at intersections (in 50% of accidents), and illegal U-turns. Other causes are related to vehicles, the road, and the environment (e.g., road layout, which contributes to 20% of accidents) [8]. While, in Malaysia, it was showed that driver factors contribute 41% to road accidents [9]. Most of *the road accidents* were *due to lack of awareness* on *road* safety guidelines. Moreover, the negative attitudes of some drivers such as impatient, careless, inconsiderate lead to conflict and resulting in traffic accidents.

Higher speed increased the risk of a crash for a number of reasons. One of the most commonly reported factors associated with accident is speeding. Excessive and inappropriate speed is the biggest road safety problem in many countries and this problem of speeding has increased over the years. The relationship between speeding and accident rates has been established and is two fold. Higher speeds lead to greater risk rates [10] and higher speeds lead to higher severity rates [11; 12]. High speeds increase the probability of making a perception [13] or a decision error as there is less time to react to observations. They also reduce manoeuvrability and time-to-collision (TTC), and increase the crash impact. As a results, a driver will lose control of the vehicle and cause other road users to misjudge the speed of vehicle. Many studies have established that among the major causes of road accidents, driver behaviour has been judged to be most important where road and vehicle condition are in very good state [14]. A comprehensive study of road safety by Treat et al.[15] found that human error was the sole cause in 57% of all accidents and was a contributing factor in over 90%. In contrast, only 2.4% were due solely to mechanical fault and 4.7% were caused only by environmental factors.

Vehicle factors are one of the causes of road accident. Vehicle factors refer to design or mechanical faults of a vehicle, which includes a lack of maintenance. Poorly maintained vehicles also make a large contribution to many accidents and fatalities on the roads. Vehicles that receive little or no servicing are accidents waiting to happen and there are several components that are regularly neglected such as tyres, brakes, steering, lights and indicators. Statistics suggest that 1.3% of accidents in Japan are attributable to a defect in the vehicle [16]. Haworth et al. [17] conducted a case controlled study of fatal single vehicle crashes in Victoria from December 1995 to November 1996. Of all the crashed cars, 37% had defects that rendered them unroadworthy. However, it was found that mechanical defects contributed to 3% of crashes. Tyre and brake problems were the most common defects. In Malaysia, vehicles factors also one of the factors that influence road accident which contribute for about 7% [9]. Among the reasons are failure of brake system, tire wear situation, age of the vehicles and other failures that can cause road accidents.

Some studies also show the numbers of fatal, serious and slight road accidents are caused by road environment factors. Road environment factors include all aspect of road design and maintenance, construction work, weather conditions and problems with signage and lighting. These factors are reported in a larger proportion of accidents in rural areas than urban areas. Glennon [18] found roads with limitations of sight distance due to crest curves will have a 52% higher frequency of accident occurrences than roads with vertical sag curves. In addition, the grade also has a direct impact on accident occurrences since it reduces driving visibility [19], in that accident rates and its severity will be increased by following the grade levels [20].

Parry & Read [21] comment that the effects of adverse conditions on road transport are immediate, but varied. Most constraints caused by hazardous weather arise from reduced visibility or the loss of vehicular control, and many are common to several different conditions. Weather-related crashes are defined as those crashes that occur in adverse weather (i.e., rain, sleet, snow, and/or fog) or on slick pavement (i.e., wet pavement, snowy/slushy pavement, or icy pavement). The past studies of Wang et al. [22] and Chen and Chen [23] identified weather condition as a major accident factor, by which rainy or foggy conditions will cause a higher chance of accident. Hıjar et al.́ [24] verified that driving under unusual weather conditions has a 5.33 times greater chance of accident than driving under normal weather conditions. It also found that the pavement condition had significant effect on single- and multiple vehicle accident rates [25].

METHODOLOGY

Location of the Study. This study was focuses on Senai Desaru Expressway (E22), which connecting Senai in western of Johor to Desaru in eastern of Johor as shown in Figure 1. The total length of Senai-Desaru Expressway is 77 km and it is the fourth longest highway concession awarded by the Malaysian Government. In order to achieve the objectives of the study, accident data from Senai Utama Interchange until Ulu Tiram Interchange was investigated. The length of this segment is 21.2 km which start from Kilometer 0 to kilometer 21.2. The allowable speed for this location is 110 km/h. The road has two lane dual carriageways with the lane width of 3.65m.

Figure 1: Senai-Desaru Expressway

Data Requirement. Accident data is a crucial element for any road safety intervention. But it is not only the description of the accident circumstances that are needed. Contributing factors like road and traffic characteristics, vehicle parameters, and information about the people involved in the accident have to be registered as well. The data required for this study are accident data including date and time, direction, section of road, location of crash and also type of accident, as well as alignment and geometry of the road. Accident data were obtained from Senai-Desaru Expressway Berhad for kilometer 0 to kilometer 21.2 in years 2014 and 2015. As stated in Interim Guide from Public Works Department [26] if such a long period is not available on the local computer database, shorter periods can be investigated as long as caution is exercised over the conclusions can be made.

Data Processing and Analysis

Overall Crash Pattern and Site Condition. Traffic accident data in Microsoft Word file obtained from Senai-Desaru Expressway Berhad were stored into Microsoft Excel Spreadsheet for the purpose of analysis. Data were carefully checked in order to ensure no redundant data. All these data were then used to develop collision diagram. The purpose of collision diagrams is to graphically represent crashes at a particular location. Then, crash patterns and site conditions from Senai Utama Interchange until Ulu Tiram Interchange were identified. Accident data stored in Microsoft Excel Spreadsheet for 2 years were analyzed to determine crash severity, crash type, pavement condition and light condition.

Methods for Selecting Hazardous Locations. It is very important to identify high risk location for vehicle crash in order to reduce risk in these areas by improving physical conditions or management (e.g. improving lighting). To improve physical condition of the roadway, accident mitigation process was divided into several steps. The process was started with identification of high risk location. There are any techniques to determine the high risk location, however in this study, only two techniques known as Average Crash Frequency Method and Equivalent Property Damage Only (EPDO) Average Crash Frequency Method were used.

The concept of these two methods is to rank the locations from most likely to least likely. The highest score represent the high risk location, while the lowest score represent the low risk location. Since the length of the segment considered in this study is 21.2 km, it needs to be divided into small segment. According to Interim Guide from Public Works Department [26], the treatment of specific types of accident at a single location usually considered 300-500m stretches of road. Therefore, this study was decided to divide 21.2 km segments into small segment in which one segment consists of 500m for the purpose of analyzing accident data. The total segment in this study is 42.

Assessment of Hazardous Locations and Countermeasure. In this study, two high risk locations were selected based on score given by these two methods. The results obtained were then compared with collision diagram to ensure the analysis is precise. Then, detail crash patterns and site conditions for each high risk location were identified. Accident data stored in Microsoft Excel Spreadsheet were sorted and analyzed to determine crash severity, crash type, pavement condition and light condition. These locations were assessed based on collision diagram, crash patterns and site

conditions. Condition diagram is not produced in this study due difficulty to assess the real condition at these locations. Lastly, suitable countermeasure was suggested.

RESULTS AND DISCUSSION

Overall Crash Pattern and Site Condition. Collision diagram is presented in appendix. From the analysis, it was found that property damage only (PDO) has the highest percentage which is 71% of crash severity compare with fatal and injury severity for 2 years crash history along kilometer 0 to kilometer 21.2. The highest percentage of accident pattern for 2014 and 2015 is runoff roadway which is about 59%. This might happen due to some probable causes such as excessive speed, inadequate roadway lighting and also inadequate of pavement maintenance. It was also found that 58% and 75% of the crashes occur in dry pavement condition and during day condition, respectively. Possible factors that lead to the accident during these conditions are high traffic volume and excessive speed. Most of the accidents involve cars followed by motorcycles.

Hazardous Location. 42 segments were ranked based on average crash frequency method in descending order by three categories: total crashes, fatal and injury crashes, and by property damage only crashes. The ranking based on total crash shown that segment 25 has the highest crash followed by segment 10. For the segment 25, the number of fatal and injury is 2 and the number of accident involve property damage only is 8. While for segment 10, which has total accident of 7, 3 accidents come from fatal and injury categories and the rest is property damage only. While, the same 42 segments that were analyze using Equivalent Property Damage Only (EPDO) Average Crash Frequency Method shows segment 10 has highest score followed by segment 12. Segment 25 however has a rank of 6, which is still among the high risk location. This might be because of fatal and injury crashes is given high weightage over a PDO crash. In this study, segments 25 and 10 were chosen for further analysis.

Assessment and Countermeasures

Segment 25. As shown in Figure 2, the dominant crash severity at segment 25 is PDO, which contribute for about 80% and the rest is injury. From all accidents occur at this segment, 100% were involved is car. It was found that the vast majority of crash type is run-off road crash as presented in Figure 3. Besides, from the analysis, 90% of the accidents were occurred during day conditions and 80% of the accident occurred during wet condition. The risk of accident is high due to hydroplaning which can occur on any wet surface. Other possible factors that lead to accident are improper maintenance of pavement and bad pavement conditions that might affect to road user. Therefore, the potential countermeasures that can be considered in this segment are increasing the lane or shoulder install guardrail, reduces the speed limit or install speed camera (speed control) and provide "slippery when wet" sign.

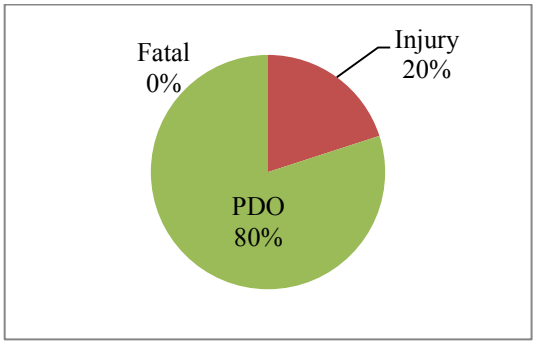


Figure 2: Segment 25 Crash Severities

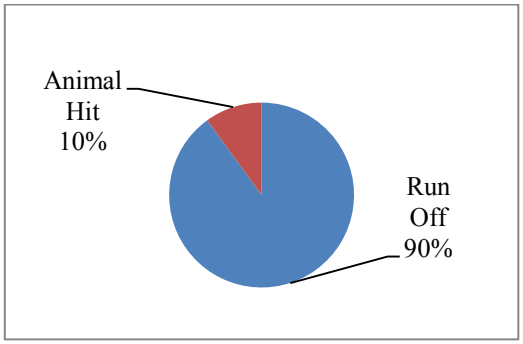


Figure 3: Segment 25 Crash Type

Segment 10. In the period of 2 years, road accidents at this segment cause 57% of PDO crashes and 29% of injury crashes as illustrated in Figure 4. Most of the accidents occur in westbound direction. From the analysis, 86% of the accidents occurred during day and dry conditions. It was observed that 43% of the crash type occurred at segment 10 is run off collision as shown in Figure 5. Among possible contributing factors for run off crash include inadequate pavement maintenance, inadequate roadway shoulders, inadequate median width, and also inappropriate approach speed. It is also suspected that run off accident might be happen because of driver swerving to avoid an animal on the road. Therefore, the potential countermeasures that can be considered in this segment are similar with segment 25 such as increasing the lane or shoulder, install guardrail, reduced the speed limit by installing speed reducing and improve the road surface which can reduce vehicles from running off of the road. Besides, it also suggested to install or improve warning sign.

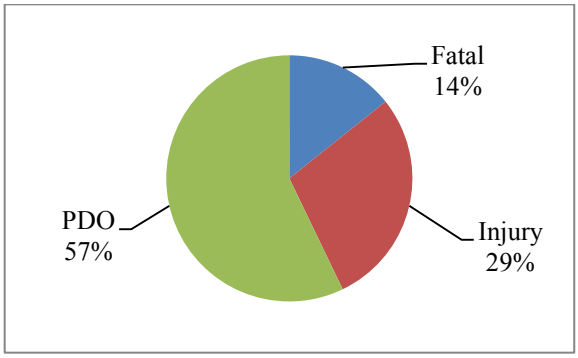


Figure 4: Segment 10 Crash Severities

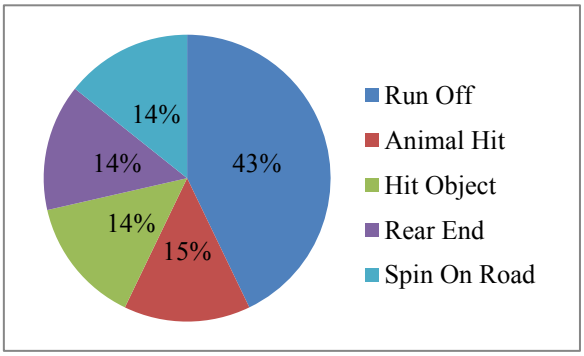


Figure 5: Segment 10 Crash Type

CONCLUSION

This study presents the *accidents* analysis of Senai Desaru Expressway (SDE) from Senai Utama Interchange until Ulu Tiram Interchange. From the study, it can be concluded as below:

4. Accidents occur everywhere with various factors of the crashes reported for 21.2 km segment, 71% crashes resulted in PDO and the predominant crash type was run-off, which comprised 59%. 75% of the crashes were recorded frequently during daylight hours and 58% occurred during dry road condition.
5. Based on Average Crash Frequency method, the ranking based on total crash shows that segment 25 has the highest crash followed by segment 10. While, in EPDO Average Crash Frequency method, segment 10 has highest score followed by segment 12 out of the 42 segments, segment 25 however has a rank of 6, which is still among the high risk location.
6. Segment 25 and segment 10 shows that run-off collision is a predominant type of crash. Overall, PDO crashes were found higher than other fatal and injury. Of the crashes reported, a majority of segment 25 (71%) occurred during dry road conditions but for segment 10, a majority is wet road condition. Approximately more than 80% of the crashes occurred during daylight hours for both segments. Among the potential countermeasure for run-off collision are increasing the lane or shoulder, install guardrail, reduced the speed limit by installing speed reducing signboard, improve the road surface and install or improve warning sign.

REFERENCES

[1] Kumar, S., & Toshniwal, D. (2015). A data mining framework to analyze road accident data. *Journal of Big Data*, *2*(1), *26*.

[2] World Medical Association. (2006). Statement on Traffic Injury. Adopted by the 42nd World Medical Assembly Rancho Mirage, CA., USA, October 1990 and revised by the WMA General Assembly, Pilanesberg, South Africa, October 2006.

[3] Babalola, O. R., Adebayo, O. O. and Oluwadiya, K. S. (2015). Injury Pattern among Patients with Road Traffic Crash Presenting At a Tertiary Health Facility. *IOSR Journal of Dental and Medical Sciences 14*(5), *71–75*.

[4] Kareem, A. (2003). Review of Global Menace of Road Accidents with Special Reference to Malaysia- A Social Perspective. *The Malaysian Journal of Medical Sciences : MJMS, 10*(2), 31–39.

[5] Shariff, N. M. (2012). Private Vehicle Ownership and Transportation Planning in Malaysia. *2012 International Conference on Traffic and Transportation Engineering (ICTTE 2012)*, *26*, 436–447.

[6] Baguley, C. (2011). The importance of a road accident data system and its utilisation, Transport Research Laboratory, Research Report 2011.

[7] Munteanu PL, Roşu M, Panaitescu V, Pungă A. Human and environmental factors contributing to fatal road accidents in a Romanian population. *Rom J Leg Med*. *2014;22*:97–100.

[8] Al-Naami, M.Y., Arafah, M.A. and Al-Ibrahim, F.S. (2010). Trauma care systems in Saudi Arabia: an agenda for action. *Ann Saudi Med*, *30* (1), pp. 50–58

[9] Kementerian Kerja Raya Malaysia (2016). Jalan Raya di Malaysia. Kuala Lumpur: Kementerian Kerja Raya Malaysia

[10] Kloeden, C. N., Ponte, G. and McLean, A. J. (2001) Travelling Speed And The Risk Of Crash Involvement On Rural Roads, Australian Transport Safety Report CR 204.

[11] Nilsson, G. (1982) 'The Effects Of Speed Limits On Traffic Crashes In Sweden', Proceedings Of The International Symposium On The Effects Of Speed Limits On Traffic Crashes And Fuel Consumption, Dublin Organisation For Economy, Co-Operation, And Development (OECD), Paris.

[12] Elvik, R., Christensen, P., and Amundsen, A. (2004) Speed And Road Accidents: An Evaluation Of The Power Model, TOI Report 740/2004.

[13] Hale, A. E. (1990) 'Safety And Speed. A Systems View Of Determinants And Control Measures', *IATSS Research, 14*(1), pp. 59 – 65.
[14] Jacobs, G and Baguely, C. (2004) Traffic Safety, In: Robinson, R and Thagesen, B (Ed.), Road Engineering for Development, 2nd Edition, Spon Press, Ed.
[15] Treat, J. R., Tumbas, N. S., McDonald, S. T., Shinar, D., Hume, R. D., Mayer, R. E., Stanisfer, R. L. and Castellan, N. J. (1977) Tri-level study of the causes of traffic accidents. *Report No. DOT-HS-034-3-535-77 (TAC).*
[16] Rechnitzer G, Haworth N, Kowadlo N. (2000).The effect of vehicle Roadworthiness on crash incidence and severity Report No. 164 Monash University Accident Research Centre.
[17] Haworth, N., Vulcan P., Bowland L, & Pronk N. (1997), Case-control study of fatal singlevehicle crashes. Reports No. 120 & 122, Monash University Accident Research Centre, Australia.
[18] Glennon, J.C. (1987). Effect of alignment on highway safety, State of the Art Report, pp. 48–63.
[19] Vogt, A. and Bared, J. (1998). Accident models for two-lane rural segments and intersections. *Transportation Research Record: Journal of the Transportation Research Board, 1635*, 18–29.
[20] O.E.C.D., O.E.C.D. (1986). Road Safety Research: a Synthesis, (ed.), pp. 106.
[21] Parry, M. L. & Read, N. J. (editors) (1988). The Impact of Climate Variability on UK Industry. Atmospheric Impacts Research Group, School of Geography, The University of Birmingham, 71 pp.
[22] Wang, C. et al. (2011). Predicting Accident Frequency At Their Severity Levels And Its Application In Site Ranking Using A Two-Stage Mixed Multivariate Model, *Accident Analysis and Prevention 43,* 1979–1990.
[23] Chen, F. and Chen, S. (2011). Injury severities of truck drivers in single- and multi-vehicle accidents on rural highways. *US National Library of Medicine National Institutes of Health, 43*(5), 1677–1688.
[24] Hıjar, M. et al. (2000). Risk factors in highway traffic accidents: a case control study, Accident Analysis and Prevention. *US National Library of Medicine National Institutes of Health, 32*, 703–709.
[25] Al-Masaeid, H. (1997). Impact Of Pavement Condition on Rural Road Accidents. *Canadian Journal of Civil Engineering, 24 (4),* 523-532.
[26] Transport and road research laboratory. Interim Guide on Identifying, Prioritizing and Treating Hazardous Locations on Roads In Malaysia. Ministry Of Public Works Malaysia -1995

Accident Analysis at Senai-Desaru Expressway

Norsyabiyah binti Mohammad Tahar, Sitti Asmah Hassan

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

sasmah@utm.my

Keywords: Accident Analysis; Blackspot; Point Weightage; Collision Diagram.

ABSTRACT. This paper presents the study carried out of accident analysis and black spot study based on data collected at Senai-Desaru Expressway, Malaysia. There many actions have been taken by authorities to overcome this problem, however, it seems like there no change to the number of accident. The key objective of this research is to identify the causes of an accident in Senai-Desaru Expressway. The road trends and black spot ranking were established and will concentrate in package 3 only from KM 52.3 to KM 70. The ranking of the blackspot will be identified by calculating point weightage of accident injury and frequency of an accident each 100m. Then, suggestion on how to reduce accidents will be made according to ranking of the blackspot and accident trends on the area under investigation.

INTRODUCTION

There are various infrastructure facilities are available in all countries followed the flow of development in each country, including a highway. The road is one of the most important infrastructure for land relations in the field of transport. Following the rapid growth of economy in the country, the number of vehicles on the road also growing. Therefore, the probability of road accidents will also increase. To reduce the rate of accidents, futher researches and studies on road accident shall be carried out to find the method or solution.

Problem Statement

Various measures have been taken by authorities for resolving the problem of road accidents including rehabilitating existing roads, provide campaigns about safety and conduct operations such as 'Ops Sikap'. However, the effectiveness of the measures taken are not at a satisfactory level. The discussions on this issue are never ends until now. Therefore, detail study needs to be done on this issue to find solutions to the problem.

Objectives

The objectives of this study are:

11. To compare the number of accidents in 2014 and 2015 at Senai-Desaru Expressway.
12. To identify the type of road accidents that occur at Senai-Desaru Expressway.
13. To identify the location of highest accidents at Senai-Desaru Expressway.
14. To identify collision diagram at the site of the highest accidents.

Scope of Study

To achieve the goals and objectives of the study, a detailed and thorough planning must be done to investigate the accident that occurred in the study area. Therefore, the study is focused on the rural road at package 3 of Senai-Desaru Expressway which started from km52.3 and analysis will be created in the region. In addition, information from the parties concerned regarding the date and time, weather, type of vehicle involved and other aspects will be collected. The collected data are the statistic of accidents in year 2014 and 2015.

LITERATURE REVIEW

Accident is undesirable and unexpected event to occur, which can cause damage and injuries. According to the World Health Organization (WHO), road accidents included in the top ten causes of death have recorded worldwide which is ranked ninth in the list that contain 1,254,526 of the deaths [1]. Malaysia has contributed 6,813 of the deaths that put Malaysia in the rank 34th among 172 countries which have highest number of the record in Asia after Thailand. In 2015, the number of road accidents and deaths caused by road accidents increase and it more worsen. Datuk Seri Liow Lai, minister of transport said that the number of the road accidents will increase further in 2020, i.e. approximately 10,716 cases [2].

Most of the researcher state the main factor that cause the road accidents are road environment, vehicles condition and behaviour of the users. Behaviour of the users is the most influenced factor that causes the road accident. There are

various types of behaviour of the users that can cause the accidents such as inexperienced drivers, factor of the age, illness of disability, drunk, sleepiness and fatigue, under the influence, speeding and more [3]. Factors caused by vehicles can also cause problems for the driver and at the same time give a negative impact on their driving. The problems arising from the vehicle that caused the road accident are leaking tire while driving, vehicles that has over passenger or cargo, improper types of tyre, vehicles are not serviced properly and so on [4]. In road environment factor, the condition of the road surface, the weather and volume of the traffic are the causes of the road accidents.

There are many methods that have been used by the researchers to study road accidents analysis such as review data manually, accident prediction model, death index and collision diagram. Review data manually is the easiest methods that have done manually by collecting the accident data from the police accident report. Police data reported obtained a lot of information that can be variables as an explanation in generating modelling extent of the injury, the cause of the accident, the weather, geometry of the road and so on [5]. Meanwhile, accident prediction model (APM) is a method that is well known and often used by researchers to analyze road safety which developed using hierarchical poisson-gamma, poisson-lognormal and the latest finding is zero inflated [7]. One of the road safety level of a country that is globally accepted is a calculation index of road accident deaths per 10 000 registered vehicles (Death Index) [6]. For collision diagram, it is showing the details of the passage of the vehicles and pedestrians involved in an accident before and after the collision [8].

There another method can be used based on Interim Guide on identifying, priopritising and treating hazardous locations on roads in Malaysia by JKR. It is stated that there are 10 steps need to be taken in treatment of hazardous locations on road for reducing road accidents which is identify high accident sites, preliminary accident analysis, initial site visit, collect other data, site studies and analysis, select counter measures, prioritise treatments, detailed design and installation, monitoring and evaluation [9].

METHODOLOGY

The research methodology refers to the method used when conducting research to achieve the goals and objectives set. The research design is structured parallel with the goals and objectives to be achieved are a very important part in the study. The method use in the study is divided into three stages, namely the preliminary study, detailed study and recommendations.

Prelimenary Study

The study was conducted in advance of the initial stages to determine the guidelines for ongoing study. Preliminary study stage includes the statement of the problem, identification of goals and objectives as well as the collection of information or data are required. Collection of this information is derived from statistical records which have been listed by the Senai-Desaru Expressway Berhad which contains the date and time, weather, kilometre and section of the road, type of vehicle, the description of the accident and the consequences of the accident. The collision diagrams of each accident are also attached and the data obtained are starting from 2014 until 2015.

Detailed Study

A detailed study is involving the process of restructuring the obtained data by kilometres or road package, as well as the weather. Compilation of data is done to facilitate the process analysts to achieve the objectives that have been submitted.

The data is compile by using Microsoft Excel. The data is sorted according to the same category, for example, by the rainy or good weather. These data will be used to analyze the factors which are likely to cause road accidents. In addition, graphs and pie charts are also drawn based on the data that has been classified. Then, these data are also sorted by type of accident that occurred to determine the pattern of accidents, where it is used to determine the rehabilation is likely to be done to reduce accidents. The level of injury accidents is also recorded in the data for determining the ranking of the location that have highest accident. Point weightage would be calculated based on the degree of injury by using the following formula:

$$\text{Point Weightage} = 6x1 + 3x2 + 0.8x3 + 0.2x4$$

x1 = the number of fatal accidents
x2 = number of accident injuries
x3 = the number of accidents injured
x4 = the number of accident damage only

After the calculation of "point weightage" is done, the data will be sorted by decreasing order based on the calculated point. Accidents that have highest point weightage will be prioritized and labeled as problem areas that require remedial action to reduce the rate of road accidents. From the list of selected areas, collisions diagram will be drawn for the next process, which recommends actions that can be done in the recovery process. Analysis carried out at this stage is to achieve the goals and objectives set.

Recommendations
Some suggestions will be addressed based on studies that have been done to reduce the number of accidents that occur every year and the improvement of security in the region. Conclusion and discussion can also be created after all data are analyzed and recommendations made.

RESULTS AND DISCUSSION

Senai-Desaru Expressway is divided into three packages of road section which is package 1 start from Senai Utama Interchange to Toll Ulu Tiram, package 2 start from toll plaza Ulu Tiram to toll plaza Cahaya Baru and including north-south direction from the toll plaza Cahaya Baru to Pasir Gudang Interchange, and packages 3 start from toll plaza Cahaya Baru to junction at Penawar. This can be seen more clearly in Figure 1. Package 1 and 2 is two lane two ways road and design speed is 120km/h, while package 3 is two lane one way road and design speed is 90km/h. The road trends will be focus on overall section of the road and blackspot study will focus on package 3 which is start from km53.2 until the end of road section.

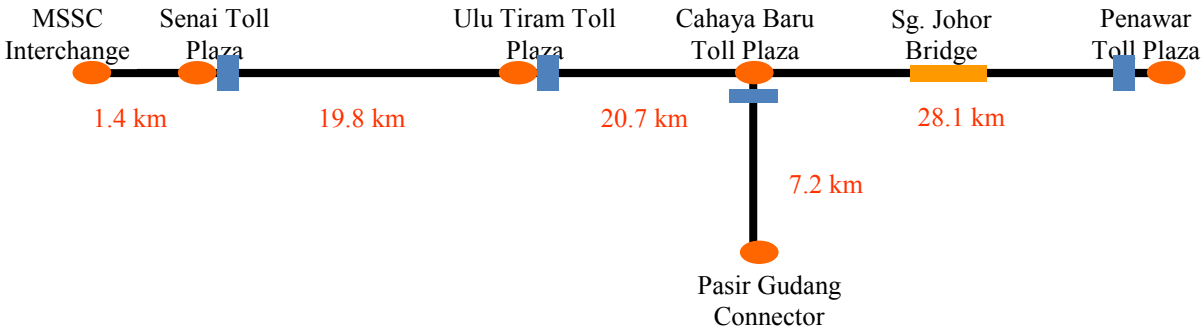


Figure 1: Sketch of road at Senai-Desaru Expressway

The Road Trends
Figure 2 shows the trend of accidents each month in Senai-Desaru Expressway from year 2014-2015. The figure represents the increasing number of accident each month from year 2014 to 2015, but the number of accident decrease in September. The highest number of accident for both year is in May with 18 accidents in 2014 and 25 accidents in 2015.

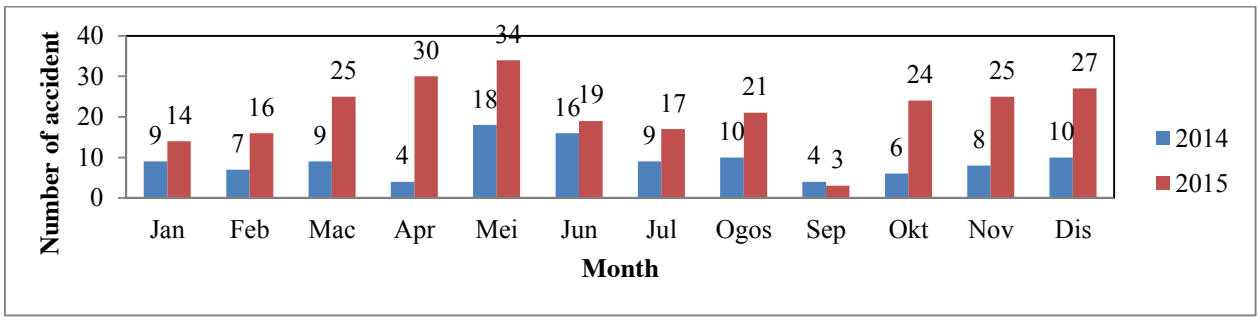


Figure 2: Number of accident by month for year 2014 and 2015

***Type of vehicles*.** Figure 3 shows the number of accidents by class of vehicles in Senai-Desaru Expressway. Class of vehicles will be shown in detail in Table 1. Class 0 and class 1 is the bigger contributor to the number of accident in Senai-Desaru Expressway. Class 1 recorded the highest number of accidents, which is 74.18 percent from the total number of vehicles involved, followed by class 0 with 16.19 percent and the third is class 3 which 5.69 percent. The total number of vehicles involved in accidents in Senai-Desaru Expressway in 2014-2015 is 457 of vehicles.

Table 1: Type of vehicles according to the class

Class	Type of vehicles
Class 0	Motorcycle
Class 1	2 axles
Class 2	2 axles (6 tyres)
Class 3	3 axles and more
Class 4	Taxi
Class 5	Bus

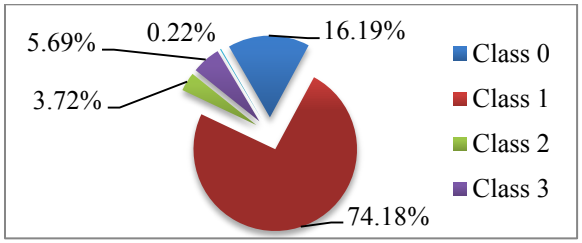


Figure 3: Number of accident by class of vehicles

***Accidents by weather*.** Weather can be one of the causes of a road accidents that happen in Senai-Desaru Expressway. Therefore, an analysis about the weather has been conducted to analysis the cause of accidents. The weather is divided into two elements which is good and rain. Figure 4 shows the percentage of accidents by weather in Senai-Desaru Expressway. 73 percent of accident was occurred during good weather, while 27 percent during rain.

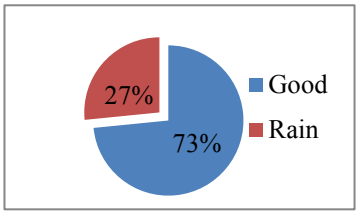


Figure 4: Percentage of accident by weather

***Accidents by condition of the day*.** Condition of the day also can be one of the causes of a road accidents that happen in Senai-Desaru Expressway. There 4 condition of the day which is day, night, dawn and dusk. Figure 5 shows the percentage of accidents by condition of the day in Senai-Desaru Expressway. An accident that happen during the day recorded the highest number which 72 percent with 266 accidents. Meanwhile, the percentage of accidents occur at night were 25 percent. Furthermore, the accident occurred at dusk and dawn are 1 and 2 percent respectively.

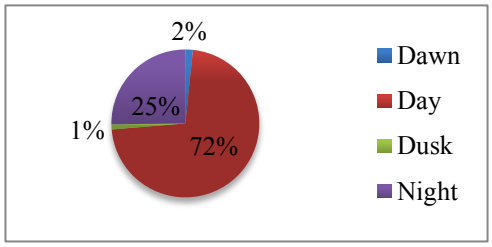


Figure 5: Percentage of accident by condition of the day

Blackspot Study.

***Types of accidents*.** Road accident have various type of accident or pattern of collision. In study site, there have 9 pattern of collision which is rotate on the road, hit the road assets, rear-end, head-on, hit the animal, hit an object, side swipe, loss of control dan loss of control then hit the road assets. Figure 6 shows data of type of accident that occur in package 3 start from km52.3 to km70. The types of accidents that often occur is loss of control then hit the road asset with 12 accidents, follow by rear end with 9 accidents and then head on with 8 accident.

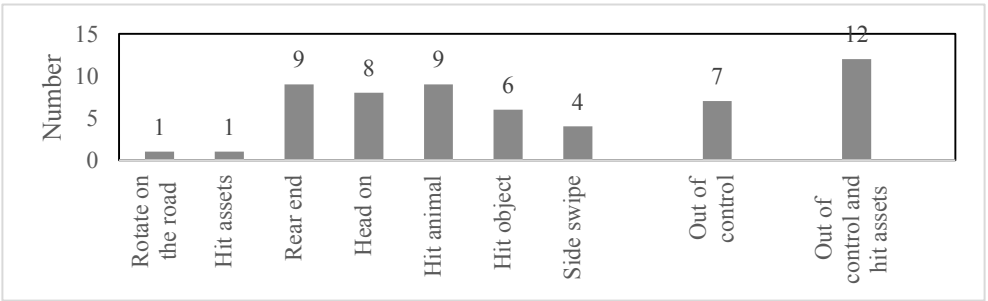


Figure 6: Types of accident

***Rank of location based on frequency*.** Table 2 show the list of worst locations each 100m of section based on frequency of accidents. The total number of accident that occur in site study is 57 accidents, however, only a few locations have a highest number of accidents. Based on table 2, the worst location is km 68.0 that have 9 accidents in 2 years. Other locations only have 2 or 1 accidents that occur in 2 years. Therefore, km 68 is label as problem location that need rehabilitation to decrease the rate of accident.

Table 2: List of worst 100m sections

Kilometre	Frequency
68.0	9
53.8	2
57.5	2
58.9	2
61.5	2
66.5	2

***Accident point weightage*.** The number of accidents per kilometer in the Senai-Desaru can be categorized by accident point weightage. This method is based on the value set by the Transport Research Laboratory in the Interim guide on identify, prioritize and treat hazardous locations on the road in Malaysia where the value is determined by the degree of injury which is fatal accidents (6 points), serious injury (3 points) slight injury (0.8 points) and damage only (0.2 points). Table 3 shows the types of injuries that occur in the study area for each 1km. According to Table 3, accident point weightage was calculated to determine ranking of the section and show in Table 4.

Table 3: Types of injuries

Kilometer	**Jumlah**	
52.0 – 52.9	1	o
53.0 – 53.9	4	++oo
54.0 – 54.9	3	**o
55.0 – 55.9	2	+o
56.0 – 56.9	2	+o
57.0 – 57.9	6	**+ooo
58.0 – 58.9	3	x++
59.0 – 59.9	3	*oo
60.0 – 60.9	2	*+
61.0 – 61.9	2	*+
62.0 – 62.9	3	xoo
63.0 – 63.9	2	*o
64.0 – 64.9	2	+o
65.0 – 65.9	3	ooo
66.0 – 66.9	5	*++oo
67.0 – 67.9	3	*+o
68.0 – 68.9	10	+ooooooooo
69.0 – 69.9	1	+
70.0	0	
Total	57	x = Maut * = Cedera Parah + = Cedera Ringan o = Kerosakan

Table 4: Ranking based on accident point weightage

Kilometer	**Jumlah**	**"Point Weightage"**
58.0 – 58.9	3	7.6
57.0 – 57.9	6	7.4
62.0 – 62.9	3	6.4
54.0 – 54.9	3	6.2
66.0 – 66.9	5	5.0
67.0 – 67.9	3	4.0
60.0 – 60.9	2	3.8
61.0 – 61.9	2	3.8
59.0 – 59.9	3	3.4
63.0 – 63.9	2	3.2
68.0 – 68.9	10	2.6
53.0 – 53.9	4	2.0
55.0 – 55.9	2	1.0
56.0 – 56.9	2	1.0
64.0 – 64.9	2	1.0
69.0 – 69.9	1	0.8
65.0 – 65.9	3	0.6
52.0 – 52.9	1	0.2
70.0	0	0

***Collision diagram*.** Figure 7 shows collision diagram of km 68 that have the highest frequency of accidents.

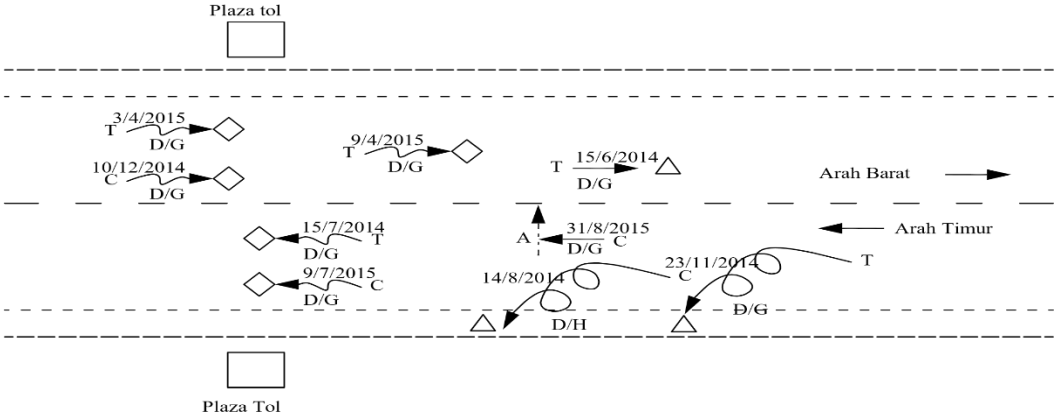


Figure 7: Collision diagram at km 68.0

CONCLUSION

This research presents the accident analysis based on the trends of accident and blackspot study to find a way to reduce the rate of accident. The following conclusions derived from the analysis carried out:

7. The study found that there has been an increase in the number of accidents from 2014 to 2015 along the Senai-Desaru. 57 percent increase in the number of accidents in 2015 compared to 2014. Comparing the number of accidents per month in 2014 and 2015 also have an increased very significantly except in September where the number of accidents in 2015 decreased compared to 2014.

8. There are various types of accidents that occur along the Senai-Desaru, including a head on, rear end, out of control and so on. From the analysis that has been made, the type of road accidents, out of control and hit the road asset is the pattern of frequent accidents, which recorded a total of 12 accidents occurred in the last 2 years.

9. To identify the location of the highest accident, accident data collated and rank by the frequency of accidents and accident point weightage. Accident point weightage is a value calculated based on the level of injury accidents. Accident data prepared in accordance with the rank of the worst locations for each 100m by frequency of occurrence. Problem locations can be identified through this analysis, which is 68 kilometers categorized as problem locations recorded 9 accidents. In addition, data are compiled based on the level of injury accidents per 1 km area of study is divided into four categories, namely fatalities, serious injuries, slightly injuries and damage only. Each level has a value which will be multiplied by the frequency of accidents to get the point weightage.

10. Collision diagram of the problem location is drawn to identify the surrounding environment of location and to analyze the factor that likely cause the road accidents. After that, some suggestion of rehabilation will be proposed based on the factor that have been analyze.

REFERENCES

[1] World Life Expectancy. (2014). World Ranking-Total Deaths. Retrieved from World Life Expectancy website: http://www.worldlifeexpectancy.com/world-rankings-total-deaths

[2] Tan Yi Liang. (2016, April 18). Malaysia Catat Hampir Setengah Juta Kemalangan Jalan Raya Pada 2015. *Berita Semasa Mstar*. Retrieved October 20, 2016, from http://www.mstar.com.my

[3] Petridou, E. & Moustaki, M. (2000). Human factors in the causation of road traffic crashes. *European journal of epidemiology*. *16*(9), 819-826.

[4] Jones, I.S. (2016). *The effect of vehicle characteristics on road accidents*. Elsevier.

[5] Mannering, F.L. & Bhat, C.R., (2014). Analytic methods in accident research: methodological frontier and future directions. *Analytic Methods in Accident Research*. *1*, 1-22.

[6] Malaysia Transport Ministry. (2016). Indeks Kematian Akibat Kemalangan Jalan Raya. Retrieved from Malaysia Transport Ministry website: http://www.mot.gov.my

[7] Lord, D., Washington, S.P. and Ivan, J.N. (2005). Poisson, Poisson-gamma and zero-inflated regression

models of motor vehicle crashes: balancing statistical fit and theory. *Accident Analysis & Prevention*. *37*(1), 35-46.
[8] V.N.Vazirani. Traffic Engineering in Transportation Engineering vol 1. 1977
[9] Chris Baguley. (1995). Interim Guide on Identifying, Prioritising and Treating Hazardous Locations on Roads in Malaysia. Kuala Lumpur, Malaysia: JKR.

Moisture Variations in Jointing Sand Stockpiles and Sand Drying For Concrete Block Pavement

Siti Nadhirah binti Abdul Hamid, Hasanan Md. Nor

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

hasanan@fka.utm.my

Keywords: Moisture Content; Jointing Sand; Stockpiles; Moisture Content Test; Sand Drying Process.

ABSTRACT. Jointing sand is one of the components in concrete block pavement. Many application of block paving relies on the retention of sand in its joints to provide interlock and stability of pavement surface. In order to provide and maintain the interlock of block paving structure stability, it depends upon the characteristics and mechanism of the sand itself. Hence, such criteria to meet the jointing sand requirements are fine particles and dried sand shall be used to prevent from pavement failure. The key objectives of this research is to investigate the moisture content of jointing sand for various stockpile sizes during drying process, in addition to determine the effects of drying period of jointing sand under the sun along with to study the water contour profile for jointing sand stockpiles after sand drying under the sun. There are 9 stockpiles with 3 different heights was built and performed sand drying experiment as well as moisture content test and its results is used to make comparison between moisture content and parameters such as height and drying period under the sun. According to the research, the stockpiles height does not give any significant impacts to jointing sand dryness. Besides that, 6 hours of sun exposure is insufficient to dry the whole jointing sand stockpiles.

INTRODUCTION

Concrete block pavement (CBP) is also known as segmental concrete paving. It consists of few layers from subgrade to sub-base followed by bedding layer, jointing sand and block paving units which literally provides a durable wearing course for this system. If it is properly designed and constructed, this pavement can last up to decades with minimum or even zero maintenance necessary. Concrete block pavement can be said to be "Strong, Green and Attractive" and it is for these reasons that it has been widely used in almost all forms of pavement, especially in industrial and heavy-duty pavement.

Problem Statement

Although concrete block pavement is incredibly durable, the wearing course should be properly managed prior to installation. Improper procedure when installing jointing sand in concrete block pavement will lead to certain effects such as errosion of jointing sand, paver are uneven and tipping as well as allowing water to seep into the pavement layers when the joint is insufficient with sand. Therefore, all of these effects will affect the performance of concrete block pavement due to its low strength and lead to pavement failure.

Nowadays, certain construction industry especially that is not specialized in paving installment will create such mistakes due to lack of knowledge regarding jointing sand requirements. Using very fine particles with less than 2.36 mm in size and dry sand is one of the most important criteria for jointing sand characteristics. This is because coarse sand that is use as joint filling materials will not fit the gaps between the concrete block which significantly affect the strength of the pavements unit. Hence, none interlocking bond was developed between the block since joint filling materials are absent. Consequently, the load from the vehicles will directly transmitted to only one unit block which literally would not be able to sustain high pressure which will result to crack.

Meanwhile, using damp or wet sand as joint filling materials will also contributes to similar effects. Wet sand will create large and clumpy texture. Thus, only certain amount of sand will be able to fill the gaps between the blocks eventhough proper compaction has been made. Insufficient joint filling materials will cause errosion of jointing sand which is not only none existence interlocking function, but it also will experienced settlement as it allows water to penetrate into the pavement and seep into the bedding layer. However, these are common short cuts taken by several contractors in industry while preparing an area for a paver installation.

Objectives

The objectives of this study are:

15. To investigate the moisture content of jointing sand for various stockpile heights during drying.
16. To determine the effects of drying period of jointing sand under the sun.
17. To study the water contour profile for jointing sand stockpile after drying under the sun.

Scope of Study

This study will be conducted mostly within outdoor area. It will mainly focus on moisture variations of jointing sand stockpile. Three jointing sand stockpiles will be tested under similar condition in type of sand and place. However, the height of the stockpile and the point sample taken for conducting moisture content test will be varies from others. Sieve analysis test will be carried out in order to obtain the grading curve and grading zone for joint filling material. The sand is then will be oven dried to ensure that it is zero moisture content before the sand will be mixed with water. The sand will be distributed into several stockpiles according to its sizes and lay out under the sun for sand drying process. The moisture content of these stockpiles will be taken on specific location point and the experimental result will be compared accordingly to its height and time exposure under the sun.

LITERATURE REVIEW

Concrete block are placed very closely to other concrete blocks, however there are gaps between the blocks often range width from 2 to 3 mm depending upon block shape, laying pattern, aesthetic consideration and application areas [1]. The requirements of this jointing sand based on standard specification includes jointing sand shall be screened and conform to the grading requirement, shall be very fine particles of sand, free of deleterious quantities of soluble salts and contaminants, shall be impermeable to water and should not be in wet condition as well as shall be more easy to sweep and pressed firmly into the joints along with jointing sand should not be eroded from the gaps between the blocks [10].

Refering to the British Standard 1973, the most effective sieve for jointing sand is passing the sieve of 2.36 mm [1]. Meanwhile some reasearcher suggested the use of coarse sand as joint filling based on the studied of dilatancy and angle of shearing resistance [7]. Furthermore, Yusoff et al. (2012) found that the maximum size of jointing sand particles is 1.18 mm and less than 20% of the sand passing the sieve size 75 □m shows the better performance [12]. Other than that, coarser sand will be more suitable for bigger width and vice versa [6]. Later discover that Livneh et al. (1988) specified a maximum particle size of jointing sand is 1.2 mm and with 10% passing 75 □m sieve size [9]. Nonetheless, the use of fines sand in range of 5 to 10% has been reported to provide good results [3].

Basically as mentioned earlier, bigger joints will require coarser sand while small joints require finer sand. Unsuitable or applicable materials used for joint filling may result to jointing sand losses. This case can be caused by confined to incidents where poor quality sands or crushed rocks were used as the joint filling materials [4]. Past finding by Yusoff et.al. (2012) stated that, presence of water reduce the maximum effort needed to pull off the interlocking concrete block pavement [12]. In 1986, The Concrete Masonry Association of Australia (CMAA) established that the joint filling sand must be in fairly dry conditions in order to get the best result [3].

An important relationship was discovered when the effect of moisture content on the extraction force was studied. It can be seen that a moisture content of 2 per cent and less in the jointing material during the construction can be immediately applied in practice as it creates the best resistance for this pavement [2]. According to Hashemi (2011), sand contains approximately 20-25% of moisture content when stockpiled, dependent on the type of sand and size as well. Generally 10-12 m height takes around 7 days to stockpile. The sand stays for another 8 days until the stockpile achieves the desired moisture content such as 5-6% which is saleable moisture content [5]. Properly managing the stockpiles produces savings such as lower drying costs, increase production capacity, lower paving costs, decrease material loss and so much more [11].

METHODOLOGY

The main objective of the research is to study the performance of the moisture variations in jointing sand stockpile and sand drying process. In addition, reduction of moisture content also can be studied from the water contour profile after the sand drying process. This research methodology consist of 5 key activities which are oven drying sand activity, sieve analysis test, sand drying process preparation and sand drying experiment along with moisture content test.

Oven Drying Sand

Oven drying sand is one of the methods to ensure all the water in jointing sand is zero percentage. This is because in order to identify the grading range and grading zone for the stockpile used, sand needs to be in dry condition. The total amount of sand used in this experiment is almost 500 kg, hence it tooks approximately 2 weeks for all of the sand to oven dried. All of the sand is placed in a tray gradually each day and let it dry in the oven for 24 hours at the temperature of 100°C. The dried sand will be stored in closed bin for protection.

Sieve Analysis Test

Sieve analysis test used to determine the gradation of sand use as jointing sand stockpiles. The jointing sand for testing shall be obtained in accordance with the procedure described in BS 1377: Part 1 (1990). The prepared sample shall be oven dried and shall be free from any contamination. All of the sand shall be mixed together to achieved even form and few sample will be taken for sieving. The sand is run through the sieve shaker machine for atleast 5 to 10 minutes. The weight of each siever before placing the sand is recorded. After sieveing, carefully weight and record the percentage of each sieve and pan with its retained sand. The grading requirements for jointing sand were shown in Table 1.

Table 1: Grading requirements for jointing sand

Sieve Size	Percentage Passing For Jointing Sand (%)
3/8 in. (9.5 mm)	-
No. 4 (4.75 mm)	-
No. 8 (2.36 mm)	100
No. 16 (1.18 mm)	90 – 100
No. 30 (0.600 mm)	60 - 90
No. 50 (0.300 mm)	30 - 60
No. 100 (0.150 mm)	15 - 30
No. 200 (0.075 mm)	5 - 10

Preparations of Sand Drying Process.

Following are the preparation before carry out sand drying process in order to let the sand dry on an appropriate weather and to ensure that the moisture content of the sand is similar to the real condition of raining period. There are three things need to be prepared before carrying out sand drying process which are; weather forecast monitoring, moisture content test during rainfall period and water mixing process.

Weather Forecast Monitoring. Before carry out the sand drying process, weather monitoring need to be done to ensure that the test will run out smoothly. All of the details is recorded from time to time starting 8.30 a.m. until 2.30 p.m. The details that are taken into account in order to carry out the sand drying process are date (day), time, ambient temperature, humidity, wind, UV index and also precipitation.

Moisture Content during Rainfall Period. As mentioned previously, in order to achieve the real condition of the raining time, moisture content test during rainfall period has been conducted and recorded. Water will be added to each of the jointing sand stockpiles accordingly to this test. The moisture content during raining time has been taken and calculated. Example details during this test are temperature, humidity, wind, UV index and precipitation.

From the experiment, the dry condition of the sand is only on the surface of the stockpiles as it was exposed to the sun while the rest are having moisture content in the range from 5% to 8%. The maximum moisture content obtained from the test is 8% hence this value will be used as constant moisture content throughout the test in each stockpiles which referred to as the most critical condition.

Water mixing process. Mixing process is one of the methods to gain uniform moisture content. As mention before, all of the jointing sand has been dried completely so that constant moisture content can be achieved throughout the sand drying process. Therefore, in order to distribute the water evenly through the sand, mixing process should be done. The sand is mix using heavy duty mixer with 8% of moisture content. Sand that is mixed with water will be seperately placed in gunny or plastics according to its weight for each height of stockpile.

Sand Drying Experiment

Sand drying experiment is a sand drying process for jointing sand stockpiles to dry naturally under the exposure of the sun. Once all of the sand has been mix well, sand will be poured free falling according to its height. The jointing sand will be separated into 9 stockpiles model which 3 stockpiles with 10 cm height, 3 stockpiles with 20 cm height and another 3 stockpiles with 30 cm height. The number indicates the height of the stockpile while the alphabets refer as duration exposure to sunlight. Thermocouple and thermogun also were being used to record the ambient temperature and temperature of the stockpiles. The drying process of the jointing sand stockpiles will start at 8.30 a.m. and end at 2.30 p.m.. Every 2 hours duration exposure to sunlight, several samples on specific point will be taken from 3 stockpiles for moisture content test.

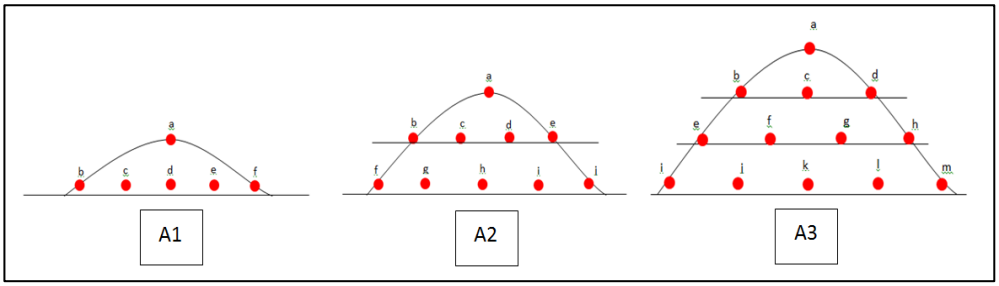


Figure 1: Layout of stockpiles for 2 hours drying period and the location of sample point taken

Moisture Content Test

This test is carried out to measure the moisture content of the sand stockpiles. Each stockpiles will have varies moisture content depending on the point where it is taken. In order to fill the gap between the concrete block pavements, the moisture content should be as dry as possible or at least less than 2%. If the moisture content is not within the range, the sand is not applicable to use as joint filling material. This test will be performed after the dying process of sand stockpiles within the specific duration. The measured moisture content will be used to compare among each stockpiles according to its height and duration exposure to the sunlight. The water reduction contout profile also can be obtained from this test.

RESULTS AND DISCUSSION

The results of sieve analysis test for the jointing sand, moisture content test and sand drying experiment on 9 stockpiles model under certain duration was obtained. The moisture content variations was analyse to define the water content reduction in jointing sand stockpiles after several hours laying under the sunlight.

Sieve Analysis Test

According to the data measured, the distribution of jointing sand less than 2.36 mm full filled the specification, where the distribution of jointing sand is in the range of the upper limit and the lower limit. This size of jointing sand will be used as controlled size of this study. The result for this test is shown in Figure 2 below.

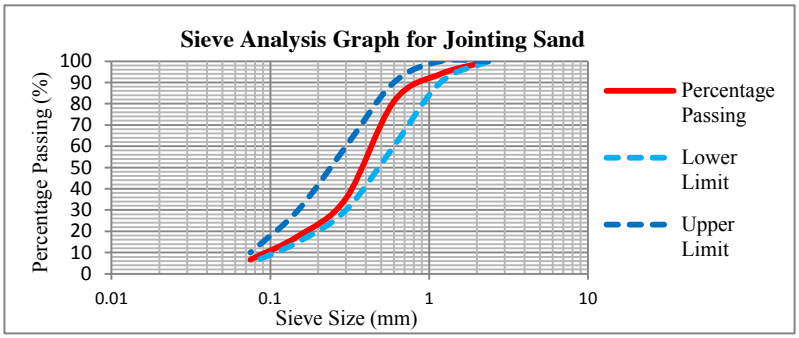
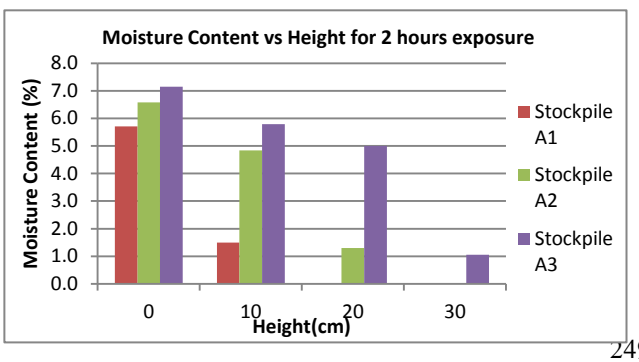


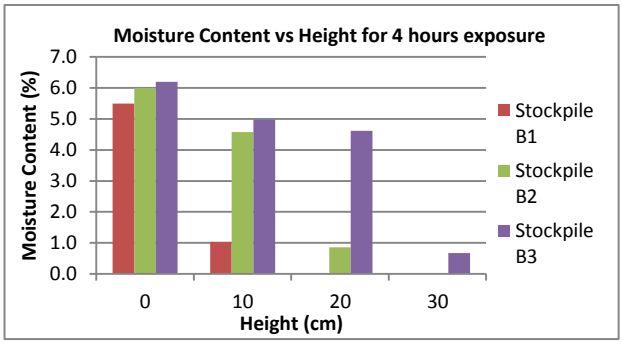
Figure 2: Distribution size of jointing sand less than 2.36 mm

Moisture Content for Various Stockpile Heights

The result of moisture content in jointing sand stockpile decreased with height. The height is measured as zero from datum to the top of the stockpile. All of the three stockpiles show more than 5% moisture content at the bottom of the stockpiles. While at the surface part for all of the stockpiles shows less than 1% moisture content. Therefore, these indicate that height does not give any significant effects to jointing sand drying process. This is because the result shows almost similar outcome through out the height eventhough it is being exposed within different duration to sun exposure. Hence, whether the jointing sand is being exposed within short or longer time the moisture content still represent a similar trend through out the height. Generally, it can be concluded that all of the stockpiles are not applicable to be used as jointing sand since only a part of the stockpile which is the surface are less than 2% moisture content.

However, when comparing the stockpiles according to layer with an interval of 10 cm each, this study can shows which part of jointing sand that can be use. For instance, further investigation can be seen on stockpile A3 which at 20 cm height it shows moisture content of 4%. This means by, the sand that is lower than interval of 20 cm height could not be use as joint filling material, meanwhile above the interval of 20 cm height can be used at certain part. Nevertheless, if stockpile A1 were taken into consideration, almost all of the stockpiles can be utilize. This is because the result shows less than 2% moisture content at below interval of 10 cm height. Probably the higher moisture content represent in the graph is located only few height away from the datum. Figure below shows the result of moisture content for various stockpile height in X-X axis direction which taken on 2,4 and 6 hours duration of sun exposure. While for Y-Y axis direction appears to be in similar trend.





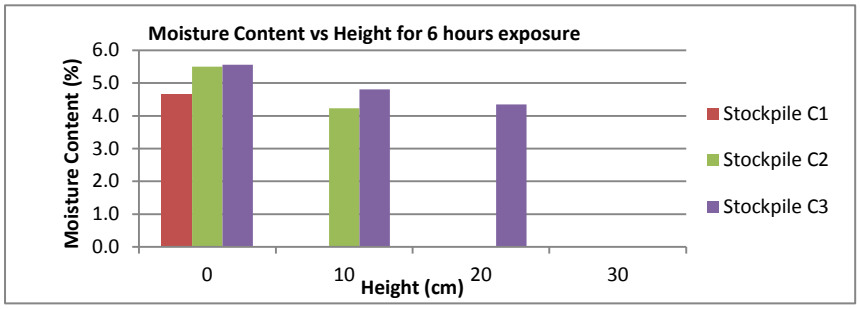


Figure 3: Result of Moisture Content for Various Stockpile Height in X-X axis direction

Effects of Drying Period of Jointing Sand under The Sun

Based on result of moisture content test for different period of sun exposure, indicates that dryness of jointing sand decreased linearly with time. Figure 4 shows an example of declination in moisture content against time for stockpile A2, B2 and C2 which is in 20 cm height. The figure represents the same size of jointing sand stockpile with different time exposure which is in 2 hours, 4 hours and 6 hours respectively. Point a, b, e, f and j shows moisture content less than 2% which is lower than point c, d, g, h and i. This is because these points are located at the surface of the stockpile where it is directly being exposed to sunlight. Hence, this is the only part of the jointing sand that can be used after the drying process. The entire points that are located inside the stockpiles display more than 4% moisture content which is not applicable for joint filling material even though it is being exposed under the sun until 6 hours and have an equivalent in size. Furthermore, this outcome appeared to be the same as other stockpiles that have similar in height and the trend for Y-Y axis direction also shows almost alike.

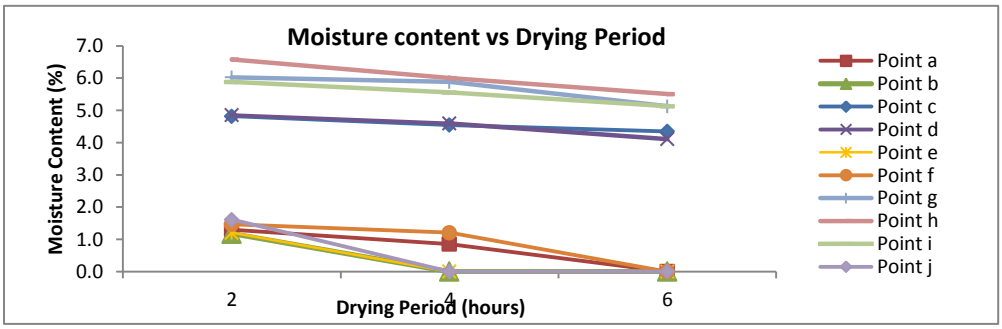


Figure 4: Moisture content vs Drying Period for Stockpile A2, B2 and C2 in X-X axis direction

The average reduction of moisture content test for all of the stockpiles can be observed as Table 2 below. The reduction is measured from initial reading of moisture content which is by 8%. Moisture content for 6 hours duration shows the highest average reading which is mostly 5% reduction for all of the stockpiles. Nonetheless, as mentioned previously on Figure 4, the jointing sand does not suitable to use as joint filling material. This denotes that the jointing sand required more than 6 hours of sun exposure to be able for it to use before paving installation. Besides, this can be supported by one of the literature review done by Hashemi (2011).

Table 2: Average Reduction of Moisture Content for all of the stockpiles

	Average Reduction of Moisture Content (%)		
Stockpile Height (cm)	A (2 hours)	B (4 hours)	C (6 hours)
X-X			
10	2.9	4.3	4.2
20	4.3	4.3	5.1
30	4.3	4.8	5.6
Y-Y			
10	2.9	4.0	4.3
20	4.2	4.3	5.0
30	4.0	4.5	5.4

Water Contour Profile for Jointing Sand after Sand Dryness

Determination of water contour is essential to estimate the reduction moisture content in stockpile. Besides that, it also can determine on which layer of sand is appropriate and ready to be used. According to Figure 5, it is observed that the

water contour moves rapidly approaching the red line and slowing down towards the bottom of the stockpiles. The water that leaves the surface shows reduction of moisture content which later might be used as jointing sand while the water that moves slowly towards the bottom contains highest moisture content.

Other than that, the contour profile also represent almost similar gap between other contour lines. This means that the water moves gradually downwards by gravity and estimation on suitable layer of jointing sand can easily be made. Further analysis can be estimated, which is all off the stockpiles can be used approximately 4 cm from the surface layer. Same goes to stockpile B and C which display likely the same contour on X-X axis and Y-Y axis direction.

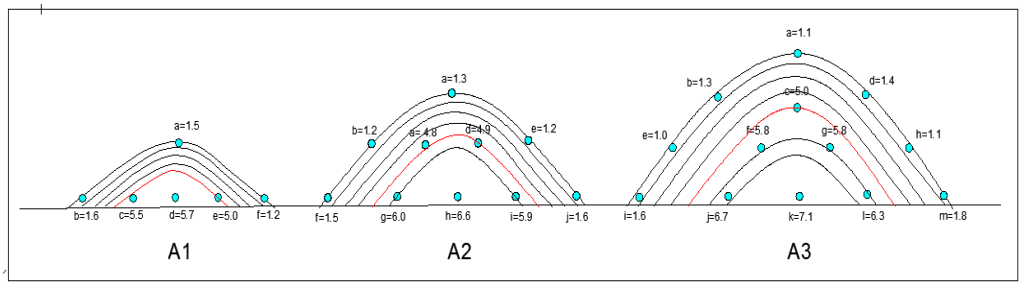


Figure 5: Water contour profile for all drying period on X-X axis

CONCLUSION

Jointing sand can be used when the moisture content below 2%. Common practiced made by contractor is ignoring the sand dryness before paving installation. This study investigates the effects of moisture variations in jointing sand stockpile and sand dryness using free fall method. The findings of this study are:

11. The height of the stockpile does not give any significant effect to the sand dryness since in moisture content test result it shows almost similar outcome for all drying period case.

12. The drying rate of jointing sand is linearly increased along time. However, 6 hours period of drying are inadequate to completely dry the whole stockpile. Thus, it is recommended to dry the stockpiles within longer period.

13. The water contour profile of the stockpiles prove that only a part of the stockpile can be utilize even after 6 hours of sun exposure. For all of the stockpiles, a layer of approximately 4 cm from the surface only can be used as joint filling material.

14. This research recommended using surface area as controlled parameter instead of height, since evaporation rate depends on surface area. Jointing sand can be spreaded widely under the sun before paving installment.

15. However, there is space limitation when it comes to site area. Therefore, another technique that might be useful in stockpile drying is by using spiral drain or even suction system.

16. Weather forecast monitoring is also crucial in sand drying process. It is important to have appropraiate weather through out the sand drying and installation process.

REFERENCES

[1] AHMED, A. and Singhi, B., 2013. Overview on structural behaviour of concrete block pavement. *International Journal of Scientific and Engineering Research*, *4*(7), pp.782-789.

[2] Clifford, J.M., 1983. *Segmental Block Pavements: Optimizing Joint Width and Joint Material* (No. Tech Rept NRP/14/83). National Institute for Transport and Road Research.

[3] Concrete Masonry Association of Australia (CMAA). 1986. *Concrete Segmental Pavements; Design Guide for Residental Accessways and Roads*. NSW, Australia

[4] Emery, J.A., 1992. Erosion of jointing sand from concrete block paving. In *Proceedings, Fourth International Conference on Concrete Block Paving, Auckland, New Zealand* (pp. 295-300).

[5] Hashemi, E., 2011. Experimental study for enhanced drainage from sand stockpiles.

[6] Knapton, J. and Barber, S.D., 1979, May. The behaviour of a concrete block pavement. In *Institution of Civil Engineers, Proceedings* (Vol. 66, No. Pt1).

[7] Panda, B.C. and Ghosh, A.K., 2001. Source of jointing sand for concrete block pavement. *Journal of materials in civil engineering*, *13*(3), pp.235-237.

[9] Panda, B.C. and Ghosh, A.K., 2002. Structural behavior of concrete block paving. I: sand in bed and joints. *Journal of Transportation Engineering*, *128*(2), pp.123-129.

[10] Standard Specification for Urban Infrastructure Works, (September 2002). *Segmental Paving; Section 1*. Retrieved from Transport Canberra and City Services (ACT Government) website: http://www.tccs.act.gov.au/__data/assets/pdf_file/0011/397109/SS12_Segmental_Paving_01_00.pdf

[11] Simmons, G.H., ND. *Technical Paper : Stockpiles* (No Tech Rept T-129). Arizona Simulation Technology and Education Center (ASTEC)

[12] Yusoff, N.I.M., Hainin, M.R. and Nor, H.M., 2012. Cirian pasir pengisi sambungan turapan blok konkrit saling mengunci pada jarak sambungan dan kecerunan yang berbeza (Jointing sand characteristics of interlocking concrete block pavements at different slopes and joint widths). *Sains Malaysiana*, *41*(1), pp.103-110.

The Effect of Bedding Sand on Joint Filling of Concrete Block Pavement

Zaidatul Shakirah Zaba, Hasanan Md. Nor

Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

hasanan@fka.utm.my

Keywords: Bedding Layer; Bedding Sand; Joint Filling; Concrete Block Pavement.

ABSTRACT. The aim for this study the relationship between the bedding sand and the height of bedding sand passing the joint filling in terms of three parameters which are the bedding sand size, the moisture content of bedding sand and the compaction passes. Bedding sand is the layer used as bedding component in concrete block pavement to provide the flat surface for the differences in blocks thickness. Joint is the gap between the block and be filled with the jointing sand that provides to transferring the load between blocks. The concrete block used in this study is 200 mm x 100 mm x 50 mm and the bedding sand thickness is 70 mm before compacted and 50 mm after the compaction. The joint used is in the range 2 mm to 7 mm. The height of joint filling is tested by measuring the blocks settlement. It can be concluded that the bigger the sand size the higher the block settlement, the moisture content only has slightly differences in block settlement, and the higher the compaction passes the higher the block settlement.

INTRODUCTION

Concrete block pavement consists of five layers which starts with subgrade, subbase if needed, non-erosive road base, the bedding layer to get the flat surface of concrete block pavement and the concrete block layer. Concrete block pavement also consists of joint filled with sand in between the gap of concrete block to ensure the uniformity of load transfer between the block happen. It is also consisting of edge restraints at the end of the road to prevent the concrete block for collapsed. Concrete block pavement can be seen at the intersection of the road and also the parking area.

The technique to construct concrete block pavement generally starts by compacting the most bottom layer which is the subgrade, followed by compacting the subbase and road base, then a layer of bedding sand will be laid on top of the road base in the loose condition. Concrete block will be arranged according to the joint thickness and the layer pattern then the concrete block will be compacted. After that, the jointing sand will be filled into the compacted concrete block by the vibrating method.

Problem Statement

The components of concrete block pavement are subgrade, subbase, road base, bedding layer, concrete block and jointing sand. Bedding layer is a layer that used bedding sand for providing the flat surface for the concrete block pavement. Jointing sand is the component for transferring the load between the concrete block pavements. Jointing sand is filled in the joint which is a gap between the concrete block.

Bedding sand layer is placing in loose thickness before the concrete block arrangement. After the concrete block arrangement, the compaction on the concrete block will be conducted. After the compaction conducted, there will be the bedding sand from the bedding layer getting into the joint. The height of bedding sand getting into the joint can be differ in terms of bedding sand parameter which is in the bedding sand size, the moisture content of bedding sand and the amount of compaction of bedding sand.

Objectives

This study will cover the following objectives which are:

1. To identify the relationship between the size of bedding sand and the height of bedding sand getting into the joint filling.

2. To study the relationship between the moisture content of bedding sand and the height of bedding sand getting into the joint filling.

3. To determine the relationship between the compactive efforts of bedding sand and the height of bedding sand getting into the joint filling.

Scope of Study

This research is carried out to study the structural behavior and failure mechanism of IBS blockwork system so that the IBS blockwork system can be implemented in residential building construction. A scaled down 1:5 model is assembled

using autoclaved aerated lightweight concrete blocks and jointed using just a bolted connection. The model is loaded and tested in cyclic pushover test by applying lateral load monotonically up to collapse state. The robustness or ultimate strength of lightweight concrete blockworks is not investigated in this research. The experimental result will be compared with modelling results from numerical non-linear finite element analysis.

LITERATURE REVIEW

Concrete block pavement has been used since early 1950s as a replacement for baked clay brick roads in The Netherland [2]. Concrete block pavement has been applied to the reasons of the rising cost of bitumen and also the cost for construction and maintenance of asphalt pavement. Concrete block pavement comes with four to five components that helps to provide the better performance of the pavement. Components of concrete block pavement are starting with the low layer which is subgrade, subbase, base layer with is optional, bedding layer and concrete block layer. Concrete block pavement also consists of jointing sand and edge restraint component. Edge restraint are placed on the both end of the pavement for maintaining it with the fixed boundary of the road.

Bedding layer is a loose layer that laid after the subbase or base layer are being compacted in concrete block pavement. The bedding layer is used as to provide the flat surface for the differences in the block thicknesses, to prevent the damage to block by initiate the consistent support for each block and to level the instability of layer at the layer below [1]. The process of chosen the size of bedding sand is important for better concrete block pavement. A maximum sand size of 9.52 mm with a maximum limit of 10 % passing the 75 μm sieve[6].

Thickness of bedding sand affect the deflection occur at the concrete block pavement. The bedding layer using the river sand size more than 2.36 mm with 20 mm to 80 mm thickness of bedding layer, the deflection decrease gradually and increase at the thickness 50 mm to 80 mm. At 50 mm thickness, the deflection occur is the minimum [7].

Jointing sand is the gap between the concrete block filled with sand which acts to distribute load to become uniform and make the interlock between those concrete block. The presence of sand in the joints plays the important role in promoting load transfer between blocks. Frictional resistance is developed in the joints under load, this prevent the blocks from undergoing excessive relative displacements and transmits part of the load to adjoining blocks [4].

The concrete block in the pavement without jointing sand acts as individual blocks due to no transmit of load between blocks. For each joint width 2.5 mm and 4 mm, the pavement without jointing sand will deflect three times than pavement with jointing sand [7].

The joints filling with sand are important part of concrete block pavement as they permit and provide the interlocking for stresses to be distributed among the adjacent blocks. The width of joint need to be sufficiently to allow this stress to be distributed. The width of joint may varies from 2 mm to 7 mm. The optimum width of joint between blocks is 3 mm [4].

METHODOLOGY

The objectives of this study are to identify the relationship between the size of bedding sand, the moisture content of bedding sand and the compaction efforts of concrete block and the height of bedding sand passing the joint filling. This research methodology consists of four key activities: sieve analysis test, moisture content test, concrete block pavement preparation and compaction test.

Sieve Analysis Test

Sieve analysis test is to grade and identify the soil based on the suitable sand. The procedure and specification for this test are followed the BS:1377 Part 1 (1990) Clause 3. For this study, the dry sieve analysis is used with three different samples labelled sample 1, sample 2 and sample 3. Each samples are sieved with the vibrator at 15 minutes.

Moisture Content Test

Moisture content test is to determine the moisture content in the sand for the sampling preparation. The optimum moisture content for bedding sand are in range 4% to 8%. Therefore, three sample of moisture content of bedding sand is tested to identify the effect of moisture content of bedding sand on the percentage passing bedding sand into the joint. The moisture content of bedding sand tests is 4%, 6% and 8%.

Placing Bedding Sand and Concrete Block Pavement Arrangement

The concrete block preparation is used the pull in test box with dimension 1000 mm x 1000 mm. The loose thickness of bedding sand before compaction is 70 mm and after compacted is 50 mm. The concrete blocks arrangement is in the grid system shown in Figure 1. The dimension for concrete block used is 200 mm x 100 mm x50 mm.

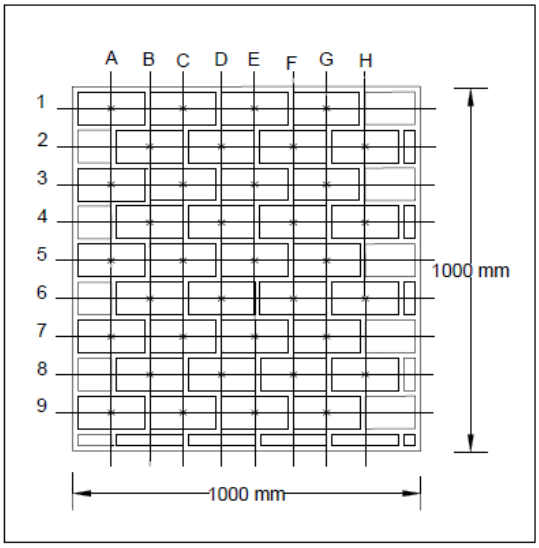


Figure 1: The grid arrangement for concrete blocks

Compaction Test

The purpose of compactor test is to compact the concrete block into the bedding sand for providing the flat surface of concrete block. There are three compaction passes used in this research study which are two passes, four passes and six passes.

RESULTS AND DISCUSSION

The results of sieve analysis test, moisture content test, compaction test and block settlement is discussed as below. The relationship between the bedding sand and joint filling in terms of bedding sand size, moisture content of bedding sand and the compaction passes of bedding sand are present through table and chart.

Sieve Analysis Test

The sieve size used for bedding sand in sieve analysis test are from 9.50 mm to 0.075 mm. There are three samples that have been tested to determine the average of the distribution of bedding sand. In Figure 2, it shows that all the three samples are in the gradation limit. Therefore, the bedding sand is suitable to be used as bedding layer in this study. According to ASTM D-2487, the results that shows more than 50% retained on the 0.075 mm sieve size can be classified as course-grained soils and for it classified as sands if 50% or more of course fraction passes the 4.75 mm sieve size. From the data collected, the bedding sand can be classified as course-grained soil and sands as there are 98.9% that retained on the 0.075 mm sieve size and 97.4 % that passes the 4.75 mm sieve size in average.

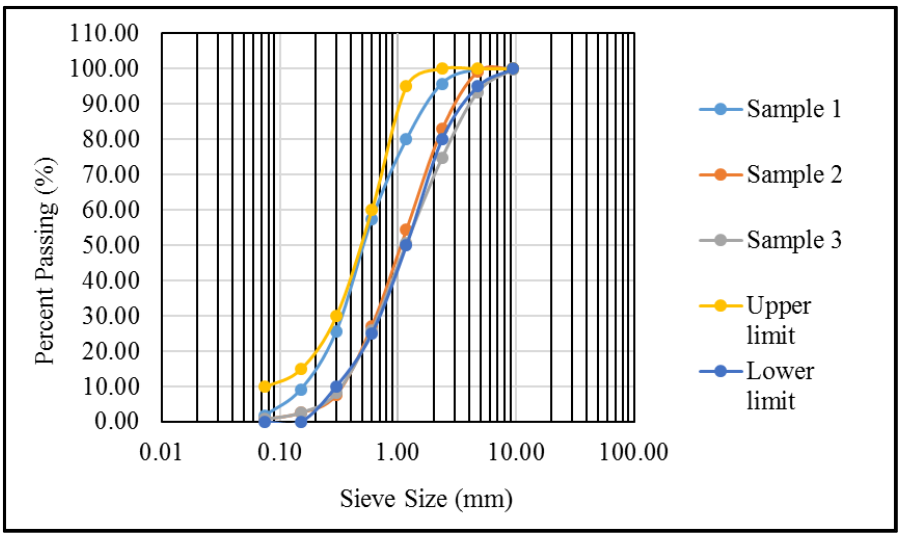


Figure 2: Distribution size of bedding sand

Moisture Content Test

The moisture content test is being tested on the bedding sand to determine the percentage of moisture content for the samples. There are three samples of moisture content being used for the experiment which are 4%, 6% and 8%. For each samples, before layered the bedding sand in the pull in test box, there are three sample from the bedding sand taken to determine the moisture content. Table 1, Table 2 and Table 3 show that the all samples for determine the moisture content is in the range of the moisture content required which are 4%, 6% and.8%. There is difference between the samples as the sand before compacted has difference moisture content. After the compaction, the moisture content of the sand be in the required moisture content.

Table 1: Data collected for moisture content for sample 4%

	Sample 1	Sample 2	Sample 3
Container No.	A	B	C
Mass of container, g	51.1	51.1	51.1
Mass of wet sand + container , g	106.3	106.5	107
Mass of dry sand + container , g	104.3	104.2	105
Mass of moisture, g	2.0	2.3	2
Mass of dry soil, g	53.2	53.1	53.9
Moisture content, %	3.8	4.3	3.7
Average (%)	3.9		

Table 2: Data collected for moisture content for sample 6%

	Sample 1	Sample 2	Sample 3
Container No.	A	B	C
Mass of container, g	51.2	51.1	51.1
Mass of wet sand + container , g	109	108.2	107.7
Mass of dry sand + container , g	105.5	104.3	104.9
Mass of moisture, g	3.5	3.9	2.8
Mass of dry soil, g	54.3	53.2	53.8
Moisture content, %	6.4	7.3	5.2
Average (%)	6.3		

Table 3: Data collected for moisture content for sample 8%

	Sample 1	Sample 2	Sample 3
Container No.	A	B	C
Mass of container, g	51.1	51.1	51.1
Mass of wet sand + container , g	109.4	108.2	108.5
Mass of dry sand + container , g	105.3	103.9	104.2
Mass of moisture, g	4.1	4.3	4.3
Mass of dry soil, g	54.2	52.8	53.1
Moisture content, %	7.6	8.1	8.1
Average (%)	7.9		

Compaction Test

The compaction test is conducted for this experiment on the concrete block for levelling the block on the bedding sand layer. There are three different compaction passes being used on this experiment which are two passes, four passes and six passes. The compaction of concrete block is needed to levelling the concrete block pavement.

Settlement of Concrete Block

This data collected for this test is based on the grid as shown in Figure 1. Each sample has 36 points. For all the samples for this study, there are 288 points for data collected. The data of settlement of concrete block is collected after the compaction test being conducted. The loose thickness of concrete block to the bedding layer is collected before the compaction test. The settlement of concrete block is collected based on difference in the parameter of bedding sand which are in bedding sand size, the moisture content of bedding sand and the compaction passes.

Settlement of Concrete Block in relation to Bedding Sand Size

There are two samples of bedding sand size being used for this study which are retained 4.75 mm and passing 9.50 mm. The moisture content is fixed at 6% for both samples and compaction passes used is two passes. Figure 3 shows the average block settlement after the two compaction passes.

The average block settlement after the two compaction passes for bedding sand size passing 9.50 mm is higher than bedding sand size retained 4.75 mm. The average settlement for both sand size in the range of 8 mm to 15 mm. From Figure 3, it shows that the sand size which passing 9.50 mm will have lower settlement compare to sand size retained 4.75 mm. This show that the bigger sand size will have the lower settlement compare to the smaller sand size.

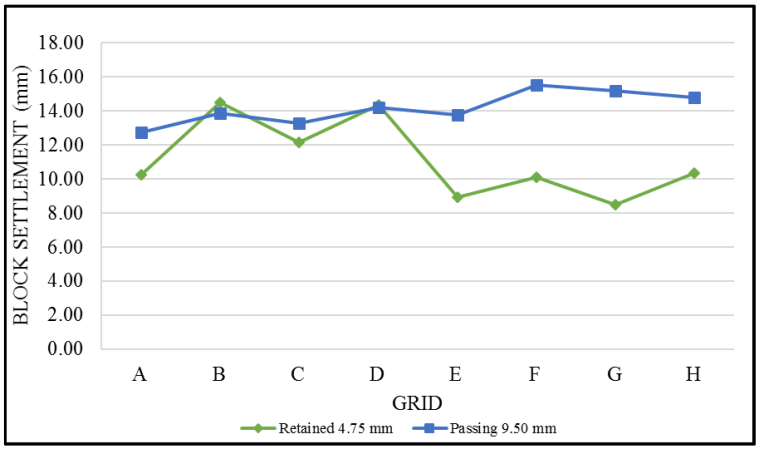


Figure 3: The average block settlement after the two compaction passes

Settlement of Concrete Block in relation to Moisture Content

There are three samples of moisture content of bedding sand being used for this study which are 4%, 6% and 8%. The bedding sand size is fixed at retained 4.75 mm for all samples and the compaction passes used is two passes. Figure 4 shows the average block settlement for moisture content 4%, 6% and 8%. The average block settlement after the two compaction passes for moisture content bedding sand 4%, 6% and 8% are in the range of 10 mm to 16 mm. This shows that the difference in moisture content of bedding sand will just have a slightly difference in the block settlement.

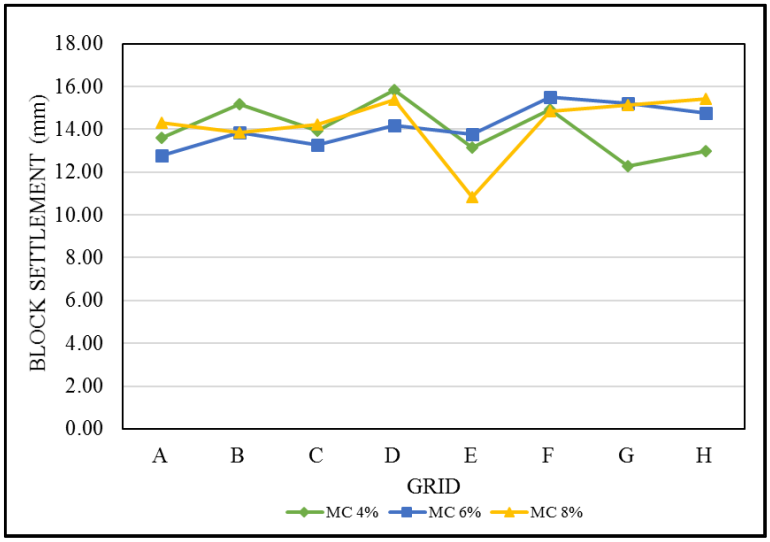


Figure 4: The average block settlement for moisture content 4%, 6% and 8%

Settlement of Concrete Block in relation to Compaction Passes

There are three samples of compaction passes of bedding sand being used for this study which are 2 passes, 4 passes and 6 passes. The bedding sand size is fixed at retained 4.75 mm for all samples and the moisture content used is 6%. Figure 5 shows the average block settlement for compaction 2 passes, 4 passes and 6 passes samples. The average block settlement after the six compaction passes is higher than two and four compaction passes. The average settlement all moisture content samples in the range of 12 mm to 18 mm. From Figure 5, it shows that the higher the compaction passes the higher the block settlement due to the increment of load applied on the concrete blocks.

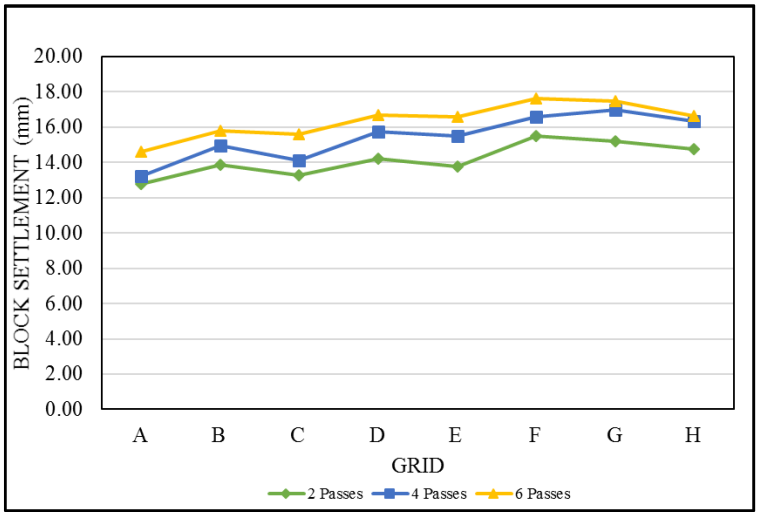


Figure 5: The average block settlement for compaction 2 passes, 4 passes and 6 passes samples

CONCLUSION

This research presents the relationship between the bedding sand and the height of bedding sand passing the joint filling.

1. From the settlement due to bedding sand size, it can be concluded that the bigger the sand size the lower the block settlement.

2. From the settlement due to moisture content of bedding sand, it can be concluded that the moisture content only has slightly differences in block settlement.

3. From the settlement due to compaction passes, it can be concluded that the higher the compaction passes the higher the block settlement.

REFERENCES

[1] Lilley, A.A. and Dowson, A.J., 1988, May. Laying course sand for concrete block paving. In *Proceedings* (pp. 457-462).

[2] Van der Vlist, A.A., 1980. The development of concrete paving blocks in the Netherlands. In *First International Conference on Concrete Blocks Paving*.

[3] Shackel, B., O'Keeffe, W. and O'Keeffe, L., 1993. Concrete block paving tested as articulated slabs. In *Fifth International Conference on Concrete Pavement Design and Rehabilitation* (Vol. 1).

[4] Mudiyono, R. and Nor, H.M., The Effect of Joint Width between Blocks in Concrete Block Pavement Rachmat Mudiyono, Hasanan Md. Nor 2 and Tung Chai Ling 3.

[5] Mohamed, A., Nor, H.M., Hainin, M.R., Yaacob, H., Ismail, C.R. and Ahmad, N., 2011. Interaction of Underside Shaped Concrete Blocks and Bedding Sand. In *Research Seminar in Civil Engineering (SEPKA)* (pp. 469-476).

[6] Livneh, M., Ishai, I. and Nesichi, S., 1988, May. Development of a pavement design methodology for concrete block pavements in Israel. In *International Conference on Concrete Block Paving, 1988, 3rd, Rome, Italy*.

[7] Panda, B. C. & Ghosh, A. K. 2002. Structural behavior of concrete block paving. I: sand in bed and joints. Journal of Transportation Engineering 128(2):123-129.

[8] Panda, B.C. and Ghosh, A.K., 2002. Structural behavior of concrete block paving. II: Concrete blocks. *Journal of transportation Engineering*, *128*(2), pp.130-135.

[9] Shackel, B., 1980. The performance of interlocking block pavements under accelerated trafficking. In *Proc., 1st Int. Conf. on Concrete Block Paving* (pp. 113-120).

[10] Shackel, B. and Lim, D.O.O., 2003. Mechanisms of paver interlock. In *7th International Conference on Concrete Block Paving*.

[11] Rosli H., Che Ros, and Haryati (2010). *Highway Engineering SKAA 2832*. (Edition 2015). Faculty of Civil Engineering, Universiti Teknologi Malaysia: Desktop Publisher.