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TECHNOLOGY**

**JST**

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*A special issue devoted to*  
**Technology for Future Sustainability**

Guest Editors

**Ismail Abdul Rahman, Sasitharan Nagapan & Rohana Hassan**



**PERTANIKA**  
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## *Journal of Science & Technology*

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43400 Serdang, Selangor Malaysia.

Gen Enq.: +603 8947 1622 | 1616

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**Kamariah Mohd Saidin**

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43400 UPM, Serdang, Selangor, Malaysia.

Tel: +603 8946 8855, 8946 8854

Fax: +603 8941 6172

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# Preface

We are very pleased to present this special issue of the International Journal of Science & Technology (JST). It is a compilation of 34 selected papers, out of 52, that were presented at the International Conference on Sustainable Engineering and Technology (InConSET 2016), held on 29th September 2016 in Malacca, Malaysia. The InConSET 2016 was a collaboration between Universiti Tun Hussein Onn Malaysia (UTHM), Universiti Teknologi Mara (UiTM) Shah Alam, Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA) and Concrete Society of Malaysia (CSM). In line with the theme 'Technology for Future Sustainability', the InConSET 2016 conference tracks included but not limited to: Constructions and Materials, Highway & Transportation Engineering, Soil & Water Engineering,, Survey Engineering, Build Environment, Facility Management & Building Services, Wood Based Technology, Knowledge Management, Safety & Risk Management, Electrical & Electronic, Bio Medical, Artificial Intelligent, Signal Processing, Computing & Information Technology, Manufacturing, Material Science, Packaging & Technology, Robotics & Automation, Instructional Design & Technology, Sports & Recreation, Talent Management & Character Building, Applied Science & Mathematics, Green Technology & Sustainability and others (social sciences).

We would like to thank the contributors as well as reviewers for their commitment and hard work which made this JST InConSET 2016 a successful endeavour. It is hoped that this publication would encourage researchers from around the world to be more active in publishing their research papers.

Special thanks goes to the Chief Executive Editor, UPM Journals, Dr Nayan Kanwal, for his support in making this publication possible. This has certainly motivated us to do better in the future.

## **Guest Editors:**

Ismail Abdul Rahman (*Prof. Dr.*)

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**May 2017**



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## Influence of Kenaf Fibre Orientation Effect on the Mechanical Properties of Hybrid Structure of Fibre Metal Laminate

L. F. Ng<sup>1\*</sup>, D. Sivakumar<sup>1,2</sup>, K. A. Zakaria<sup>1,2</sup>, O. Bapokutty<sup>1,2</sup> and Sivarao<sup>3</sup>

<sup>1</sup>Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

<sup>2</sup>Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

<sup>3</sup>Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

### ABSTRACT

Efforts to reduce manufacturing cost and negative environmental impacts have seen the mixture of natural fibre with synthetic fibre in composite structures. However, there are limited studies on the notch effect and fibre orientation on mechanical properties of hybrid fibre metal laminate (FML). In this study, tensile properties of FML with notch and different fibre orientation were investigated. The hybrid FML incorporated with kenaf fibre at the middle layer was compared with FML with three layers of E-glass fibre. Kenaf fibre and E-glass fibre used were in plain woven form. The FML in 2/1 configuration was manufactured through hot press manufacturing method to bond layers of annealed aluminium 5052 to the composite. Tensile test was conducted in a quasi-static manner according to ASTM E8. The results showed FML with three layers of glass fibre exhibited higher tensile strength compared with hybrid FML. However, the introduction of kenaf fibre in hybrid FML reduces the notch and fibre orientation sensitivity compared with glass fibre reinforced FML.

*Keywords:* Fibre metal laminates, fibre orientation, hybrid, mechanical properties, notch effect

### ARTICLE INFO

#### Article history:

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#### E-mail addresses:

[nglinfeng@yahoo.com](mailto:nglinfeng@yahoo.com) (L.F. Ng),

[sivakumard@utem.edu.my](mailto:sivakumard@utem.edu.my) (D. Sivakumar),

[kamarul@utem.edu.my](mailto:kamarul@utem.edu.my) (K. A. Zakaria),

[omarbapokutty@utem.edu.my](mailto:omarbapokutty@utem.edu.my) (O. Bapokutty)

\*Corresponding Author

### INTRODUCTION

Fibre Metal Laminate (FML) as shown in Figure 1 has been used in a wide variety of applications especially in the aerospace industry over the last decades. The FML is made of alternative layers of metallic alloys and polymer composites bonded using an adhesive agent. Thermosetting-based FML was developed in Delft University of

Technology to overcome the disadvantages of aluminium alloys and polymer composites. It combines the advantages of metallic alloys and polymer composites (Pawar et al., 2015). The development of FML overcomes poor fatigue and corrosion characteristic of metal and low tensile and impact strength as well as reparability in composites (Sinmazcelik et al., 2011).

In recent times, FML is being considered for several applications in the automotive field due to its outstanding impact properties and fatigue crack resistance as well as strength to weight ratio compared to conventional aluminium alloy. Previous experimental work on FML with glass fibre reinforced polypropylene composite had shown this structure provides excellent resistance under low and high impact loadings (Reyes & Cantwell, 2000). Glass fibre reinforced epoxy (GLARE) FML was proven to have superior tensile strength than monolithic aluminium at high strain rate (Zhu & Chai, 2012). Furthermore, Vogelesang and Vlot (2000) found that fatigue crack growth rate in FML was one tenth or one hundredth compared with monolithic aluminium. Cheah (2010) stated that 10% weight reduction in vehicle can reduce 7% energy consumption. Glass fibre reinforced polypropylene FML is found to be lighter than aluminium alloys and steel up to 30% and 65% respectively (DharMalingam et al., 2014; Subesh et al., 2015).

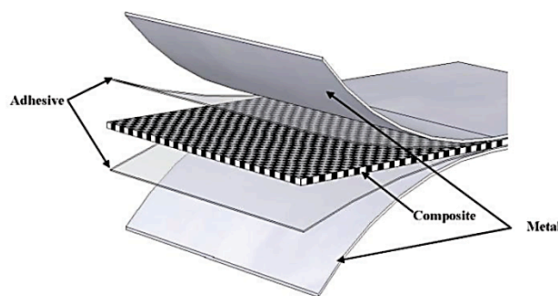


Figure 1. FML structure (DharMalingam & Kalyanasundaram, 2013)

In order to reduce energy consumption and negative impact on the environment, natural fibres such as kenaf, flax and jute fibres together with thermoplastic are explored in FML fabrication. Natural fibres have a relatively lower density and biodegradable characteristic compared with synthetic fibre, and are a good candidate to substitute synthetic fibre (Shinji, 2008). The main limitation in natural fibre is its hydrophilic behaviour which results in poor compatibility with thermoplastic matrices and low mechanical strength (Fiore, 2015). One way to overcome its limitations is through hybridization of natural fibre with synthetic fibre. It had been shown that hybridization of natural fibre with synthetic fibre can reduce hydrophilic behaviour, therefore, improving the tensile strength and impact properties of the composite structure (Khalil, 2009).

In the transport industry, holes are drilled for assembly purposes but this eventually affects the service performance of the structure. There are limited studies that address the notch effect and fibre orientation on the mechanical properties of FML. Pawar et al. (2015) on



their analysis of drilling hole in GLARE found 2-fluted drill provided the best quality in the drilling of GLARE without delamination and acceptable burr formation compared with 3-fluted, 4-faceted and 8-faceted drills. A study by Qi et al. (2015) on the effect of fibre orientation on mechanical properties of carbon fibre reinforced aluminium matrix composite, concluded that fibre orientation had a significant effect on the ultimate tensile strength of the composite. There are not many studies on bio-based hybrid FML and therefore, in this study, tensile test at the quasi-static rate was conducted to study the effect of notch, fibre configuration and fibre orientation on the mechanical response of bio-based hybrid FML.

## **MATERIALS AND METHODS**

Plain weave woven kenaf fibre, 295 g/m<sup>2</sup> in areal weight, was obtained from Lembaga Kenaf dan Tembakau Negara. Meanwhile, plain weave woven E-glass fibre with an areal weight of 600 g/m<sup>2</sup> was obtained from ZKK Sdn. Bhd. Homopolymer polypropylene (PP) granule with a density of 0.9 g/cm<sup>3</sup> was supplied by Al Waha petrochemical company. The coupling agent, Maleic Anhydride Polypropylene (MAPP), was provided by Sigma-Aldrich Co Inc. Skin layers of FML, aluminium 5052-H32, was obtained from Novelis Inc. The thickness of aluminium used was 0.5 mm. Modified polypropylene with a density of 0.91 g/cm<sup>3</sup> was used as an adhesive agent to bond aluminium skin layers to composite.

### **Preparation of FML**

A composite with a thickness of 3 mm was manufactured using GOTECH hydraulic hot press machine. PP was first mixed with 3 wt% of MAPP using HAAKE Rheomix OS internal mixer at 175°C and 50 rpm. This process was aimed at improving the adhesion between thermoplastic matrix and reinforcement thereby boosting its mechanical properties (Agung et al., 2012; Fabiola et al., 2010). The mixtures were then compressed to form PP sheets with 0.5 mm thickness. Three layers of woven fibre were aligned according to their warp direction. PP sheets were stacked between the layers of fibre and the entire stack was compressed at 3.5 MPa hydraulic pressure and temperature of 175°C to form composite panels. The total fibre volume fraction for composites was controlled at around 22%. The FML was prepared through hot press compression method. Aluminium 5052-H32 was first annealed at 345°C using Nabertherm N41/H furnace. The FML with 2/1 configuration was stacked as shown in Figure 1 in a picture frame mould and adhesive agents were located at the bilayer. The configuration was then hot compressed at a controlled temperature of 170°C and pressure of 1 MPa. Glass fibre reinforced FML was represented as [G/G/G] whereas hybrid FML was represented as [G/K/G]. The produced FML panels were cut according to ASTM D3039. Some of the specimens were drilled to form 4 mm diameter hole.

### **Mechanical Test**

A tensile test was conducted at a quasi-static cross-head displacement rate of 2 mm/min according to ASTM D3039 standard using Instron 8802 Universal Testing Machine (UTM). The tensile properties of notched specimens were determined in accordance with the net cross-

sectional area. Failed specimens were then analysed using Scanning Electron Microscope (SEM).

## RESULTS AND DISCUSSION

The tensile behaviour of glass fibre reinforced thermoplastic FML are compared with FML which is hybrid of natural fibre and synthetic fibre. Figure 2 shows the boxplot for FML and hybrid FML. The results show the effect of kenaf fibre is not significant for un-notched specimens ( $p$ -value = 0.122) and specimens with  $\pm 45^\circ$  fibre orientation ( $p$ -value = 0.287) whereas notched specimens ( $p$ -value = 0.073) are close to being statistically significant at a confidence level of 95%. Figure 3 shows the stress-strain curve for un-notched FML specimens. From Figure 3, failure mechanism for both FML shows the combination of tensile behaviour of aluminium and composite. Failure of the specimens started in composite followed by aluminium layers. Glass fibre reinforced thermoplastic [G/G/G] FML exhibited higher tensile strength than hybrid [G/K/G] FML. Since glass fibre is stronger than natural fibre, FML has higher ultimate tensile strength compared with hybrid FML. The ultimate tensile strength and modulus of FML and hybrid FML were found to be  $91.9 \pm 3.7$  MPa,  $23.6 \pm 0.3$  GPa,  $87.6 \pm 0.9$  MPa and  $23.1 \pm 1.3$  GPa respectively.

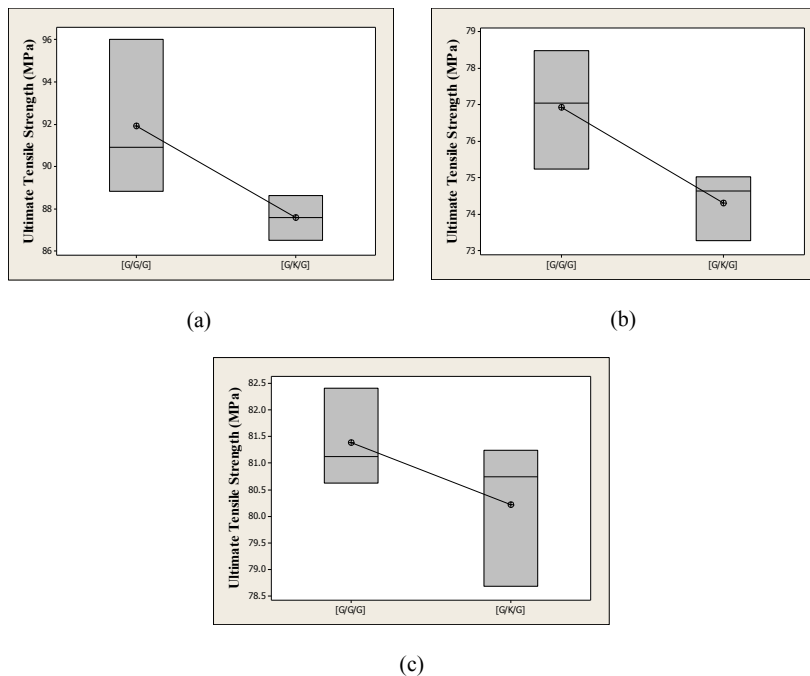


Figure 2. Boxplot for FML and hybrid FML: (a) un-notched; (b) notched; and (c)  $\pm 45^\circ$  fibre orientation

Figure 4 shows the stress-strain curve for notched FML specimens under tensile test at quasi-static rate. Notch develops stress concentration in the specimens, thus, reducing their tensile strength. The presence of notch reduced the ultimate tensile strength of FML and

hybrid FML by 16.3%, from  $91.9 \pm 3.7$  MPa to  $76.9 \pm 2.6$  MPa and 15.2%, from  $87.6 \pm 0.9$  MPa to  $74.3 \pm 1.6$  MPa respectively. The tensile behaviour of FML implied that glass fibres are more sensitive to notch effect compared with kenaf fibre. Notch develops damage in the layer of glass fibres and kenaf fibre. When the load increases, the damage starts to propagate around the notch due to high stress concentration. The higher notch sensitivity of glass fibres is because they mainly depend on the matrix for stress transfer whereas kenaf fibres are able to transfer stress across their filaments through sliding friction. The cell walls of natural fibres consist of helically wound cellular microfibrils (John & Anandjiwala, 2008). This alignment of kenaf fibre allows the fibres closely hold together under tensile test and hence, stress can be transferred efficiently thereby postponing failure in the notched hybrid FML.

Figure 5 shows the stress-strain curve for FML with  $\pm 45^\circ$  fibre orientation. The results showed the ultimate tensile strength for both FML with  $\pm 45^\circ$  fibre orientation was lower compared with FML with  $0^\circ/90^\circ$  fibre orientation. Ultimate tensile of  $0^\circ/90^\circ$  [G/G/G] FML was higher by 10.5% compared with  $\pm 45^\circ$  [G/G/G] FML. Meanwhile, ultimate tensile of  $0^\circ/90^\circ$  [G/K/G] FML is higher than  $\pm 45^\circ$  [G/K/G] FML by 10.2%. When the load is applied to the specimen, ultimate tensile strength of both FML with  $\pm 45^\circ$  fibre orientation is dominated by matrix behaviour whereas the ultimate tensile strength of both FML with  $0^\circ/90^\circ$  fibre orientation is governed by fibre properties. Fibre is considered to fully reinforce the matrix when the load is applied along the fibre axial direction, hence it is the main carrier of the load. However, when the fibre orientation is  $\pm 45^\circ$ , it is affected by tensile stress and shear stress which weakens the reinforcement effect. The presence of shear stress reduces the bearing capacity of fibre to fully carry the load. It was observed [G/G/G] FML ultimate tensile strain was higher than hybrid FML for  $\pm 45^\circ$  fibre orientation and vice versa for  $0^\circ/90^\circ$  fibre orientation.

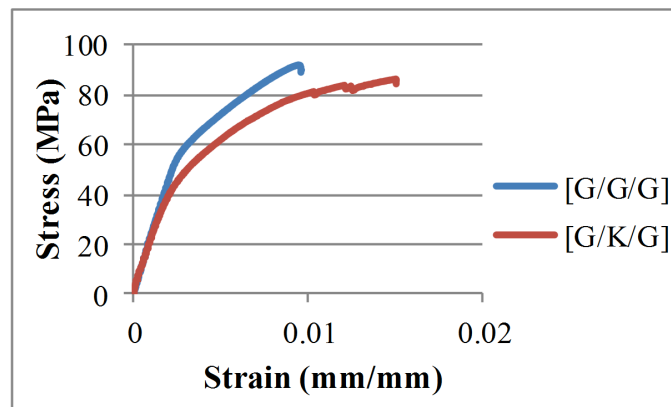


Figure 3. Stress-strain curve for un-notched FML

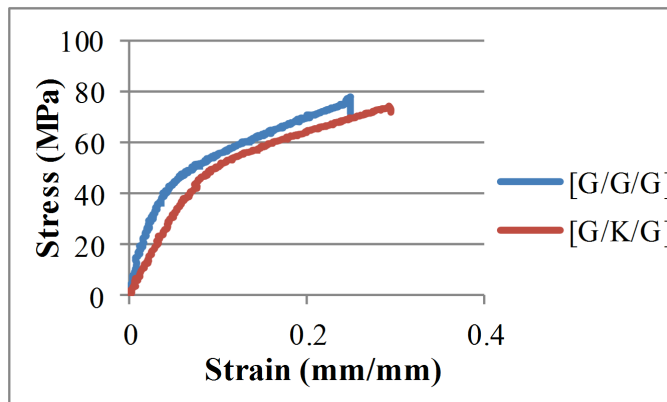


Figure 4. Stress-strain curve for notched FML

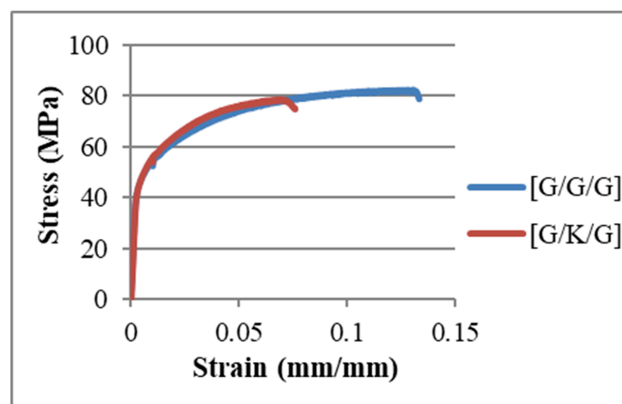


Figure 5. Stress-strain curve for un-notched FML with  $\pm 45^\circ$  fibre orientation

Figure 6 and Figure 7 show the damage mechanism of tensile failure for FML with  $0^\circ/90^\circ$  and  $\pm 45^\circ$  fibre orientation which can be characterised by delamination, fibre pull out and matrix cracking. The introduction of kenaf fibre does not significantly affect the failure mechanism. Fibre splitting was observed in glass fibre for every failed FML specimens. However, fibre splitting behaviour cannot be observed in kenaf layer either in FML with  $0^\circ/90^\circ$  fibre orientation or FML with  $\pm 45^\circ$  fibre orientation. This is due to the mechanical interlocking behaviour of woven kenaf layer.

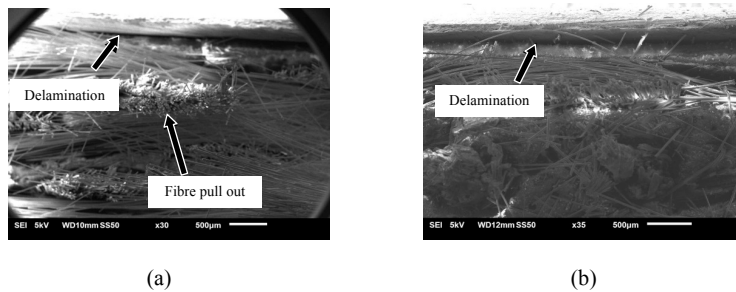


Figure 6. Typical tensile fracture view of failed FML specimens with  $0^{\circ}/90^{\circ}$  fibre orientation under SEM: (a) [G/G/G]; and (b) [G/K/G]

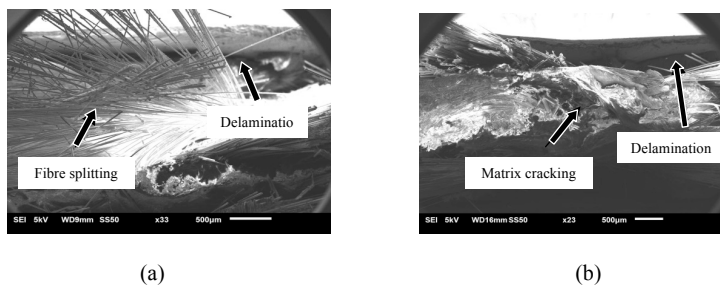


Figure 7. Typical tensile fracture view of failed FML specimens with  $\pm 45^{\circ}$  fibre orientation under SEM: (a) [G/G/G]; and (b) [G/K/G]

## CONCLUSION

This study investigated the effect of notch, fibre orientations and fibre configuration on the tensile properties of FML. Two fibre configurations were considered: FML with three layers of woven glass fibre [G/G/G] and FML with hybridization of one layer of kenaf fibre with glass fibre [G/K/G]. The mechanical properties of hybrid FML were relatively lower than glass fibre reinforced FML irrespective of notch and fibre orientation effect. The introduction of notch reduces the ultimate tensile strength of FML in both configurations. However, the notch sensitivity of hybrid structure of FML was relatively lower than glass fibre reinforced FML. The FML with  $\pm 45^{\circ}$  fibre orientation showed reduced ultimate tensile strength in comparison to FML with  $0^{\circ}/90^{\circ}$  fibre orientation due to shear stress which causes damage to the fibre and hence, weakens the fibre strength. Overall, the hybrid structure of FML shows less notch and fibre orientation sensitivity compared with glass fibre reinforced FML.

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## REFERENCES

- Abdul Khalil, H. P. S., Kang, C. W., Khairul, A., Ridzuan, R., & Adawi, T. O. (2008). The effect of different laminations on mechanical and physical properties of hybrid composites. *Journal of Reinforced Plastics and Composites*, 28(9), 1123–1137.
- Agung, E. H., Sapuan, S. M., Hamdan, M. M., Zaman, H. M. D. K., & Mustofa, U. (2012). Effects of composition parameters on tensile and thermal properties of abaca fibre reinforced high impact polystyrene composites, *Pertanika Journal of Science and Technology*, 20(2), 415–423.
- Cheah, L.W. (2010). Cars on a diet: The material and energy impacts of passenger vehicle weight reduction in the U.S. (PhD Thesis dissertation). *Massachusetts Institute of Technology*.
- DharMalingam, S., & Kalyanasundaram, S. (2013). Temperature effect on forming of self-reinforced polypropylene based lightweight metal composite structure. *Journal of Engineering and Technology*, 4(1), 147-157.
- DharMalingam, S, Sivaraos, Selamat, M. Z., Said, M. R., & Kalyanasundaram, S. (2014). Effects of process parameters during forming of glass reinforced polypropylene based sandwich structure. *Advances in Environmental Biology*, 8(8), 3143-3150.
- Fiore, V., Di Bella, G., & Valenza, A. (2015). The effect of alkaline treatment on mechanical properties of kenaf fibers and their epoxy composites. *Composites Part B: Engineering*, 68, 14–21.
- John, M. J., & Anandjiwala, R. D. (2008). Recent developments in chemical modification and characterization of natural fiber-reinforced composites. *Polymer Composites*, 29(2), 187-207.
- Ochi, S. (2008). Mechanical properties of kenaf fibers and kenaf/pla composites, *Mechanics of Materials*, 40, 446–452.
- Pawar, O. A., Gaikhe, Y. S., Tewari, A., Sundaram, R., & Joshi, S. S. (2015). Analysis of hole quality in drilling glare fiber metal laminates. *Composite Structures*, 123, 350–365.
- Qi, L. H., Ma, Y. Q., Zhou, J. M., Hou, X. H., & Li, H. J. (2015). Effect of fiber orientation on mechanical properties of 2d-cf/al composites by liquid-solid extrusion following vacuum infiltration technique. *Materials Science and Engineering A*, 625, 343-349.
- Reyes Villanueva, G., & Cantwell, W. J. (2004). The high velocity impact response of composite and fml-reinforced sandwich structures. *Composites Science and Technology*, 64(1), 35–54.
- Sexton, A., Cantwell, W. & Kalyanasundaram, S. (2012). Stretch forming studies on a fibre metal laminate based on a self-reinforcing polypropylene composite. *Composite Structures*, 94, 431-437.
- Sinmazçelik, T., Avcu, E., Bora, M. Ö., & Çoban, O. (2011). A review: Fibre metal laminates, background, bonding types and applied test methods. *Materials and Design*, 32(7), 3671–3685.
- Subesh, T., Nafeez, A. L., & Logesh, K. (2015). A survey on fiber metal laminate sandwich panel. *International Journal of Innovative Research in Science, Engineering and Technology*, 4(3), 110–114.
- Vilaseca, F., Valadez-Gonzalez, A., Herrera-Franco, P. J., Pèlach, M. A., López, J. P., & Mutjé, P. (2010). Biocomposites from abaca strands and polypropylene part 1: Evaluation of the tensile Properties. *Bioresource Technology*, 101(1), 387–95.
- Vogelansang, L. B., & Vlot, A. (2000). Development of fibre metal laminates for advanced aerospace structures. *Journal of Materials Processing Technology*, 103, 1–5.
- Zhu, S., & Chai, G. B. (2012). Low-velocity Impact response of fibre–metal laminates – experimental and finite element analysis. *Composites Science and Technology*, 72(15), 1793–1802.



## Digital Learning Resource for Basic Movement Therapy Course: Blended Learning Approach

Zahidah Abd Kadir<sup>1\*</sup>, Shanti Balraj Baboo<sup>2</sup>, Nurul Shuhadah Rosni<sup>1</sup>,  
Zaidatul Husna Abd Rahman<sup>3</sup> and Nurulain Abu Bakar<sup>3</sup>

<sup>1</sup>Universiti Kuala Lumpur, Malaysian Institute of Information Technology, 50250 Kuala Lumpur, Malaysia

<sup>2</sup>Universiti Sains Malaysia, 11800 Gelugor, Pulau Pinang, Malaysia

<sup>3</sup>Universiti Kuala Lumpur Royal College of Medicine Perak, 30100 Ipoh, Perak, Malaysia

### ABSTRACT

This paper is aimed at examining the use of blended learning and how it affects students' score in examination. Basic Movement Therapy (BMT) Digital Learning was constructed and developed based on multimedia design guidelines. A quasi-experimental design using two groups with pre-test post-test approach was used. A total of 103 students from the Universiti Kuala Lumpur, RCMP (Royal College Medical, Perak) were divided in two groups. The Control group received standard teaching sessions (N=51). The Treatment group received the same standard sessions but additionally used BMT Digital Learning application (N=52). Written test on basic movement therapy was done by students before and after intervention. Statistically significant better scores for the treatment group were noted. The results suggest that the use of BMT Digital Learning application was suitable for practical procedure purposes.

*Keywords:* Basic movement therapy, blended learning, digital learning resource, education, therapy

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*E-mail addresses:*

zahidah@unikl.edu.my (Zahidah Abd Kadir),  
shanti@usm.my (Shanti Balraj Baboo),  
nr1shuhadah.adda@gmail.com (Nurul Shuhadah Rosni),  
zaidatulhusna@unikl.edu.my (Zaidatul Husna Abd Rahman),  
nurulain.bakar@unikl.edu.my (Nurulain Abu Bakar)

\*Corresponding Author

### INTRODUCTION

Despite the development in education using digital media, there is insufficient evidence to support blended learning. Blended learning provides a unique balance in the teaching and learning approach because the method offers the convenience of e-learning without losing face-to-face contact (Vernadakis et al., 2012). Therefore, current higher education does not foster recent needs in teaching and learning process. Many issues need to be reconsidered in designing effective application for optimal



learning environments. Currently, teaching and learning approaches are merely based on lectures, collaborative learning, group discussion, practice in tutorial sessions and practical in the physiotherapy exercise room without the use of technology. Technology-mediated teaching and learning in physiotherapy education appear to be less than satisfying with limited research available on the appropriate use of technology-enhanced learning environments (Rowe, Frantz, & Bozalek, 2012). Teaching and learning skills in physiotherapy are inadequate to promote learning. Self-study is required for students after completing class. However, lack of learning resources and materials is an impediment for effective learning. Azer et al. (2013) also found that for many years, students relied on their teachers as one of their main sources for learning practical skills because they do not have structured resources for references.

E-learning environment increases flexibility and provides opportunity for students to self-regulate learning for better performance regardless of space and time issues, while face-to-face learning permits immediate and spontaneous feedback from instructors. In this study, e-learning resource is defined as additional learning material in which computers are used for learning and to assess student response. According to the constructivist perspective, learners must construct knowledge from constructive activity so each learner individually (and socially) constructs meaning when he or she learns. Hence, a constructivist individual student works with instructional material on his or her own time, without direct supervision or guidance from instructor. Learners are independent in terms of self-instruction. Self-instruction is the most appropriate approach and suitable for learners with different levels of knowledge on the same topic.

Table 1  
*Multimedia guidelines for e-learning design (Clark & Mayer, 2012)*

Design guidelines for e-learning	
Multimedia and Modality Principles	To communicate content, learner uses relevant graphics explained via audio narration
Exception to Modality Principle	To maintain information that learner needs time to process, use text on the screen (e.g. direction to tasks)
Temporal Contiguity Principle	Do not separate visual and audio that describes the visual
Redundancy Principle	When using graphics on the screen, do not present words as both onscreen text and narration
Coherence Principle	Avoid irrelevant video, animations, music, stories, and lengthy narrations
Personalization Principle	Use conversational style using first and second person for audio scripting
Segmentation Principle	Break content down into small chunks using continue or next button
Pre-training Principle	Teach important concepts and facts prior to procedures or processes

Based on the previous studies, e-learning for physiotherapy education has employed video-based learning that simulates patient-therapist activities, which have been used effectively in clinical education (Weeks & Horan, 2013). The use of video-based learning provides students



with learning experience to construct new knowledge. Furthermore, video resources offer students flexibility in terms of learning as well as offer self-regulated learning. Video-assisted in teaching health professionals, specifically clinical practice, can make learning more enjoyable and engaging (Weeks & Horan, 2013). The proper e-learning design is essential for learning to occur by applying appropriate multimedia guidelines when using audio and visual modes (Clark & Mayer, 2012).

## MATERIALS AND METHODS

Key topics and subtopics were identified for the content development. The learning material can be accessed using a hyperlink in non-linear format to ensure that key topics and sub topics are connected. The digital learning material consists of printed materials and electronic materials. A printed material is provided for long reading information whereas an electronic material contains video learning and 3D simulation assessments. The design phased used guidelines adopted from Clark and Mayer (2012) to develop the digital learning material. The main interface includes buttons to access topic 1 until topic 7 in a nonparallel way (Figure 1(a)). Adobe Captivate 8 was used as the main authoring software in this project. Learning contents using video-based learning demonstrate the procedures in left layout, while in right layout space text are used to highlight the procedures. Body landmark, pointing arrows and degree of movement information in the video provide information about procedures (Figure 1(b)). For learning assessment 3D simulation are provided in every topic to assess students' comprehension (Figure 1(c)). The character modelling was developed using 3Ds Max software and Unity 3D was used for coding and programming the interactivity works. Experienced therapists were used to demonstrate the procedures and to create a precise movement of the 3D simulation, motion capture equipment was used.

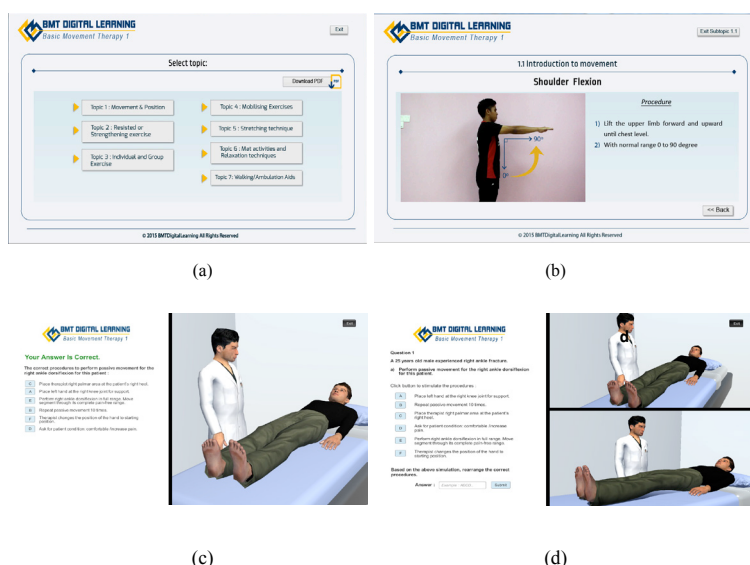


Figure 1. (a) Main menu interface; (b) video-based learning; (c) 3D simulation assessment; and (d) assessment feedback

The study employed quasi-experimental with two groups using pre-test/post-test approach. The research design is as follows:

Table 2  
*Research design*

	Pre-test (Rubric Test)	Treatment	Post-test (Rubric Test)
Experimental group	X	X	X
Control group	X		X
	Week 7	Week 8 – Week 14	Week 15

Participants' characteristics such as gender, age, self-motivation, previous knowledge, computer literacy and learning styles were reviewed (Muijs, 2004). The study population consisted of 104 students in year 1 who had basic movement therapy course for the current semester. Students were assigned randomly into two groups of practical class where the researcher did not have any involvement. There are 15 weeks in one semester; from the first week until week 7, both groups attended class as usual. On week 7, pre-test was done to collect baseline data on students score performance before the treatment begins; from week 8 until week 14, the experimental group were exposed to blended learning. The instructor and students were handed DVD consisting of learning materials in exe format. The instructor used the digital learning material in lab practical session as a strategy to get students to use the learning material as additional references post class. The control group were exposed to teaching and learning via face-to-face method only. On week 15, post-tests were done to collect data on students' score for both groups after intervention.

## RESULTS AND DISCUSSION

Data was analysed using statistical analyses using Statistical Product and Service Solutions (SPSS), version 23. The following hypotheses are tested in this study:

H1: The use of BMT digital learning in blended learning intervention will not show improvement in students' achievement from the pre-test score to post-test score.

H2: The use of BMT digital learning in blended learning intervention will show improvement in students' achievement from the pre-test score to post-test score.

The independent variable is the BMT digital learning application, and the dependent variable is students' achievement. The experimental group completed the basic movement therapy course using BMT digital learning, while the control group used conventional learning method only. It was generally anticipated that the blended learning would yield improved learning outcomes and that generally higher student post-test scores were expected when compared with group whose lessons incorporate conventional teaching method only. If the null hypothesis was rejected, the use of BMT digital learning would statistically show a significant difference between the different scores of the groups. Therefore, it could be reasonably expected that the control group would perform less well than the experimental group.

Table 3  
Independent t-test result

Groups	N	Mean	Std.
Blended learning (experimental group)	52	9.09	0.77
Face-to-face method only (control group)	51	8.70	0.91

An independent-samples t-test was conducted to compare students' scores for practical test in blended learning intervention and face-to-face learning method only. There was a significant difference in the scores for blended learning intervention (M=9.09, SD=0.77) and face-to-face method only (M=8.70, SD=0.91) condition;  $t(101) = -2.33$ ,  $p = 0.022$ . These results suggest that blended learning does have an effect on students' scores for practical test. Specifically, the results suggest that when learning is technology driven, it could elevate students' performance.

Table 4  
Mean diff, t-value and p-value

Groups	Mean diff	t-value	p-value
Before intervention (pre-test)	-.08211	-.746	.901
After intervention (post-test)	-.39052	-2.331	.022

An analysis of variance (ANOVA) was also conducted which shows that there is significant difference between achievement of students who used BMT digital learning and students who completed the course without utilising of BMT digital learning. Figure 2 shows the plot of the mean scores for each group based on the pre-test and post-test where each line represents a group. From this graph, it is clear that the experimental group performed better than the control group in pre-test and post-test.

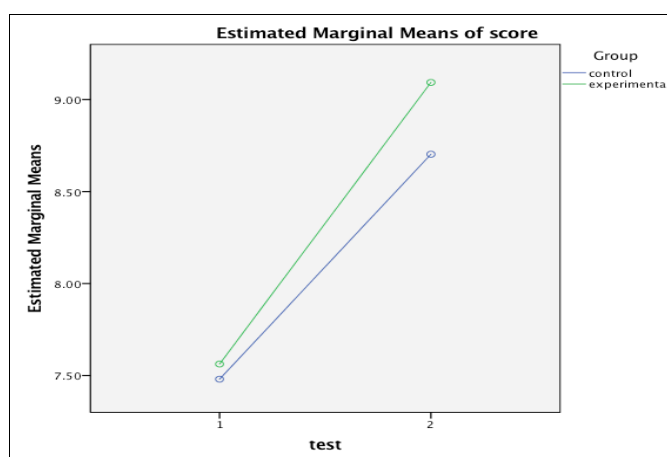


Figure 2. Plot of Means

Table 5  
*Difference scores (Post-test vs Pre-test)*

Group	Test	Mean	Std. Error	Lower bound	Upper bound
Control group	Pre-test	7.480	.078	7.325	7.635
	Post-test	8.703	.119	8.467	8.939
Experimental group	Pre-test	7.562	.077	7.409	7.716
	Post-test	9.093	.118	8.860	9.327

*Note:* 95% confidence interval

The development of digital learning project takes about 1 year. A multidisciplinary team including physiotherapy instructors, instructional multimedia expert, 3D animator, programmer and new media professionals was recruited to develop this project. The inclusion of video-based learning and 3D simulation as learning materials in physical therapy training may benefit student outcome. Physical therapy requires proficiency in procedural skills to perform physical therapy activities. To acquire such expertise it demands for sustained practice in order to improve specific aspect of the performance (Kneebone, 2005). Wulf, Shea and Lewthwaite (2010) found that observational practices, feedback and self-controlled practices are influential in enhancing motor skills learning. Building on these attributes to multimedia instruction might contribute to appropriate development of e-learning material in practical skills. This results in effective learning when it permanently changes learners' capability to perform such skills through demonstration of retention and transfer skills.

## CONCLUSION

E-learning has been studied as an instructional format across a range of health education topics and context for decades. However, the contents are still insufficient to support blended learning to foster current needs in teaching and learning process. This research is important because it shifts learning from standard teaching method to blended learning approach where learning can be done independently and help students to self-regulate their learning. Thus, the digital learning resource is effective in increasing students' capability to perform practical skills. Blended learning approach with the design of interactive video learning and 3D simulation for assessments make learning more interesting and engaging. Thus, through the integration of educational technology tools, teaching and learning can be addressed more effectively and learners become more accountable for their own education.

## REFERENCES

- Azer, S. A., Al Grain, H. A., AlKhelaif, R. A., & AlEshaiwi, S. M. (2013). Evaluation of the educational value of youtube videos about physical examination of the cardiovascular and respiratory systems. *Journal of Medical Internet Research*, 15(11). Retrieved from <http://doi.org/10.2196/jmir.2728>
- Clark, R. C., & Mayer, R. E. (2012). E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning. Retrieved from <http://doi.org/10.1002/9781118255971>

- Gosper, M., Mcneill, M., Phillips, R., & Preston, G. (2010). Web-based lecture technologies and learning and teaching: a study of change in four Australian universities. *ALT-J*, 18(3), 251–63. Retrieved from <http://doi.org/10.1080/09687769.2010.529111>
- Kneebone, R. (2005). Evaluating clinical simulations for learning procedural skills: a theory-based approach. *Academic Medicine: Journal of the Association of American Medical Colleges*, 80(6), 549–553. Retrieved from <http://doi.org/10.1097/00001888-200506000-00006>
- Muijs, D. (2004). Muijs, Daniel. Doing quantitative research in education with spss. London, GBR: SAGE Publications Inc. (US), 2004. ProQuest ebrary. Web. 30 June 2015. Copyright © 2004. SAGE Publications Inc. (US). All rights reserved.
- Rowe, M., Frantz, J., & Bozalek, V. (2012). The role of blended learning in the clinical education of healthcare students: a systematic review. *Medical Teacher*, 34(4), e216–21.
- Vernadakis, N., Giannousi, M., Tsitskari, E., Antoniou, P., & Kioumourtzoglou, E. (2012). A comparison of student satisfaction between traditional and blended technology course offerings in physical education. *Turkish Online Journal of Distance Education*, 13(1).
- Weeks, B. K., & Horan, S. A. (2013). A video-based learning activity is effective for preparing physiotherapy students for practical examinations. *Physiotherapy (United Kingdom)*, 99(4), 292–297. Retrieved from <http://doi.org/10.1016/j.physio.2013.02.002>
- Wulf, G., Shea, C., & Lewthwaite, R. (2010). Motor skill learning and performance: A review of influential factors. *Medical Education*, 44(1), 75–84.





## **A Model to Manage Remanufacture of Used-Products**

**Magdalene Andrew-Munot\*, Abdullah Yassin, Syed Tarmizi Syed Shazali and Marini Sawawi**

*Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia*

### **ABSTRACT**

Remanufacturing of used-products is becoming an important activity in many production companies. This paper reviews key remanufacturing process, highlights eight unique characteristics of remanufacturing process environment and proposes a generic conceptual remanufacturing process model that considers the presence and interactions of these eight features. The generic conceptual model could be modified to suit remanufacturing process of any given used products to be remanufactured. Future research can modify the generic remanufacturing model to suit used automotive parts remanufacturing with unique characteristics and apply simulation technique to model and analyse the corresponding remanufacturing process.

*Keywords:* Control, planning, production, remanufacturing, used-products

### **INTRODUCTION**

Over the years, stricter environmental legislations imposed on manufacturing companies had forced them to include their manufacturers' responsibility for products that have been used and retired. For example, automobile manufacturers in Europe must accept full disposal

responsibility for cars manufactured from 2002 onwards and not pass on the cost to the final owners (EU Directive, 2000). In addition, customers have become increasingly concerned about the effects of disposing used-products to the environment. As reported in (Morel & Kwakye, 2012), more than 80% of the survey respondents agree that "an important deciding factor when buying a product is the product's impact on the environment". Strict governmental legislation

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*E-mail addresses:*

ammagdal@unimas.my (Magdalene Andrew-Munot),

yabdullah@unimas.my (Abdulla Yassin),

starmizi@unimas.my (Syed Tarmizi Syed Shazali),

smarini@unimas.my (Marini Sawawi)

\*Corresponding Author

and consumer concern on environment put pressure on manufacturing companies to designing products and corresponding production process that makes it possible to recover used-products through remanufacturing activity (Andrew-Munot et al., 2015). Remanufacturing can be defined as an industrial process whereby used, worn-out or broken products are converted into like-new conditions (Kim et al., 2006). Specifically, Nasr (2007) defines that a product is remanufactured if it fits several criteria. These criteria are: (i) main components comes from a used product; (ii) condition of the components are determined after disassembly process; (iii) components are thoroughly cleaned to remove rust and corrosion; (iv) missing, defective, broken or worn out parts are either restored to sound, functionally good condition, or replaced with new or remanufactured parts; (v) components/product are reprocessed either by machining, rewinding, refinishing, etc; and (vi) reassembly of product and to ensure it operates similar to the new product with respect to reliability, life-cycle and operational cost.

Unlike traditional manufacturing activities, remanufacturing activities is complex in nature due to the presence of several unique characteristics. Therefore, this paper proposes a generic conceptual remanufacturing process model with eight unique characteristics. This generic conceptual model is developed taking into account the key remanufacturing process and eight unique characteristics that are presence within the remanufacturing environment. This paper is organised as follows. Section 2 is a discussion on the remanufacturing process; Section 3 highlights the unique characteristics that are present within the remanufacturing environment and proposes a generic conceptual remanufacturing process model. Section 4 concludes the paper.

## A REVIEW OF REMANUFACTURING PROCESS

Figure 1 shows a generic process for remanufacturing that commences with the arrival of used-products, which are then inspected, disassembled, reprocessed and reassembled to produce remanufactured products. This generic remanufacturing process, as described by Lund (1984) is one of the oldest description of remanufacturing process reported in the literature. Hammond et al. (1998) and Guide (2000) define remanufacturing process to include arrival of used-products, disassembly, cleaning, sorting/inspection, reprocessing, reassembly & testing. The exact number of processes and sequences for a specific product type depends on the conditions of the used-products (Ilgin & Gupta, 2012). For example, Andrew-Munot et al. (2013) give examples of remanufacturing process for photocopiers, automotive engines, ink cartridges and medical devices, which are the actual industry remanufacturing process. Therefore, it is clear that there are some processes that are similar and hence, general to remanufacturing process of all types of used-products.

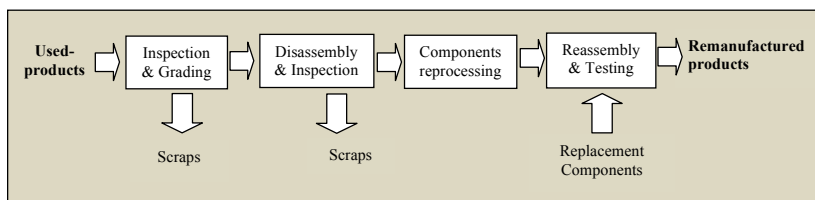


Figure 1. Generic remanufacturing process (Lund, 1984)



## Used-Products

Generally, used-products can be obtained from two sources, the market-stream or the waste-stream (Jayaraman, 2006). Used-products from the market-stream (e.g. retailers) are usually products that still functions but are not required by the owners anymore. This could be an old model of a mobile phone that is traded-in for new model with new and stylish features. However, the waste stream used-products are no longer useful; some examples are damaged automotive vehicles and malfunctioned electrical home appliances. Between the two sources, used-products coming from the waste stream yields uncontrollable quality and uncertain quantity (Ghoreishi et al., 2011). Generally, the availability of used-products for remanufacturing is influenced by the number of new products sold in the preceding periods (Esenduran et al., 2012).

**Process 1: Inspection and grading.** Incoming, used-products are inspected to determine whether they are acceptable for remanufacture or not (scraps). Scraps are either sold to scrap brokers or disposed off. Used-products accepted for remanufacture, define as “*remanufacturables*”, could be categorised into several quality groups, and highest priority is given to remanufacture the best quality group (Aras et al., 2006). Used-products obtained from the waste stream with uncontrollable quality conditions require longer and different inspection times for each unit, compared with those obtained from the market-stream. The market-stream used-products having controllable quality conditions, results in a higher proportion (yield) of “*remanufacturables*” compared with the waste-stream.

**Process 2: Disassembly and Inspection.** Used products accepted for remanufacture are disassembled completely into its constituent component. The disassembled components are inspected to assess whether the components can be reprocessed or disposed off as scraps. The market-stream used-products would give more components that are accepted for reprocessing (higher disassembly yield) compared with the waste-stream. The constituent components could also be categorised into several quality groups and priority is given to reprocess components with the best quality. The disassembly and inspection processes may occur either simultaneously or sequentially - this depends on the product structure and volume. For remanufacturables with simple product structure and in high volume, both the disassembly and inspection process could occur simultaneously. Similarly, for remanufacturables with complex product structure and in low volume, the disassembly and inspection process could occur simultaneously. However, for remanufacturables with complex product structure and in high volume, the disassembly and inspection process occur sequentially.

**Process 3: Components Reprocessing.** This usually involves process such as cleaning, repairing and surface finishing (Sundin & Bras, 2005). Depending on the component quality group, the exact number of reprocessing steps and time would be different. For instance, the best quality component may need simple reprocessing (e.g. cleaning & surface finishing) compared with components from the average quality group. For components with complex design, multiple reprocessing steps might be required to return the components to the original

condition. Some non-replaceable parts such as electrical wire or cellular phone casing are just replaced with new components.

**Process 4: Reassembly and Testing.** The reprocessed and replacement components are reassembled into remanufactured products, which are tested to ensure these products meet the specified function.

### **Remanufactured Products**

Remanufactured products which are perfect substitutes for new products are sold in the primary market (Souza & Ketzenberg, 2002); this would be original equipment manufacturers (OEM) remanufactured products, which are as good as new products. The price of remanufactured products which are sold side by side with new products could be cheaper (Ferrer & Swaminathan, 2009) even at the same price as the newly products (Gallo et al., 2012). On the other hand, remanufactured products sold in the secondary market are popular among customers with financial restrictions, who are satisfied with their cheaper and low-level functions.

### **PROPOSED GENERIC CONCEPTUAL MODEL**

As discussed in the review of remanufacturing process, unlike the traditional manufacturing process, remanufacturing process is uncertain with respect to several aspects. Andrew-Munot & Ibrahim (2013), emphasise that these uncertainties complicate production planning & control activities and therefore, need to be treated as important criteria in modelling & simulation of remanufacturing operations. These uncertainties become the unique characteristics of remanufacturing environment which are: (i) highly uncertain quality conditions of incoming used-products, due to their different degree of usage; (ii) uncertain quantities of used-products available for remanufacture; (iii) varying inspection yield from one batch to another; (iv) varying disassembly yield from one batch to another; (v) varying reprocessing efforts of constituent components from one unit to another and from one batch to another; (vi) reprocessing multiple types of constituent components; (vii) requirements to match and reassemble the same set of constituent components into a final product; and (viii) the need to balance customer demand with availability of used-products to avoid excess inventory build-up and maximise level of customer service. Therefore, based on the review of remanufacturing process and statements of unique characteristics above, this paper proposes a generic conceptual model for remanufacturing process environment, as shown in Figure 2. The generic conceptual model is characterised by key remanufacturing process as well as the presence of eight unique characteristics. The generic conceptual model could be further modified to model remanufacturing process and unique characteristics of any specific used-product to be remanufactured. Furthermore, this generic conceptual remanufacturing process model would become an important decision-making support tool for industry as well as academicians.

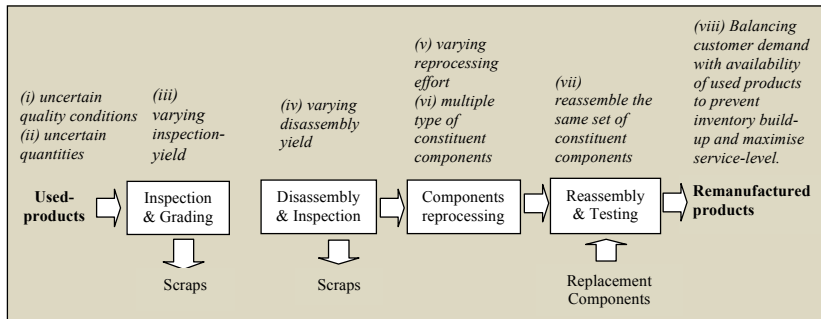


Figure 2. Proposed conceptual remanufacturing process model with eight unique characteristics

## CONCLUSIONS

In the recent past, many companies have been involved in remanufacturing activities. This progress has been primarily motivated by three emerging factors: strict environmental regulations, increasing customer regard for green environment and economic benefits. This paper has highlighted the key remanufacturing process and corresponding unique characteristics also in addition to proposing a generic conceptual remanufacturing process model considering the presence and interactions of eight unique characteristics. The model could be further modified taking into account remanufacturing process and unique characteristics of any specific used-product to be remanufactured. Inevitably, the generic conceptual remanufacturing process model becomes a valuable managerial decision-making support tool. Given the existence of eight unique characteristics within the remanufacturing process environment, it is imperative that such unique characteristics and their interactions are treated as a set of critical criteria in the modelling and analysis of remanufacturing operations. Therefore, the future directions of this research work are to modify the generic conceptual model above for used-automotive parts remanufacturing process & corresponding unique characteristics. This used-automotive parts remanufacturing process would be modelled and analysed using simulation technique.

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## REFERENCES

- Andrew-Munot, M., & Ibrahim, R. N. (2013). Development and analysis of mathematical and simulation models of decision-making tools for remanufacturing. *Production Planning and Control*, 24(12), 1081-1100.
- Andrew-Munot, M., Ibrahim, R. N., & Junaidi, E. (2015). An overview of used-products remanufacturing. *Mechanical Engineering Research*, 5(1), 12-23.

- Aras, N., Verter, V., & Boyaci, T. (2006). Coordination and priority decisions in hybrid manufacturing/remanufacturing systems. *Production and Operations Management*, 15(4), 528-543. Retrieved from <https://doi.org/10.1111/j.1937-5956.2006.tb00161.x>
- Esenduran G., Emahlioglu-Ziya, E., & Swaminathan, J. M. (2012). Product take-back legislation and its impact on recycling and remanufacturing industries in T. Boone et al. (eds.), Sustainable Supply Chains, 129. *International Series in Operations Research and Management Science*, 174. Retrieved from <http://dx.doi.org/10.1007/978-1-4419-6105-1>
- EU Directive. (2000). 53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles. *Official Journal of the European Union*, L Series, 34-42.
- Ferrer, G., & Swaminathan, J. M. (2009). Managing new and differentiated remanufactured products. *European Journal of Operational Research*. Retrieved from <http://dx.doi.org/10.1016/j.ejor.2009.08.007>
- Gallo, M., Romano, E., & Santillo, L. C. (2012). A perspective on remanufacturing business: issues and opportunities. *International trade from economic and policy perspective*, 209. Retrieved from <http://dx.doi.org/10.5772/2726>
- Ghoreishi, N., Jakiela, M. J., & Nekouzadeh, A., (2011). A cost model for optimizing the take back phase of used product recovery. *Journal of Remanufacturing*, 1(1). Retrieved from <http://dx.doi.org/10.1186/2210-4690-1-1>
- Guide, V. D. R. (2000). Production planning and control for remanufacturing: industry practice and research needs. *Journal of Operations Management*, 18(4), 467-483.
- Hammond, R., Amezquita, T., & Bras, B. (1998). Issues in the automotive parts remanufacturing industry: a discussion of results from surveys performed among remanufacturers. *Engineering Design and Automation*, 4, 27-46.
- Ilgin, M. A., & Gupta, S. M. (2012). Remanufacturing modeling and analysis. CRC Press.
- Jayaraman, V. (2006). Production planning for closed-loop supply chains with product recovery and reuse: an analytical approach. *International Journal of Production Research*, 44(5), 981-998. Retrieved from <http://dx.doi.org/10.1080/00207540500250507>
- Kim, K., Song, I., Kim, J., & Jeong, B. (2006). Supply planning model for remanufacturing system in reverse logistics environment. *Computers and Industrial Engineering*, 51(2), 279-287. Retrieved from <http://dx.doi.org/10.1016/j.cie.2006.02.008>
- Lund, R. T., & Mundial, B. (1984). *Remanufacturing: The experience of the United States and implications for developing countries* (Vol. 31). World Bank.
- Morel, M., & Kwakye, F. (2012). Green marketing: Consumers' attitude towards eco-friendly products and purchase intention in the fast-moving consumer goods (FMCG) sector.
- Nasr, N. (2007). Building a sustainable future through innovative technologies. Presentation slides to The APEC Market Access Group. Retrieve from [http://mddb.apec.org/documents/2007/MAG/WKSP1/07\\_mag\\_wksp1\\_002.pdf](http://mddb.apec.org/documents/2007/MAG/WKSP1/07_mag_wksp1_002.pdf)
- Sundin, E., & Bras, B. (2005). Making functional sales environmentally and economically beneficial through product remanufacturing. *Journal of Cleaner Production*, 13(9), 913-925. Retrieved from <http://dx.doi.org/10.1016/j.jclepro.2004.04.006>



## Site Specific Ground Response Spectra of Bakun

**Zainap Lamat\*, Yuhani Jamian and Mohd Agus Adib Eskandar**

*Politeknik Kuching Sarawak, 93050 Kuching, Sarawak, Malaysia*

### ABSTRACT

Sarawak has experienced several earthquakes of local origin and was also affected by long-distance earthquake that originated from Southern Philippine and the Straits of Macassar, Sulu Sea and Celebes Sea. The objectives for this study were to conduct site specific ground response analysis and develop design response spectra for Bakun area by using 1-D equivalent linear ground response analysis. The site characterisation was carried out utilising the soil profile and soil property data of the selected site. Local surface fault ruptures were investigated for possible hazards due to intraplate earthquakes. Earthquake ground motion records were selected based on characteristics of the controlling earthquakes for an area and the maximum magnitude faults were considered for risk assessment. The site-specific response spectra represent the predicted surface ground motions that reflect the levels of strong motion amplitude and frequency content at a particular site. The site-specific ground response analysis for Bakun site found that the peak ground acceleration at bedrock was amplified from 0.16 g to 0.33 g at the ground surface

*Keywords:* Earth ground motions, frequency, peak ground acceleration, risk assessment, site specific ground response spectra

### INTRODUCTION

Sarawak has experienced several earthquakes of local origins. In the last 35 years, a total of three earthquakes occurred in Sarawak with maximum observed intensity of IV on Modified Mercalli Scale (MM) scale (Abas, 2001). On 26 January 2006, an earthquake registering 3.2 on Richter scale was detected in Batu Niah and Suai. Sarawak is also affected by long-distance earthquake that originates from Southern Philippine and the Straits of Macassar, Sulu Sea and Celebes Sea. The maximum observed intensity produced by this distant earthquake was V on MM scale (Abas, 2001). As more and more high-rise

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##### *E-mail addresses:*

[zainaplamat@yahoo.com](mailto:zainaplamat@yahoo.com) (Zainap Lamat),

[yuhanijamian@yahoo.com](mailto:yuhanijamian@yahoo.com) (Yuhani Jamian),

[agusadib48@gmail.com](mailto:agusadib48@gmail.com) (Mohd. Agus Adib Eskandar)

\*Corresponding Author

buildings and critical industrial facilities are being built in Malaysia, it should be emphasised that these structures are safe from earthquake threats. Although the earthquake threat in Sarawak is small it still cannot be ignored. The Malaysian government has invested millions to build public infrastructure and amenities. Among them is the Bakun Hydro Dam which cost RM13.5 billion to build and took 20 years to be constructed. Thus, it is important to ensure the Bakun Hydro Dam is safe. The objective of this study was to conduct site specific ground response analysis and develop design response spectra for the Bakun area. This is because the effect of earthquake could result in huge human and monetary losses (Bommer, 2003).

Site-specific ground response analysis of a particular area is important when it involves structures and industrial facilities. The soil conditions can influence the ground motion characteristics such as amplitude of motion, frequency content and duration. The extent of the local site effect at a site depends on the geometry and material properties of the subsurface materials, in-situ topography and characteristics of the input motion. These site effects must be examined on a case-by-case basis at every particular site to account for uncertainties in the ground motion parameters.

The main objectives for conducting site-specific analysis are to identify the PGA for Bakun Hydro Dam and to conduct site-specific ground response analysis by using 1-D equivalent linear ground response analysis.

## MATERIALS AND METHODS

Figure 1 shows the general steps involved in the site-specific ground response analysis.

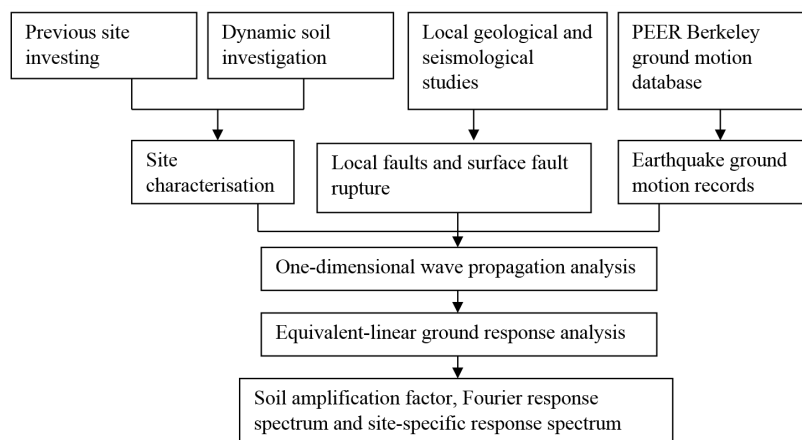


Figure 1. Steps in site-specific ground response analysis

### **Characterisation of the site**

The dynamic site characterisation can be obtained from one or more idealised soil profiles for the site of interest. The characterisation should include the shear wave velocity profile with depth, variation of shear modulus with strain and variation of damping with strain (Tezcan, Kaya, Bal, & Ozdemir, 2002). This parameter can be obtained from a field dynamic test.

### **Selection of rock motions**

The selected earthquake motions at bedrock can either be natural or synthetic acceleration time histories to represent the design motion for the site (Kalkan, 2011). The chosen bedrock motion should be associated with the source areas or provinces having similar ground motion characteristics of the estimated bedrock motions. When using real earthquake time histories, the selected histories should contain: (i) peak ground motion parameters; (ii) response spectral content; and (iii) duration of strong shaking.

### **Ground response analysis**

Ground response analysis was performed using one-dimensional shear wave propagation method. One-dimensional ground response analyses are based on the assumption that all boundaries are horizontal and that the response of a soil deposit is predominantly caused by the shear waves propagating vertically from the underlying bedrock (Kramer, 1996). Thus, this methodology is sufficient to represent the wave propagation in the ground response analysis.

### **Site specific design spectra for response spectrum analysis**

A one-dimensional equivalent linear analysis was performed to investigate the soil amplification problem at a specific site. This is mainly because the equivalent linear analysis considers the effects of earthquake input motion together with the linear properties of the soil profiles. This will include uncertainties involved in the earthquake time history characteristics when interacting with the soil profiles. SHAKE 2000 (Seed & Idris, 1970), was used in the current study for assessment of ground response at Bakun Hydro Dam in Sarawak.

## **RESULTS AND DISCUSSION**

Ground motion characteristics such as amplitude of motion, frequency content and duration can influence local soil condition which could affect the response of industrial component and services at the facility. It is impossible to prevent earthquakes but it is possible to mitigate the effects of strong earthquake and to reduce loss of life, injuries and damages. Site-specific ground response analysis is used to estimate the seismic hazard to improve building design and construction so that the structures possess adequate earthquake resistance capacity. Result for site-specific ground response analysis for Bakun site is presented in Table 1 below. It is found that the PGA at bedrock is amplified from 0.16 g to 0.33 g at the ground surface.



Table 1  
*Site-specific ground response analysis*

Depth (m)	Maximum Acceleration (g)	Time (s)	Mean sq. Fr. (c/sec.)	Acc. Ratio Quiet Zone
0	0.3333	37.6	3.07	0.155
2.50	0.30532	37.6	2.91	0.156
5.50	0.25696	37.6	2.64	0.164
7.00	0.22516	37.59	2.45	0.171
8.50	0.17628	37.58	2.16	0.176
12.00	0.16003	41.65	2.07	0.147

Average response spectrum is plotted for Bakun site, as shown in Figure 2. These response spectra correspond with the 2% POE in 50-year hazard level, with 2475 return periods. Considering the local site condition effects, the average is more accurate to represent the seismic hazard at the Bakun site. Provided the period of Bakun Dam is between 8 to 10 seconds, Bakun Dam is subjected to minimal spectral acceleration which is in the range of 0 g to 0.1 g PGA.

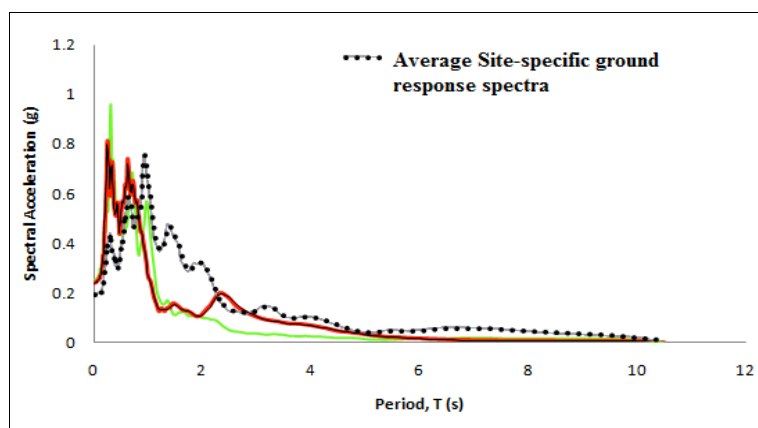


Figure 2. The site-specific response spectra corresponding to 2% POE in 50-year hazard level (2475 return period)

## CONCLUSION

The results of this study showed that the authors have achieved the objective of this study which is to identify the PGA for Bakun Hydro Dam and to conduct site-specific ground response analysis by using 1-D equivalent linear ground response analysis. The site-specific ground response analysis for Bakun site shows the PGA at bedrock was amplified from 0.16 g to 0.33 g at the ground surface and the average response spectrum is plotted as shown in Figure 2. The PGA shows the maximum hazard level which is required to estimate seismic risk in critical industrial facilities or infrastructure. These findings are very important for design of any new high-rise buildings and critical industrial facilities development in future.



## REFERENCES

- Abas, M. R. B. C. (2001). Earthquake monitoring in Malaysia.
- Bommer, J. J. (2003). Earthquake protection. *Engineering Structures*. Retrieved from [http://doi.org/10.1016/S0141-0296\(03\)00147-0](http://doi.org/10.1016/S0141-0296(03)00147-0)
- Kalkan, E. (2011). Preface to the focused issue on the 22 February 2011 magnitude 6.2 Christchurch earthquake, *Seismological Research Letters*, 82(6), 765–766.
- Kramer, S. L. (1996). Geotechnical Earthquake Engineering. *Engineering*, 6. Retrived from <http://doi.org/10.1007/978-3-540-35783-4>
- Seed, H., & Idris, I. M. (1970). Soil moduli and damping factors for dynamic response analysis. *Rep. No. EERC 70-10, Earthq. Engg. Res. Centre, Berkley, Calif., USA*, 10–43.
- Tezcan, S. S., Kaya, E., Bal, I. E., & Ozdemir, Z. (2002). Seismic amplification at Avcılar, Istanbul. *Engineering Structures*, 24(5), 661–667. Retrieved from [http://doi.org/10.1016/S0141-0296\(02\)00002-0](http://doi.org/10.1016/S0141-0296(02)00002-0)



## Sustainable Mid-Rise Vernacular Palace Architecture of Istana Lama Seri Menanti, Negeri Sembilan

Nurdiyana Zainal Abidin<sup>1\*</sup>, Raja Nafida Raja Shahminan<sup>2</sup> and Fawazul Khair Ibrahim<sup>2</sup>

<sup>1</sup>*Department of Architecture, Faculty of Built Environment, Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor, Malaysia*

<sup>2</sup>*Center for the Study of Built Environment in the Malay World (KALAM), Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor, Malaysia*

### ABSTRACT

Sustainability is an important factor in designing vernacular architecture, including vernacular palace architecture; the latter refers to low-rise buildings similar to Traditional Malay Houses (TMH). However, the Istana Lama Seri Menanti is a 4-storey mid-rise vernacular palace which was designed with sustainability in mind. This mid-rise element of the palace communicates the vernacular architecture of TMH in Negeri Sembilan whereas sustainable designs are factored in environmentally friendly materials, construction methods, and the environmental impact of the building culturally and economically. This research was aimed at examining the sustainability approach of Istana Lama Seri Menanti as a mid-rise vernacular palace in the early 20<sup>th</sup> Century, and its impact on the current generation after 109 years. The research methodologies include case and precedent studies of vernacular palaces in Malaysia as well as interviews with experts in the field. In conclusion, the architectural sustainability of Istana Lama Seri Menanti had taken into account timber availability, consumption of naturally available resources, designs with minimal environmental impact and high cultural importance in the building design with the ultimate aim of conserving it for future generations.

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*E-mail addresses:*

[nurdiyana.za@gmail.com](mailto:nurdiyana.za@gmail.com) (Nurdiyana Zainal Abidin),

[jesz199@yahoo.co.uk](mailto:jesz199@yahoo.co.uk) (Raja Nafida Raja Shahminan),

[strazawaf@gmail.com](mailto:strazawaf@gmail.com) (Fawazul Khair Ibrahim)

\*Corresponding Author

### INTRODUCTION

Traditional Malay Royal Palaces (TMRP) in Malaysia have a unique vernacular architecture, which gives an insight into the traditions and culture of the rulers in the old days (Md, Nurul & Nik, 2013). The TMRP was not only a place of residence was also an administrative and Islamic centre to expand

the reach of Islam (Hazrina et al., 2012; Ossen et al., 2010; Hairuddin et al., 2008). Vernacular palace architecture in Malaysia was designed to be low-rise timber palaces of not more than two storey's high as they were replicas of the Traditional Malay Houses (TMH) but on a bigger scale and size (Yaakub, 1996; Zulayti, 2009). However, Istana Lama Seri Menanti is a mid-rise vernacular palace of four storeys which resonates with the architecture of Traditional Malay Houses in Negeri Sembilan (Gibbs, 1987). It was built in the early 20th century using traditional construction methods and materials (Sheppard, 1969). The aim of this research is to investigate the sustainable design of Istana Lama Seri Menanti through research methodologies which include case and precedent studies of vernacular palaces in Malaysia and interviews of experts. The scope of the study revolves around Traditional Malay Royal Palaces built between late 1800s and early 1900s (Istana Lama Seri Menanti was built between 1902 and 1908). Case and precedent studies are limited to timber palaces in Peninsular Malaysia and not masonry palaces.

### Sustainable Vernacular Architecture

Vernacular architecture is an important sustainable design due to several factors which include passive design usage, economical value and cultural value of the design (Lawrence, 2006). Passive design elements are important in sustainable building designs because of its low impact on the natural environment as it takes into consideration local climatic elements. For example, as Malaysia is a tropical country, the hot and humid weather is an important factor in determining the design features of a building through natural ventilation (cooling), natural sunlight and the movement of air and heat (high roof and raised stilts). A sustainable building design also has a high cultural value as it represents the community and culture (Lawrence, 2006).

Sustainable architecture also allows for the economical aspect of the building to be considered as cost of construction affects the sustainability of the building. As such, local materials, expertise and methods contribute to the sustainability of the building through minimising the cost of transportations and manual labour. Hence, vernacular architecture reveals the identity of the local community through designs of its environmental, social and economic values. Figure 1 shows the importance of sustainable design.

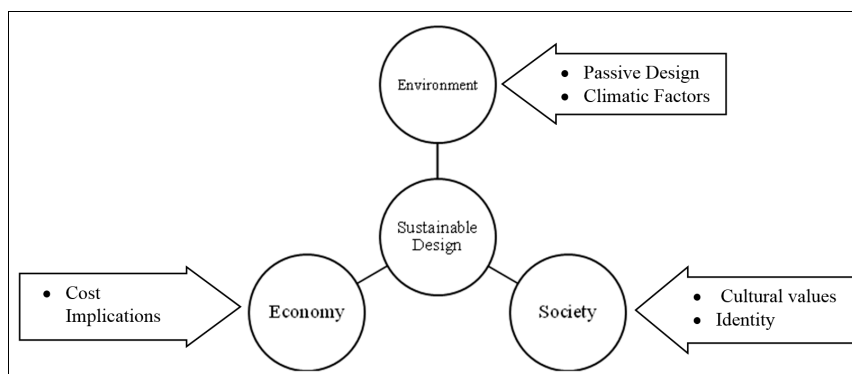


Figure 1. Factors influence sustainable design

## Traditional Malay Vernacular Architecture

Traditional Malay Vernacular architecture relates to the surrounding areas of the buildings as environmental factors are important when designing a traditional Malay home or a palace. The environmental factors include the climate, materials used and also user friendliness (Yuan, 1987). Due to the tropical climate which has high humidity, the Traditional Malay House is designed with many passive design elements so that the house is cooler and there is sufficient natural lighting. Furthermore, the use of natural construction materials reduces building costs. Figure 2 is an adaptation of an illustration (Yuan, 1987) depicting the climatic design of the Malay House.

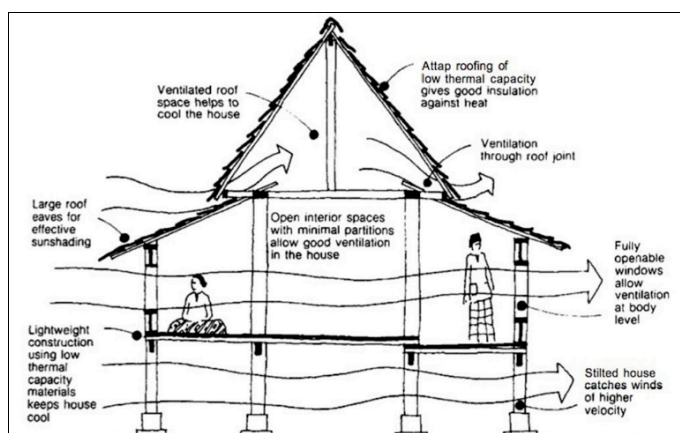


Figure 2. Diagram adapted from Yuan (1987)'s climatic design of the Malay House

## Istana Lama Seri Menanti

Istana Lama Seri Menanti is a mid-rise timber palace commissioned by Tuanku Muhammad Shah ibni Almarhum Tuanku Antah who was the 7th Yamtuan of Negeri Sembilan (Sheppard, 1969). The palace was built in order to replace Istana Pulih which was burnt down during the Bukit Putus War in 1875. Istana Lama Seri Menanti was built in 1902 and was completed in 1908 by Tukang Kahar and Tukang Taib who were appointed by Tuanku Muhammad as the designer and builder of the palace (Sheppard, 1969; Khan, 1983). The timber used for the construction was harvested from nearby forests in Negeri Sembilan and the four-storey palace was built using traditional methods without the reinforcements of steel (Yaakub, 1996). Chinese contractors were also involved in the construction while a British draftsman provided the drawings of the palace. Figure 3 shows the front elevation of the current Istana Lama Seri Menanti.



Figure 3. Front elevation of Istana Lama Seri Menanti

The palace was designed to be four storey's high which makes it a mid-rise timber palace of the 20<sup>th</sup> century during which other palaces have been constructed using masonry constructions. The spatial layout of the palace was well organised and spaces were specifically designated which differed from traditional Malay layouts that are more multi-functional. The symmetrical layout of the spaces were also uncommon in the Malay design. Figure 4 illustrates the spatial layout of spaces within Istana Lama Seri Menanti.

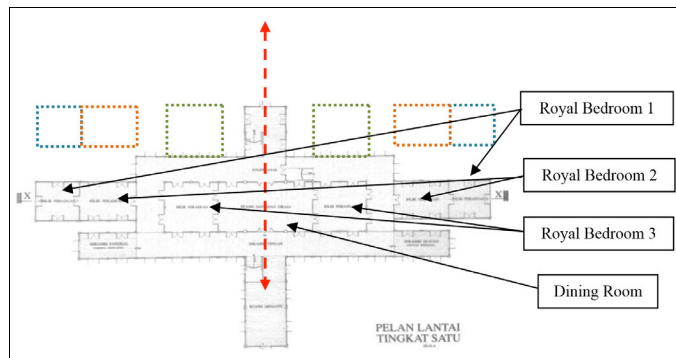


Figure 4. First Floor Plan of Istana Lama Seri Menanti (KALAM, 1993)

## MATERIALS AND METHODS

This was a qualitative research based on empirical and historical studies. The empirical research encompasses case studies and earlier studies of TMRP in Peninsular Malaysia focusing on palaces built around the 1800s until the 1900s whereas historical studies include archival research to collect primary and secondary data from the National Archives and London National Archives. Timber and masonry palaces were also examined in order to get a physical analysis on the architectural types of TMRP found in Malaysia and the timeline of the gradual change of timber palaces towards the newer and more modern masonry palaces. Figure 5 is a description of TMRP in Peninsular Malaysia with a specific focus on palaces in Negeri Sembilan.

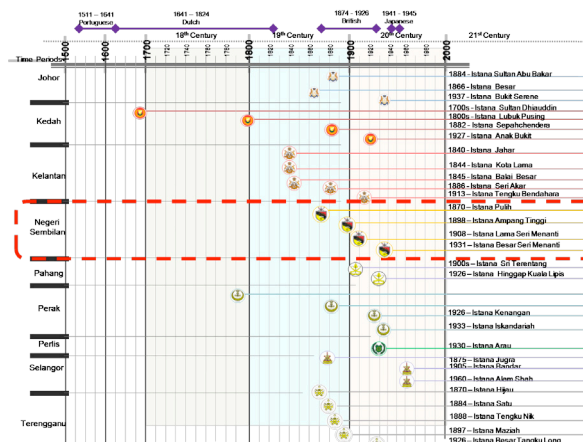


Figure 5. Case studies and precedent studies of TMRP in Peninsular Malaysia

## RESULTS AND DISCUSSION

From the list of TMRP in Malaysia, several buildings were selected based on the availability of information such as pictorial evidence, the year it was built and the materials and methods used. From the early 1800s, palaces built were made from timber but by the middle of 19<sup>th</sup> Century, masonry replaced the traditional construction methods. This coincides with the arrival of western colonial powers in Malaysia and the subsequent British occupation at the end of the 9<sup>th</sup> Century. However, in Negeri Sembilan, Istana Lama Seri Menanti, a timber palace, was built in the modern era of the 20<sup>th</sup> Century with sustainability in mind during which masonry palaces were common. Figure 6 illustrates the selected TMRP for case and earlier studies during 1800s-1900s showing the shift in architecture from timber to masonry.

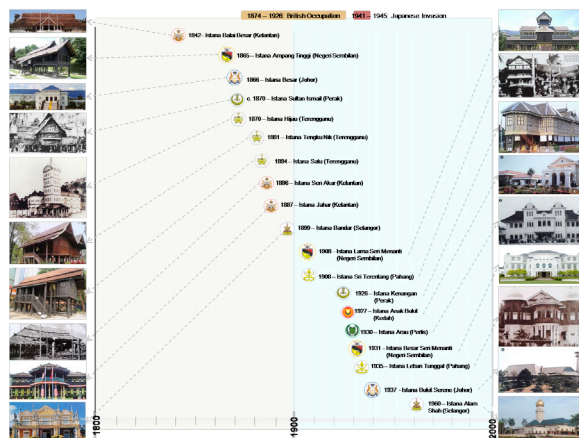


Figure 6. Selected case and precedent studies of TMRP in Malaysia during 1800s - 1900s and the changing construction materials and methods

The findings of this research indicate environmental, economic and social factors combine to influence the architecture of TMRP. Environmental factors in the sustainable design of Istana Lama Seri Menanti include both construction materials, methods and passive design elements. Passive designs for Istana Lama Seri Menanti include sun shading and veranda, natural ventilation louvers and openings for natural lightings. The mid-rise four-storey building also allows for the release of heat through the upper floors and the cooling of the lower floors through natural ventilations. Figure 7 illustrates passive design factors in the architecture of Istana Lama Seri Menanti.



Figure 7. Images illustrating the passive design features of Istana Lama Seri Menanti

The timber used for the construction was harvested from local forests in Negeri Sembilan and transported to the site. The construction of the palace was done by local craftsmen, hence, incurring minimal cost in terms of transportation and materials as the latter was harvested and transported locally. The social factors in the sustainable design of Istana Lama Seri Menanti include the cultural factors of the locals, cultural value of the design and implications on the locals. Cultural influences relate to the vertical planning of the palace as it is common for TMH in Negeri Sembilan to have two or three floors. Hence, the mid-rise construction of the palace is an identity of the TMH in Negeri Sembilan but on a grandeur and larger scale. Figure 8 illustrates the axonometric diagram of Istana Lama Seri Menanti and the impact of the passive design.

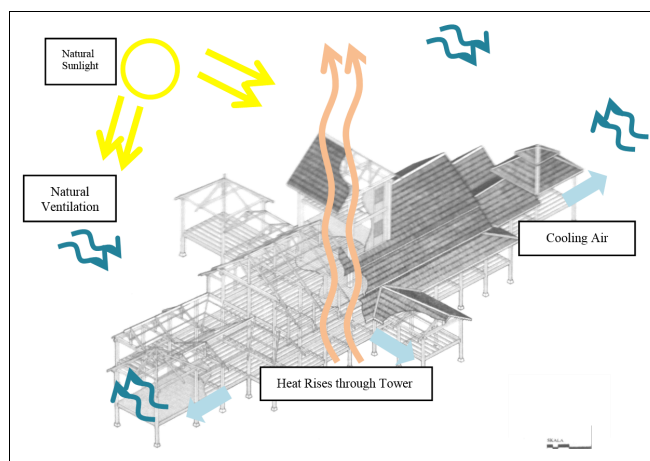


Figure 8. Passive Design of Istana Lama Seri Menanti

## CONCLUSION

In conclusion, it is essential to understand that vernacular palace architecture was important in the old days where the rulers or royalties were leaders of the state. As a sustainable vernacular palace, Istana Lama Seri Menanti is a distinctive TMRP especially since it was built in the early 20<sup>th</sup> Century. The sustainability of the palace is seen in details of the design such as the use of passive design elements, the high cultural value of the palace architecture and the economic value of the palace. Hence, a magnificent mid-rise vernacular palace was born in the turn of the 20<sup>th</sup> century and it is still standing today. It is recommended that further research is carried out on the scope of vernacular palace architecture in Malaysia and the reasons behind the ‘demise’ of these unique buildings in the 20th century.

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## REFERENCES

- Gibbs, P. (1987). *Building a Malay House*. Singapore: Oxford University Press.
- Hairuddin, L. M., & Che, A. A. (2008). Islam dalam Perlembagaan Malaysia: Kewajarannya berdasarkan faktor kesultanan melayu. *Journal of Ethics, Legal and Governance (REKAYASA)*, 4, 1-12.
- Hazrina, M. H., Farhana, R. M., & Sulaiman, K. (2012). Pengaruh Islam dalam politik dan senibina pentadbiran pada zaman kesultanan melayu Melaka. *Jurnal Teknologi (Sciences & Engineering)*, 58, 85-88.
- KALAM. (1993). Istana Lama Seri Menanti. *Measured Drawings*. Universiti Teknologi Malaysia.
- KALAM. (1993). Istana Lama Seri Menanti. *Measured Drawings*. UTM.
- Lawrence, R. J. (2006). Learning from the vernacular: Basic principles for sustaining human habitats. In: Asquith, L. and Vellinga, M. (ed.). *Vernacular Architecture in the Twenty-first Century. Theory, Education and Practice*. Milton Park, Abingdon: Taylor & Francis.
- Md, R. M., Nurul, S. H., & Nik, D. A. (2013). The concept of 4d capturing: Digitizing the history of Istana Jahar, Kota Bharu, Kelantan. *The 8<sup>th</sup> International Symposium on Digital Earth: Transforming Knowledge into Sustainable Practice*. Kuching: 8th ISDE 1-8.
- Ossen, D. R., Aziz, Z. A., & Idid, S. Z. (2010). The islamic malay traditional towns: Learning through the attributes - special emphasis on Johor Bahru, Malaysia. *First International Conference for Urban and Architecture Heritage in Islamic Countries: Its role in cultural and economic development*. Saudi Arabia: Saudi Commission for Tourism and Antiquities.
- Sheppard, M. (1969). Malay palaces of the past: Part one. *Malaya in History*, 8(1), 21-25.
- Yaakub, I. (1996). *Rumah tradisional Negeri Sembilan*. Shah Alam: Penerbit Fajar Bakti Sdn. Bhd.
- Yuan, L. J. (1987). *The Malay house: Rediscovering Malaysia's indigenous shelter system*. Institut Masyarakat. Pulau Pinang.
- Zulayti, Z. (2009). Seni bina melayu Semenanjung: Mencari asas seni bina national. *Jurnal ASWARA*. 63-80.





## Green Airport Infrastructure in Colombia: Opportunities for Public-Private Partnerships Schemes

Juan David González-Ruiz<sup>1,2\*</sup>, Eduardo Duque<sup>1</sup> and Juan Restrepo<sup>1</sup>

<sup>1</sup>Institucion Universitaria Esumer, 80126 Medellin, Colombia

<sup>2</sup>National University of Columbia, Robledo Campus, 65223 Medellin, Colombia

### ABSTRACT

This paper describes the state-of-the-art of green airport infrastructure in Colombia. It is aimed at identifying opportunities for public-private investment in this type of projects which constitute a growing global trend in the air transport industry. The study provides an insight into the green airport infrastructure industry in Colombia based on available literature. The relation to green airport infrastructure projects and Public-Private Partnerships were also analysed. Findings reveal that green airport infrastructure ensures compliance with the COP21 commitments and the Kyoto protocol.

*Keywords:* Airport management, Colombia, concessions, green airport infrastructure, public-private partnerships

### INTRODUCTION

AENA (2016), the Spanish state organisation that manages the civil airports, defines a green airport as “one that responsibly uses the natural resources it needs for its operation, reduces energy consumption and promotes the use of renewable energies to reduce emission of greenhouse gases (GHG), and to properly manage its waste”. In short, it is an airport which has minimal impact on the environment and works towards becoming a neutral facility in

terms of carbon emissions (nought GHG produced). This paper identifies the feasibility of developing green airport infrastructure in Colombia by means of Public-Private Partnerships (PPPs) with the main purpose of encouraging the development of sustainable infrastructure. This is in order to comply with its COP21 commitment as well as the Kyoto protocol (García et al., 2015).

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##### E-mail addresses:

[jdgonzalez@esumer.edu.co](mailto:jdgonzalez@esumer.edu.co) (Juan David González-Ruiz),

[eduardo.duque@esumer.edu.co](mailto:eduardo.duque@esumer.edu.co) (Eduardo Duque),

[juan.restrepo43@esumer.edu.co](mailto:juan.restrepo43@esumer.edu.co) (Juan Restrepo)

\*Corresponding Author

There have been many studies on climate change and its effects on aviation. Even the ICAO (International Civil Aviation Organization) had devoted complete chapters on this topic in its 2010 and 2013 Environmental Report. Also, the Federal Aviation Administration (FAA) has been working on this issue for several years (Transportation Research Board, 2012). In Europe, EUROCONTROL (the European Organisation for the Safety of Air Navigation, with 41 member states), which is committed to building a Single European Sky, has shown the way and among others, included future climate change in its Challenge of Growth reports since 2008 (Eurocontrol, 2013).

Globalisation has contributed to improvements in many sectors, including transportation. Air transport (passenger and cargo) is currently a major actor in the development of tourism, its demand has increased significantly over the last 16 years. Aerocivil (the Colombian Air Traffic Authority) confirms this growth in its reports. In 2014, 54 million passengers have passed through air terminals in Colombia carried representing an increase of 140% compared to 2004; only El Dorado Airport, the most important in Colombia, reported 21,046 arrivals and 21,307 departure flights last year (Aeronáutica Civil, 2016). That report also documented an increase in air cargo transport.

Colombia has associated the building of airports to territorial management plans, so progressively, they have been made part of regional economic growth strategies. This is the reason why developing sustainable projects based on PPP schemes can improve living standards as well as increased urbanisation. In fact, El Dorado Airport is the third busiest terminal in Latin America (after Guarulhos Airport in São Paulo and Benito Juárez Airport in Mexico) (El Tiempo, 2014). According to the Airports Council International (ACI) (Airports International Council, 2016), only in Latin America, passenger traffic in air terminals raised 6.6% in the first half of 2015; this is more than the world's average, which is 5%. It also reported that by 2031, the region would mobilise 1,000 million passengers (an important figure taking into account that in 2011 the figure was around 440 million) (Semana, 2015). Air traffic in Colombia is controlled by the National Planning Department (NPD). It runs under the control of the National Ministry of Transport and has presidential approval. In 2002, the NPD was focused on road and maritime transport since, at that time, they were the most popular mode of transport. At that time, there was a lack of specific regulations for air transportation.

Therefore, this paper reviews how PPP systems (particularly airports) can act as effective instruments to develop sustainable structuring in Colombia. In this way, private-public partnerships can encourage private investors to participate in these projects and, boost environmentally-friendly investments. In fact, Colombia Act 1508 (2012) and Act 1682 (2013) respectively on PPPs and infrastructure helped to accelerate the development of social and economic infrastructure projects, emphasising transport. Nevertheless, the requirements or conditions leading to sustainable development are not clear and lack consideration of environmental variables, particularly funding processes. This paper is structured as follows. The introduction section is followed by a description of green airport characteristics in the next. The main activities related to environmental sustainability are dealt with in the subsequent section. Next, the relation between PPPs and developing sustainable infrastructure will be presented.

## Becoming green

As a global trend, the advances made in air transport have forced the different administrations to acknowledge the importance of establishing concrete actions leading to improvement of general airport transport (infrastructure and management), in particular cargo and passenger transit. As a result of these and other general improvements, Colombia has turned into a middle-power regional actor with one of the most solid economies in Latin America. The Colombian government has refocused public investment towards modernising airport infrastructure, and with regards to airports with the highest air traffic rates (like El Dorado, Bogota's air terminal), it decided to outsource the managerial processes by means of concessions. The system of granting concessions to companies establishes that they must take charge of the management, modernisation, expansion, operation, maintenance and commercial exploitation of the concession area.

On this concern, El Dorado Airport's concession called OPAIN (a Swiss-Colombian firm), which started in 2006, has led the terminal to gain recognition. Thanks to the set of modernisation activities performed by OPAIN, El Dorado won an important award recently. The globally known Skytrax has been associated with the concept of quality excellence in the air transport industry. It is also recognised for its airline and airport star rating programme: The World Airline Awards and Airport Awards. El Dorado is now among the 23 airports in the world which have been granted four stars by Skytrax (Skytrax, 2016). The terminal staff is an example of good quality in aspects such as efficiency, courtesy, language, attitude and knowledge of all persons providing services.

On March 16, 2015, at a ceremony in Paris, OPAIN's manager received from Skytrax, the qualification certificate and the Four Star Prize by the best staff in South America. It is important to note that only 4 airports have got the 5 Star Qualification: Hong Kong's International Airport, Seoul's Incheon International Airport, Singapore's Changi Airport and Tokyo's Haneda International Airport. The other 19 terminals which received four stars are located in cities such as Amsterdam, Copenhagen, Dusseldorf, Kuala Lumpur, London (Heathrow), Beijing and Shanghai. This favourable scenario, in the long run, will permit Colombia to take good advantage of the multiple FTAs it has signed. However, this award represents just one aspect of El Dorado's objectives. Since this sector is growing significantly both economically and socially, the trend is to lead this terminal to reach the degree of modernisation of the main international terminals in the world. This is possible through the implementation of an effective managing system, offering excellent customer service and through the adoption and deployment of a range of technologies (apps), integrated across an open system. These are implemented not only in airports but in majority of spaces in smart cities.

In addition, passengers and cargo are beyond the currently capacity of the terminal. Therefore, by 2021, another airport (El Dorado II) will be constructed, 15 km far from El Dorado. This is mainly due to the forecasts which have determined that in five years, the passengers using El Dorado are estimated to be around 40 million (Revista Semana, 2015). However, besides interconnecting people, the new facilities, the runway repaving and the excellent services offered are El Dorado's main challenges to becoming sustainable and green. It can be said that the marketplace has become green. Undoubtedly, it will become greener

as time passes and humanity is directed towards preventing its own annihilation. The biggest challenge our world is facing is dealing with protecting the environment.

Among major environmental concerns are:

- The destruction of the ozone layer
- The destruction of rain forests
- The availability of drinking water
- The renewable-sustainable green energies
- The endangered species, and
- The air and water pollution

In this regard, Colombia has already been working on some of these issues, and thus, Duque et al. (2016) state that Colombia can participate in the international carbon credit market through the sale of CER (Certified Emission Reductions). This is encouraged by the domestic demand reduction commitments imposed by the European Union and Japan. El Dorado Airport is now currently leading in sustainable operations. Spain, Germany, Mexico, the US and India have 100% solar powered airports in the world: Cochin airport (CIAL Cochin International Airport Limited, 2016) in India have taken the lead in this regard. Many airports throughout the world have extensive programmes to mitigate carbon emissions and programmes such as the Airport Carbon Accreditation, which are gaining ground (Mosvold, 2015).

### **Green actions**

The set of actions that pushed El Dorado Airport towards a greener operation include control of the surrounding fauna (birds and mammals which threaten the safety of flights), under the guidance of OPAIN. According to OPAIN's Fauna Control System (2011), four main activities are carried out: (i) watching patrols; (ii) dispersion patrols; (iii) fauna monitoring; and (iv) new risk monitoring.

Patrols keep track of the different areas of the facilities. The runways, taxiways, ramps, parking decks and the areas surrounding the terminal are constantly monitored. This is a necessary manoeuvre since the terminal is bordered by wide green fields and ponds which attract diverse types of birds (OPAIN, 2011). Besides, the airport area is located in the middle of migration routes of certain bird species. El Dorado also has its own solid waste management system. Although air transport provides an invaluable service to people, it is undeniable that these activities have serious effects on the environment. The terminal's administration has been working on the implementation of measures leading to effectively protecting the environment and minimise negative impacts (air pollution, noise production, and the alterations to the surrounding soils, water and living organisms). Concerning the organic and inorganic disposed materials produced by El Dorado, it is important to consider the types of solid waste. The table below shows the eight categories of solid waste:

Table 1  
*Classification of the solid waste produced at El Dorado Airport*

Type of waste	Place of origin	Cause
Waste from local flights	Platforms, decks and passenger terminal	Human activities (local passengers, visitors and airport staff)
Food waste	Fast food restaurants	Biodegradable waste from food
Packaging and containers	Cargo holds, platforms, decks and passenger terminal	Product wrapping and containers
Waste from international flights	Platforms, decks and passenger terminal	Human activities (local passengers, visitors and airport staff)
Waste from cleaning services	Site serviced by the contractor	The action of sweeping, mopping and cleaning in general.
Mud	Wastewater treatment plants	Normal operation of wastewater treatment
Waste incinerator ashes	Waste Incinerator	Controlled combustion of waste
Garden and lawn mowing waste	Green fields	Green fields maintenance processes

*Source:* Ministerio del Medio Ambiente (2001)

Not only solid but liquid waste are disposed of safely. Solid waste is classified into recyclable and non-recyclable materials. Plastic, glass, metal and paper are collected to be sold. The organic disposable material is then safely incinerated. Water waste (polluted rainwater, polluted water from cleaning procedures, water polluted with oils or fuel etc.) is also treated in a responsible way through specific disposal protocols (conducts, treatment tanks, blue water collectors etc.). Rainwater is recycled and bathroom use. Around 127 m<sup>3</sup> of water are reused on a daily basis.

Unfortunately, the previous activities and measures were insufficient to elevate El Dorado to the category of a green airport. According to the Airport Carbon Accreditation Organization (2016), it is necessary to comply with different requirements such as Mapping (footprint measurement), Reduction (reduced carbon footprint), Optimisation (third party engagement in carbon footprint reduction) and Neutrality (carbon neutrality for direct emissions by offsetting) in order to get certified as a green airport. In fact, only three air terminals have been certified as ecological (green). It represents just 2% of Latin American & Caribbean air passenger traffic (Airport Carbon Accreditation Organization, 2016).

- Tijuana International Airport (operated by Grupo Aeroportuario del Pacifico) in Mexico
- Quito International Airport (operated by Corporación Quiport S.A) in Ecuador
- Galapagos Ecological Airport (operated by Corporación América) in Ecuador

### **PPPs schemes as a tool for developing sustainable airports**

The building of sustainable infrastructure will lead to the creation of intelligent cities incorporating new standards, systems and capacity to create an organic network that enable the creation of synergies between the different components of the city. Thus, the integration

of sustainable (and smart) cities, will also bring challenges, as well as opportunities (Nam & Pardo, 2012). Consequently, the enactment of Law 1508 of 2012, which is based on Project Finance schemes, allows private participation for building public infrastructure. This law is expected to close the gap between social and economic infrastructure (Congress of Colombia, 2012, 2013). In addition, the objective of these regulations is to increase the speed of developing infrastructure projects. In other words, this law established the parameters to developing infrastructure projects in Colombia, allowing the State to monitor the process of designing, managing and implementing. This is a mechanism to encourage private participation since the investors can have clear roadmaps to define the different investment strategies.

However, in order to build sustainable infrastructure, especially airports, it is necessary to find financial resources to promote the development of environmentally-friendly infrastructure. As a consequence, the Clean Development Mechanism is proposed as an alternative leading to develop sustainable projects, which, in turn, will allow Colombia to meet its COP21 commitments. Unfortunately, this mechanism has not been used in Colombia in transport infrastructure projects. It represents a real challenge for project developers to incorporate sustainable elements in funding. These facts suggest that private investors play a fundamental part. Alternatively, financial resources are becoming increasingly limited; hence, the primary challenge lies in the financing process. In the current situation (debt crises in the developed countries), raising financial resources will be hard. This leads the development of new projects to search for new funding sources. Thus, this paper proposes that elements such as sustainability and financing (which had never been linked to building airport infrastructure) are essential for the development of the sector. Thus, this paper was aimed at connecting project development via PPPs focusing on the concept of environmental sustainability and financial profitability. Therefore, PPPs must be considered as the State's management tool for encouraging the development of green airports; project developers can view it as a mechanism that enables and promotes the generation of new sources of funding for the sector.

The following figure shows the main elements of PPPs and their relationship with sustainable infrastructure.

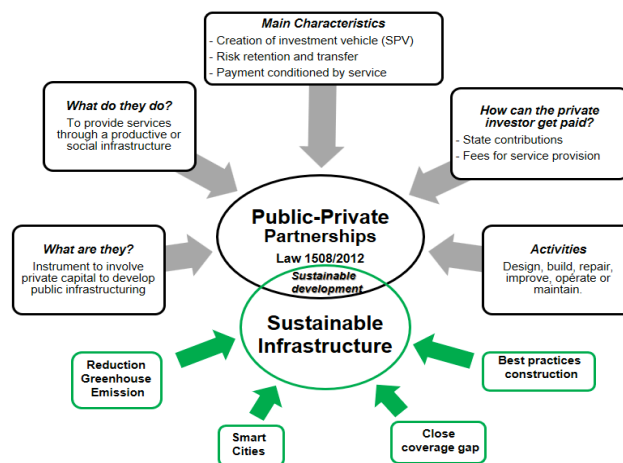


Figure 1. Relation between PPPs and the development of sustainable infrastructure  
 Source: Own elaboration



Table 2  
*Airports projects structured accordant to Law PPPs in Colombia*

Type of PPP	Name	Competent State Body	Status
Public Initiative	PPP Project for Barranquilla y South-western airports (Armenia-Neiva-Popayan)		Hired
Private Initiative without public resources	Rafael Nunez Airport (CTG) – Structuring, design and construction of a runway and expansion of the current platform		Pre-feasibility under review
Private Initiative without public resources	El Dorado Airport (BOG) – Studies, design, financing, construction and maintenance	Agencia Nacional de Infraestructura - ANI	Rejected Pre-feasibility
Private Initiative without public resources	El Dorado Airport (BOG) – offer of a private initiative hotel, aero-mall, business and complementary service centre		Pre-feasibility under review
Public Initiative	Modernisation of passenger terminal – International Matecana Airport (PEI)	Aeropuerto Internacional de Matecana	Feasible
Private Initiative without public resources	Restructuring of open-air areas of El Dorado Airport’s master plan (BOG)		Pre-feasibility under review
Private Initiative with public resources	Private initiative of El Eden Airport (AXM), Benito Salas Vargas Airport (NVA) and Guillermo Leon Valencia Airport (PPN)		Pre-feasibility under review
Private Initiative without public resources	PPP – Public Initiative of Gustavo Rojas Pinilla Airport (ADZ) and El Embrujo Airport (PVA)	Agencia Nacional de Infraestructura - ANI	Pre-feasibility under review
Private Initiative without public resources	Restructuring of open-air areas of El Dorado Airport’s master plan (BOG)-PPP		Pre-feasibility under review
Private Initiative without public resources	Airport concession for Gustavo Rojas Pinilla Airport (ADZ) and El Embrujo Airport (PVA)		Pre-feasibility under review

*Source: Departamento Nacional de Planeación (DNP, 2016)*

It is expected that in the future, environmental sustainability criteria are included in the bidding process of such projects. Thus, sustainable sources of financing such as CERs can be used. It is also important to note that the development of infrastructure projects could generate a market of securities indexed to those projects, which would result in expanding the financing and investment options. Thus, the Latin American Market (LATM) would be a good window to trade securities of various projects and sectors.

## CONCLUSION

This paper has discussed the current development pertaining to green airport infrastructure in Colombia. The need for special policies for sustainable infrastructure, particularly in the air terminals, has obstructed the development of such projects. There is no doubt that PPP sustainable projects can play a fundamental role in the design of better practices. Consequently, the idea of sustainable infrastructure will be reinforced by improving quality levels and by encouraging funding of eco-friendly assets. With the purpose of fulfilling Colombia's commitments made at the COP21, the Government must implement taxation for example, to promote the development of sustainable infrastructure. Also, it is necessary that the bidding process for projects developed under PPPs to include environmental variables. Thus, in future, the economic development of a country will be directly related to its ability to develop sustainable infrastructures. In environmental terms, El Dorado Airport has developed important mechanisms to promote sustainable infrastructure. However, there is evidence that all the other airports in Colombia are behind in terms of implementing eco-friendly environmental practices. This will impede the evolution from "grey infrastructure" to "green". It is therefore necessary to set-up a solid framework in order to ensure investors focus on ecological investments to promote green airport infrastructure in Colombia. Future research should include analysing how stakeholders such as Investment banks, project developers, the Government and multilateral banks can participate in the development of such projects.. Finally, this paper has proposed the use of dynamic of systems as instruments to measure the impact on hybrid financing mechanisms on the reduction of GHG emission.

## REFERENCES

- AENA. (2016). *Proyecto Aeropuerto Verde ¿ Qué es un Aeropuerto Verde?* Retrieved from <http://www.aena.es/csee/ccurl/343/235/Lanzarote Aeropuerto Verde online,0.pdf>
- Aeronáutica Civil. (2016). Estadísticas Aeropuertos. Retrieved from <http://www.aerocivil.gov.co/AAeronautica/Estadisticas/Estadisticas-Operacionales/Aeropuertos/Paginas/Inicio.aspx>
- Airport Carbon Accreditation Organization. (2016). *Airport and CO2*. Retrieved from <http://www.airportcarbonaccreditation.org/airport/participants/latin-america.html>
- Airports International Council. (2016). Robust passenger traffic growth to start the year; air freight volumes inch up with some modest gains - Mar 15, 2016. *ACI Media Releases*. Retrieved from <http://www.aci.aero/News/Releases/Most-Recent/2016/03/15/Robust-passenger-traffic-growth-to-start-the-year-air-freight-volumes-inch-up-with-some-modest-gains-CIAL>
- Cochin International Airport Limited. (2016). Green Airport.
- Departamento Nacional de Planeación - DNP -. (2016). *Listado de General de Proyectos*. Bogotá D. C. Retrieved from <https://saga.dnp.gov.co/PortalSaga/Default.aspx?txtAplicacion=SAGA&txtUrl=https://saga.dnp.gov.co/ruapp/>
- Duque, E., González-Ruiz, J. D., & Restrepo, J. (2016). Developing sustainable infrastructure for small hydro power plants through clean development mechanisms in Colombia. *Procedia Engineering*, 45, 224-233.

- El Tiempo. (2014). Colombia, en el “top” del tráfico aéreo de América Latina. *Economía*. Bogotá D.C. Retrieved from <http://www.eltiempo.com/economia/sectores/trafico-aereo-de-america-latina/14242022>
- García, C., Barrera, X., Gómez, R., & Suárez, R. (2015). *El ABC de los compromisos de Colombia para la COP21*. Retrieved from <http://www.wwf.org.co/?248415/El-ABC-de-los-compromisos-de-Colombia-para-la-COP-21>
- Ministerio del Medio Ambiente. (2001). *Guía ambiental para la operación y funcionamiento de aeropuertos*. Bogotá D.C. Retrieved from [http://www.aerocivil.gov.co/Aerocivil/GAmbiental/Documents/Gu%C3%ADaambiental para la operaci%C3%B3n y funcionamiento de aeropuertos.pdf](http://www.aerocivil.gov.co/Aerocivil/GAmbiental/Documents/Gu%C3%ADaambiental%20para%20la%20operaci%C3%B3n%20y%20funcionamiento%20de%20aeropuertos.pdf)
- Ministerio del Medio Ambiente. (2001). *Guía ambiental para la operación y funcionamiento de aeropuertos*. Bogotá D.C. Retrieved from [http://www.aerocivil.gov.co/Aerocivil/GAmbiental/Documents/Gu%C3%ADa ambiental para la operaci%C3%B3n y funcionamiento de aeropuertos.pdf](http://www.aerocivil.gov.co/Aerocivil/GAmbiental/Documents/Gu%C3%ADa%20ambiental%20para%20la%20operaci%C3%B3n%20y%20funcionamiento%20de%20aeropuertos.pdf)
- Mosvold, O. (2015). Climate change is here to stay: Reviewing the impact of climate change on airport infrastructure. *Journal of Airport Management*, 9(3).
- OPAIN. (2011). *Sistema de control de Fauna Aeropuerto Internacional El Dorado*. Retrieved from [http://www.opain.co/archivos/COMITE NACIONAL DE PELIGRO AVIARIO Y FAUNA 2011 .pdf](http://www.opain.co/archivos/COMITE%20NACIONAL%20DE%20PELIGRO%20AVIARIO%20Y%20FAUNA%202011.pdf)
- Semana. (2015). Se construirá un segundo aeropuerto para Bogotá. *Nación*. Retrieved from <http://www.semana.com/nacion/articulo/se-construira-un-segundo-aeropuerto-para-bogota/415655-3>
- Semana. (2015). Aeropuertos para el progreso. *Economía*. Retrieved from <http://www.semana.com/economia/articulo/especial-infraestructura-2015-aeropuertos/448400-3>
- Skytrax. (2016). The World's Top 100 Airports - 2015. Retrieved from [http://www.worldairportawards.com/Awards/world\\_airport\\_rating\\_2015.html](http://www.worldairportawards.com/Awards/world_airport_rating_2015.html)





## **Contractors' Perspective on Material Waste Reduction in Kuala Lumpur**

**Nurul Aini Osman\*, Mohd Amir Shazwan Hashim and Jye Hwoi Pok**

*QS Department INTI International University, 71800 Nilai, Negeri Sembilan, Malaysia*

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### **ABSTRACT**

In the area of sustainable development, construction waste is an important issue that must be tackled responsibly. It is an assortment of waste, at the stage of construction. This paper assesses waste minimisation or reduction measures and such practices in the Kuala Lumpur construction industry. A structured questionnaire survey was conducted to obtain contractors' views on 25 waste minimisation measures discussed in literature. Data was analysed using frequency analysis method and average index analysis method. The results showed that adoption of proper site management techniques is widely practised. The adoption of these waste minimisation measures could lead cost savings to the construction industry and prevent environmental degradation.

*Keywords:* Construction industry, Kuala Lumpur, measures, waste minimisation

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### **INTRODUCTION**

The construction industry is the main generator of waste and thus, its key challenge remains having an efficient management in reducing environmental contamination (Lachimpadi et al., 2012). Many countries push towards preserving a balance between development while at the same time attain sustainable development (Al-Hajj & Hamani, 2011). Sustainable

development that encourages re-use of built assets or minimise waste in order to reduce pollution (Ofori et al., 2000) has become the biggest challenge for nations across the globe because construction waste poses serious environmental problems (Begum et al., 2007; Osmani 2012; Poon et al., 2013).

The construction industry has posed serious environmental issues in Malaysia over the last two decades (Begum et al., 2007) had done a study on implementation of waste

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*E-mail addresses:*

[nurulaini.osman@newinti.edu.my](mailto:nurulaini.osman@newinti.edu.my) (Nurul Aini Osman),

[amirshazwan.hashim@newinti.edu.my](mailto:amirshazwan.hashim@newinti.edu.my)

(Mohd Amir Shazwan Hashim),

[hwoi\\_93@hotmail.com](mailto:hwoi_93@hotmail.com) (Jye Hwoi Pok)

\*Corresponding Author

management and minimisation in the Malaysian construction industry and found that the environmental issues are becoming more serious and should be curbed. Therefore, the vast implementation of the construction waste minimisation are the vital area of concern especially in Kuala Lumpur due to its' status as fast growth development city in Malaysia.

Waste minimisation is defined as technology, procedure or action employed to prevent, remove or lessen construction waste or transform those waste for re-use (recycling) (Singh, Brueckner & Padhy, 2015). The Environmental Protection Agency of USA (2000) defines waste minimisation as "any method that reduces the volume or toxicity of a waste that requires disposal". A variety of measures to minimise construction waste has been reported (Al-Hajj & Hamani, 2011; Begum & Pereira, 2011; Yates, 2013). Polat and Ballard (2004) opine that minimisation is most efficient for diminishing adverse impacts of construction waste and reducing waste disposal problem because cost of the latter is more expensive than waste prevention. It is important therefore, to identify and evaluate measures to reduce waste the construction industry. This paper discusses the views of contractors in Kuala Lumpur on waste minimisation measures.

## **MATERIALS AND METHODS**

This research examined 25 waste minimisation measures found in the literature (Ahankoob et al., 2012; Al-Hajj & Hamani, 2011; Lu & Yuan, 2013; Osmani, Glass & Price, 2008; Osmani, 2012). The measures were pre-tested in a pilot study involving five selected contractors in Kuala Lumpur to evaluate their applicability to the current study. Results showed the instructors had an in-depth understanding and knowledge of the waste minimisation measures.

A survey using structured questionnaire was conducted between January 2016 and April 2016. The questionnaire had three sections: respondents' background, respondents' knowledge on the measures which were pre-tested in the pilot study the level of practice of waste minimisation measures.

The research sample was selected Grade 7 construction firms listed under Construction Industry Development Board (CIDB). There were 1355 registered contractors and in order to achieve 95% confidence level with 0.5 margin of error (Kelley et al., 2003), the sample size needed was 299. However, due to time constraint, we were only able to interview 223 firms.

The 25 waste minimisation measures (WWM) were coded as WMM1 to WMM 25 and Likert scale was used to measure their efficiency. Thus, the respondents select one of the choices available for each row of answers: Always equals to 5; Never = equal 1, thus the mean is 3. If the mean score is <3.00, it indicates that the respondents are less keen to apply the measure on site. However, if the means score is >3.00, it indicates the opposite.

## **RESULTS AND DISCUSSION**

### **Respondents' Background**

The average years of experience of the contractor firms surveyed ranged between 10 and 20 years, 20% of respondents are Site Managers with the second highest responses rate, 12% are Project Managers followed by Quantity Surveyors with the highest response rate of 56%.

Lastly, 12% of respondents are from other professions such as Construction Managers and Assistance Manager.

### Waste Minimisation Measures to Waste Reduction

Respondents were interviewed on their waste minimisation measures. The outcome indicated there were no significant differences between all parties at 5% significance level. Table 1 shows average index and ranking of each type of waste minimisation measures.

Table 1  
*Average index on contribution of the waste minimisation measures*

Rank	Waste Minimisation Measure	Average Index
HIGH	Adoption of proper site management techniques (WMM 1)	4.41
	Proper storage of materials on site / Provide convenient containers for materials storage and retrieval (WMM 13)	4.18
	Encourage re-use of waste materials in projects (WMM 2)	4.18
	Early and prompt scheduling of purchases and deliveries (WMM 6)	4.12
	Good coordination between store and construction personnel to avoid over ordering (WMM 20)	4.12
	Ensure appropriate dimensions and quality of materials (WMM 14)	4.12
	Checking materials supplied for right quantities and volumes (WMM 9)	3.94
	Accurate and good specifications of materials to avoid wrong ordering (WMM 8)	3.94
	Employment of skilled workmen (WMM 19)	3.82
	Minimising design changes (WMM 4)	3.71
	Use of more efficient construction equipment (WMM 17)	3.71
MEDIUM	Purchasing raw materials that are just sufficient (WMM 10)	3.65
	Vigilance of supervisors / improving supervision (WMM 22)	3.65
	Change of attitude of workers towards the handling of materials (WMM 18)	3.65
	Recycling of some waste materials on site (WMM 3)	3.65
	Training of construction personnel (WMM 21)	3.59
	Mixing, transporting and placing concrete at appropriate time (WMM 25)	3.59
	Access to latest information about types of materials on the market (WMM 7)	3.47
	Increase use of off-site prefabrication (WMM 15)	3.41
	Careful handling of tools and equipment on site (WMM 24)	3.35
	Issuing raw materials that are just sufficient to sub-contractor (WMM 12)	3.18
	Just in time operations (WMM 5)	3.12
	Use of low waste technology (WMM 11)	3.00
	Using materials before expiry dates (WMM 16)	3.00
	Waste management officer or personnel employed to handle waste issues (WMM 23)	2.76

The 25 waste minimisation measures were further divided into three categories of waste reduction: high, medium and low contributions (Table 1). The rating was classified based on their average index score: 1 represents lowest contribution to waste reduction, 3 represents medium while 5 is the highest contribution.

Eleven measures including “adoption of proper site management techniques” (WMM 1), “proper storage of materials on site or provide convenient containers for materials storage and retrieval” (WMM 13) and “encourage re-use of waste materials in projects” (WMM 2) were categorised as high level of contribution to waste reduction, with average index rating near or more than 4.20. Contractors consider waste minimisation measures, which result in cost saving to the organisation, as representing high contribution to waste reduction. According to Sin et al., (2012), inappropriate management of construction waste has multifold adverse impacts. Thus, Malaysia government is urged to improve waste management techniques and cooperate with private sectors to adopt proper site management techniques.

“Waste management officer or personnel employed to handle waste issues” (WMM 23) is the lowest contributor to waste minimisation measure with a score 2.76. The contractors considered employing of waste manager as unnecessary and a waste of money.

### Level of Practice of Waste Minimisation Measures

The responses of contractors on waste minimisation measures were compared, and the results showed no difference at 5% significance level. The responses of both groups were therefore combined ranging from “never practiced” to “always practice” as shown in Table 2.

Table 2  
*Average index on practice of waste minimisation measures*

Rank	Waste Minimisation Measure	Average Index
OFTEN	Proper storage of materials on site / Provide convenient containers for materials storage and retrieval (WMM 13)	3.97
	Early and prompt scheduling of purchases and deliveries (WMM 6)	3.71
	Adoption of proper site management techniques (WMM 1)	3.68
	Good coordination between store and construction personnel to avoid over ordering (WMM 20)	3.68
	Minimising design changes (WMM 4)	3.53
	Ensure appropriate dimensions and quality of materials (WMM 14)	3.53
SOMETIMES	Checking materials supplied for right quantities and volumes (WMM 9)	3.24
	Accurate and good specifications of materials to avoid wrong ordering (WMM 8)	3.24
	Using materials before expiry dates (WMM 16)	3.21
	Training of construction personnel (WMM 21)	3.15
	Purchasing raw materials that are just sufficient (WMM 10)	3.09
	Use of more efficient construction equipment (WMM 17)	3.09
	Change of attitude of workers towards the handling of materials (WMM 18)	3.09



Table 2 (continue)

Access to latest information about types of materials on the market (WMM 7)	3.09
Employment of skilled workmen (WMM 19)	3.06
Careful handling of tools and equipment on site (WMM 24)	3.03
Mixing, transporting and placing concrete at appropriate time (WMM 25)	3.00
Increase use of off-site prefabrication (WMM 15)	2.94
Encourage re-use of waste materials in projects (WMM 2)	2.94
Vigilance of supervisors / improving supervision (WMM 22)	2.91
Just in time operations (WMM 5)	2.91
Issuing raw materials that are just sufficient to sub-contractor (WMM 12)	2.88
Recycling of some waste materials on site (WMM 3)	2.76
Use of low waste technology (WMM 11)	2.76
Waste management officer or personnel employed to handle waste issues (WMM 23)	2.76

A measure with the highest rank has the highest level of waste minimisation. The rating range measures was based on their average index score: 1 represents measures that were never practised, 2 represents measures rarely practised, 3 represents measures practised sometimes, 4 represents measures often practised and 5 represents measures always practised. The range between the highest and lowest values is 4. This range is divided by 5 to represent the five scales which are never, rarely, sometimes, often and always practice measure. From Figure 2 and Table 2, no waste minimisation measures that did not fall under the category of “always” had been implemented by contractors in Kuala Lumpur. The most popular measure was “proper storage of materials on site or provide convenient containers for materials storage and retrieval (WMM 13) with an average index of 3.97. The other two measures under “always” category are “early and prompt scheduling of purchases and deliveries” (WMM 6) and “adoption of proper site management techniques” (WMM 1).

“Recycling of some waste materials on site” (WMM 3), “use of low waste technology” and ‘waste management officer or personnel employed to handle waste issues’ are among the lowest practices to waste minimisation in Kuala Lumpur’s construction sites and these three measures had a score of 2.76. Although ‘recycling of some waste materials on site’ was ranked number 12 in the priority level of waste minimisation measures to waste reduction, the contractors were less keen to implement this measure on their site due to the reason it was not always cost-effective. This was confirmed by Hiete et al. (2011) and Yuan et al. (2011) as construction waste is heterogeneous, making recycling efforts difficult. However, , contractors are encouraged to re-use built assets and adopt better environmental management system to reduce waste (Ofori et al., 2000).

## CONCLUSION

This study examined waste minimisation measures by contractors in the Kuala Lumpur construction industry. Respondents perceived adoption of proper site management techniques,

proper storage of materials on site or providing convenient containers for materials storage and retrieval and boost to re-use the waste materials in projects as measures that are most effective in contributing to waste minimisation. Employing waste management officers to handle waste issues and recycling of waste materials on site are perceived as measures with low contribution to waste reduction and the least practised. This could be contractors believed these measures will increase cost rather than profit. Therefore, in order to help the construction industry in Kuala Lumpur to achieve minimisation of waste materials, it is recommended that government should enact laws and implement policies that promote positive attitudes towards waste minimisation at all levels in a construction project.

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## REFERENCES

- Ahankoob, A., Seyed, M. K., Rotami, R., & Preece, C. (2012). Bim perspectives on construction waste reduction. *Management in Construction Research Association*, pp. 195-99
- Al- Hajj, A., & Hamani, K. (2011). Material waste in the UAE construction industry: Main causes and minimisation practices. *Architectural Engineering and Design Management*, 7(4), 221–35
- Begum, R. A., & Pereira, J. J. (2011). C & D waste profile of the Malaysian construction industry: Need a centralized database. *2011 World Congress on Sustainable Technologies (WCST)*, 73–76.
- Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2007). Implementation of waste management and minimisation in the construction industry of Malaysia. *Resources, Conservation and Recycling*, 51(1), 190–202.
- Hiete, M., Stengel, J., Ludwig, J., & Schultmann, F. (2011). Matching construction and demolition waste supply to recycling demand: A regional management chain model. *Building Research and Information*, 39(4), 333–51.
- Kelly, K., Clark, B., Brown, V., & Sitzia, J. (2003). Good practice in the conduct and reporting of survey research. *International Journal for Quality in Health Care*, 15(3), 261–66.
- Lachimpadi, S. K., Pereira, J. J., Taha, M. R., & Mokhtar, M. (2012). Construction waste minimisation comparing conventional and precast construction (mixed system and ibs) methods in high-rise buildings: A Malaysia Case Study. *Resources, Conservation and Recycling*, 68, 96–103.
- Weisheng, L., & Hongping, Y. (2013). Investigating waste reduction potential in the upstream processes of offshore prefabrication construction. *Renewable and Sustainable Energy Reviews*, 28, 804–11.
- Ofori, G., Briffett, C., Gu, G., & Ranasinghe, M. (2000). Impact of ISO 14000 on construction enterprises in Singapore. *Construction Management and Economics*, 18(8), 935–47.
- Osmani, M. (2012). Construction waste minimisation in the UK: Current pressures for change and approaches.” *Procedia - Social and Behavioral Sciences*, 40, 37–40. Retrieved from <http://www.sciencedirect.com/science/article/pii/S1877042812006258>.
- Osmani, M., Glass, J., & Price, A. D. F. (2008). Architects’ perspectives on construction waste reduction by design. *Waste Management*, 28(7), 1147–58.

- Polat, G., & Ballard, G. (2004). Waste in Turkish construction : Need for lean construction techniques. *Proceedings of the 12<sup>th</sup> Annual Conference of the International Group for Lean Construction*, 3–5.
- Poon, C. S., Yu, A. T. W., Wong, A., & Yip, R. (2013). Quantifying the impact of construction waste charging scheme on construction waste management in Hong Kong. *Engineering and Management*, (May), 466–79.
- Tey, J. S., Goh, K. C., Kek, S. L., & Goh, H. W. (2013). Current practice of waste management system in Malaysia : Towards sustainable waste management current practices for Malaysia. *Multi-Disciplinary Research (MDR)*, 1106.
- Singh, M., Brueckner, M., & Padhy, P. K. (2015). Environmental management system ISO 14001: Effective Waste minimisation in small and medium enterprises in India. *Journal of Cleaner Production*, 102, 285–301.
- Yates, J. K. (2013). Sustainable methods for waste minimisation in construction. *Construction Innovation: Information, Process, Management*, 13(3), 281–301.
- Yuan, F., Li, Y. S., & Qi, M. L. (2011). Emergy analysis of the recycling options for construction and demolition waste. *Waste Management*, 31(12), 2503–11.





## Trend Analysis of Water Quality at Sungai Sarawak

**Yuhani Jamian\*, Zainap Lamat and Nurazura Rali**

*Department of Civil Engineering, Politeknik Kuching Sarawak, Beg Berkunci 3094, Km 22, Jalan Matang, 93050 Kuching, Sarawak, Malaysia*

### ABSTRACT

Sungai Sarawak is the most important river in Sarawak. This study was aimed at assessing water quality in the selected stations from Satok bridge to the downstream, Muara Tebas, located along Sungai Sarawak. Water quality trend analysis was conducted to determine the correlation between the water quality parameters. Trend analysis was carried out using Mann-Kendall Test because data collected was non-parametric. Next, Spearman rank was used in order to determine the correlation between parameters. The results obtained and the observation made in this study reveals that the trend exists only for Chemical Oxygen Value (COD). But there are trends for Biochemical Oxygen Demand, (BOD), Dissolved Oxygen (DO), Total Suspended Solid (TSS), Ammoniacal Nitrogen (NH<sub>4</sub>N) and Turbidity to decrease or increase with no trends between 2007 and 2011. The correlation between parameters is not very strong because there are many determinants of water quality parameters. The result from this study would provide useful information for water quality management in order to maintain and improve the water quality of Sungai Sarawak.

*Keywords:* Correlation, management trends analysis, water quality

### INTRODUCTION

Rivers have been utilised by mankind over the centuries to the extent that, very few, if any, are now in their natural condition (Wetzel, 2001). Kovacs (1986) describes river

pollution as an integrated, environmental problem resulting from unregulated industrial pollutants and accidental spills as well as from airborne and other non-point sources, urbanisation, deforestation, erosion and intensive agriculture. Chau et al. (2002) stated that is important to predict accurately quality of water bodies in water resource planning and management. Chang et al. (2001) stated that it is essential to assess water quality of the river

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##### *E-mail addresses:*

yuhanijamian@yahoo.com (Yuhani Jamian),

zainaplamat@yahoo.com (Zainap Lamat),

nurazurarali@gmail.com (Nurazura Rali)

\*Corresponding Author

even though data availability is limited. Additionally, there are various classification methods that have been used for estimating the changing status usability of surface water in river basins. This study provides water quality trend analysis and correlation among the parameters.

## MATERIALS AND METHODS

### Data Collection

Data was collected from Natural Resources and Environment Board Sarawak (NREB). There are about 24 water quality parameters monitored by NREB. However, only the following are assessed for this study: DO, BOD, COD,  $\text{NH}_4\text{N}$ , TSS and Turbidity while research focus was south of Sungai Sarawak.

### Research Design and Procedure

**Trend Analysis.** Hydrology data are rarely normally distributed or independent (Cluis et al., 1989). Data was analysed using Mann-Kendall Test. The purpose of the Mann-Kendall (MK) test (Gilbert 1987) is to statistically assess if there is an upward or downward trend of the variable of interest over time.

According to this test, the null hypothesis  $H_0$  assumes that there is no trend (the trend is independent and randomly ordered) and this is tested against the alternative hypothesis  $H_1$ , which assumes that there is a trend. The computational procedure for Mann-Kendall test considers time series of  $n$  data points. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistics  $S$  is incremented by 1. On the other hand, if data value from a later time period is lower than a data value sampled earlier,  $S$  is decremented by 1. The net result of all such increments and decrements yields the final value of  $S$ . Once  $S$  statistic has been calculated (in this study,  $S$ -statistic was calculated using Excel), it is compared with the table of null probability values of  $S$  for the number of data points ( $n$ ) in the series. If the probability value for the calculated  $S$ -statistic is less than the specified significance level for the test ( $\alpha=0.05$ ), the result is significant at the  $1-\alpha$  confidence level and a trend is present (David, 2005). Value of  $S$ -statistic will be in negative or positive - the former means that a decreasing trend in concentration over time is present at the 95% confidence level, while the latter of  $S$ -statistics means that an increasing trend in concentration over time is present at the 95% confidence level.

**The Correlation between Water Quality Parameters.** In order to achieve the third objective of this research which is the correlation between water quality parameters, Spearman's rank correlation coefficient or Spearman's rho have been used. Based on the result of normality test, data is nonparametric and the most suitable statistical test is Spearman's rank correlation. This test will assess how well the relationship between two variables can be described using monotonic functions. Correlation is a strength measurement for linear relation between two variables under review. Bidin Yatim in Rali (2003) described the correlation coefficient value which is near to -1 or 1 which indicates strong linear relation between two variables. Guilford's

Rule of thumbs (Guilford, in Kaprawi, 2000) was used to interpret the magnitude of the correlation between parameters to see if the correlation was strong or weak.

## RESULTS AND DISCUSSION

### Trend Analysis of Water Quality Parameter

Trend analysis was carried out using Mann-Kendall test according to the water quality parameters that have been selected. The seven selected locations were Satok Bridge (Station 1), Confluence of Sungai Bintangor (Station 2), Holiday Inn (Station 3), Confluence of Sungai Padungan (Station 4), Confluence of Sungai Sekama (Station 5), Upstream Barrage (Station 7) and Downstream Barrage (Station 8). The null hypothesis ( $H_0$ ) and alternative hypothesis ( $H_a$ ) are as below:

$H_0$ : There are no trend exist ;  $H_a$ : There are trend exist

**Dissolved Oxygen.** The analysis reveals an absence of trend for dissolved oxygen (DO) along Southern Sarawak River between 2007 and 2011. The probability value for each station is more than  $\alpha$  value (0.05). Thus,  $H_0$ : There is no trend, and is accepted. It also can be seen in Figure 1(a) where all the data are scattered with no trend throughout the year. Although there is no trend for dissolved oxygen along the river, the linear for all station shows that the dissolved oxygen has a tendency towards deterioration.

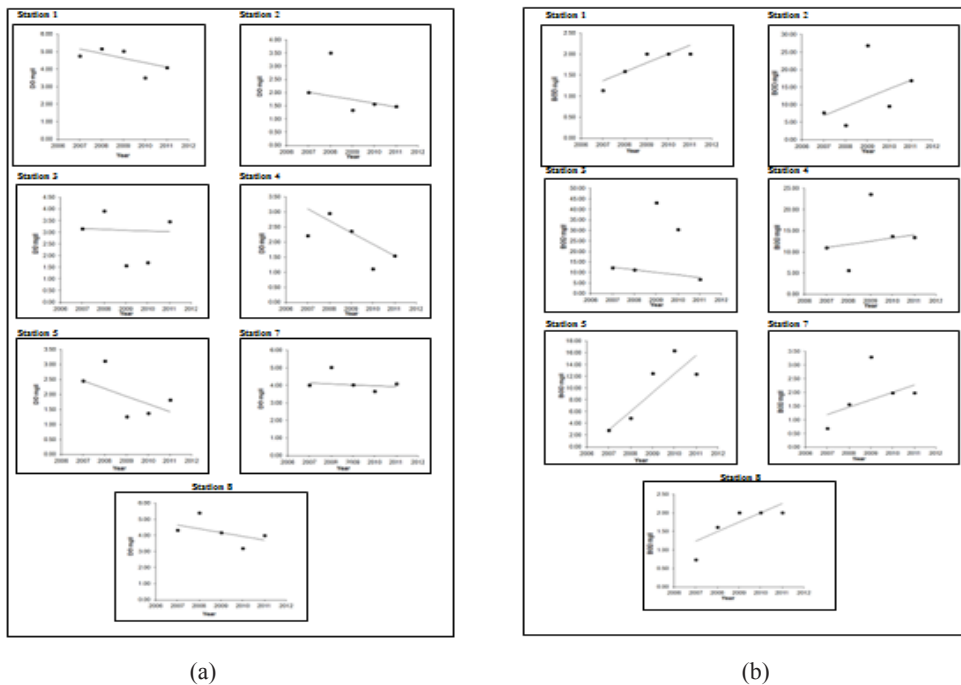


Figure 1. Linear lines for: (a) DO; and (b) BOD

### Biochemical Oxygen Demand

Results showed the lowest probability value for Biochemical Oxygen Demand (BOD) is 0.117 and the highest probability value is 0.408 which are more than the significant value,  $\alpha=0.05$ . Thus  $H_0$ : There is no trend, is accepted. Figure 1(b) shows all the data are scattered with no trend for all the year. From this figure, all the linear lines indicate the tendency of deterioration of BOD except at station 3.

**Chemical Oxygen Demand.** There is trend at stations 1, 4, 5, 7 and 8 for Chemical Oxygen Demand between 2007 and 2011 along Southern Sarawak River. By using Mann-Kendall method, probability for these station is  $0.042 < 0.05$  which means  $H_0$  is rejected and  $H_a$  is accepted. The trend indicates that COD is increasing which means there is deterioration in water quality in the study duration. However, there are 2 stations with no trend, station 2 and station 3 with the P value which is more than 0.05. Although there is no trend at station 2 and 3, but the linear lines in all graph plotted in Figure 1(c) show that the content of COD is increasing randomly with no trend at all stations along the river.

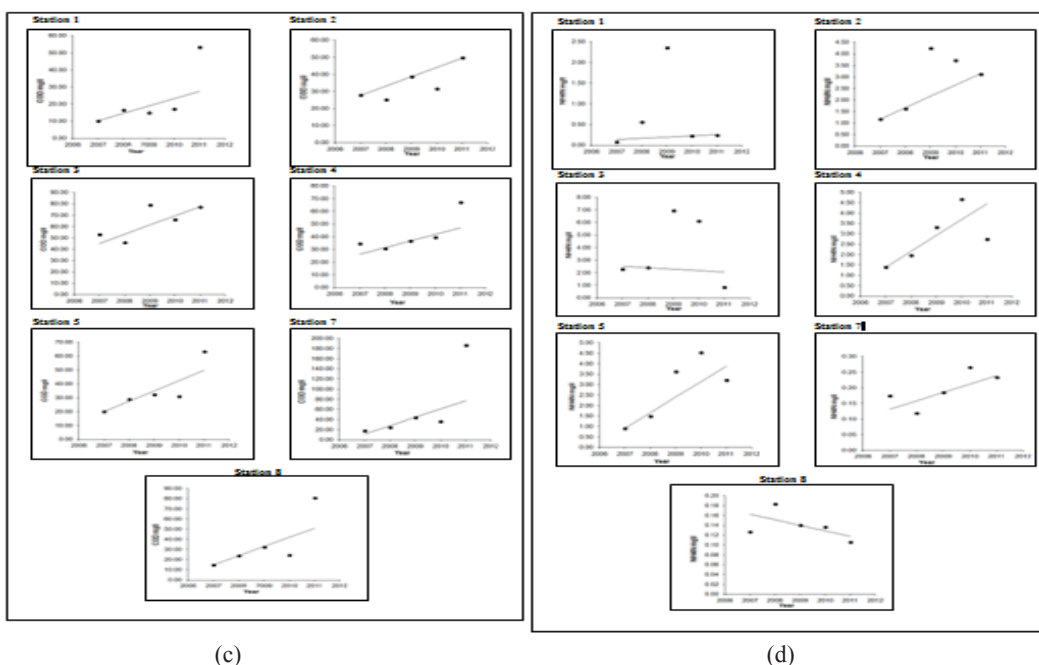


Figure 1. Linear lines for: (c) COD; and (d)  $NH_4N$

### Ammoniacal Nitrogen

From the analysis, no trend exists at all station for Ammoniacal Nitrogen between 2007 and 2011 along Sothern Sarawak River. By using Mann-Kendall method, probability for these stations is more than 0.05 which means  $H_0$  is accepted. Figure 1(d) shows all the data are



randomly plotted with no trend. However, NH<sub>4</sub>N content at stations 1, 2, 4, 5 and 7 show no trend while at stations 3 and 8, NH<sub>4</sub>N content is decreased with no trend.

### Total Suspended Solid

Analysis shows that no trend exists at all stations for Total Suspended Solid. Probability for these stations is also more than 0.05 which means H<sub>0</sub> is accepted and no trends exist. Figure 1(e) shows all the data are scattered randomly. However, Figure 1(e) shows TSS at stations 1, 2, 3, 4, 5 and 7 show no trend, while it decreased with no trend at station 8.

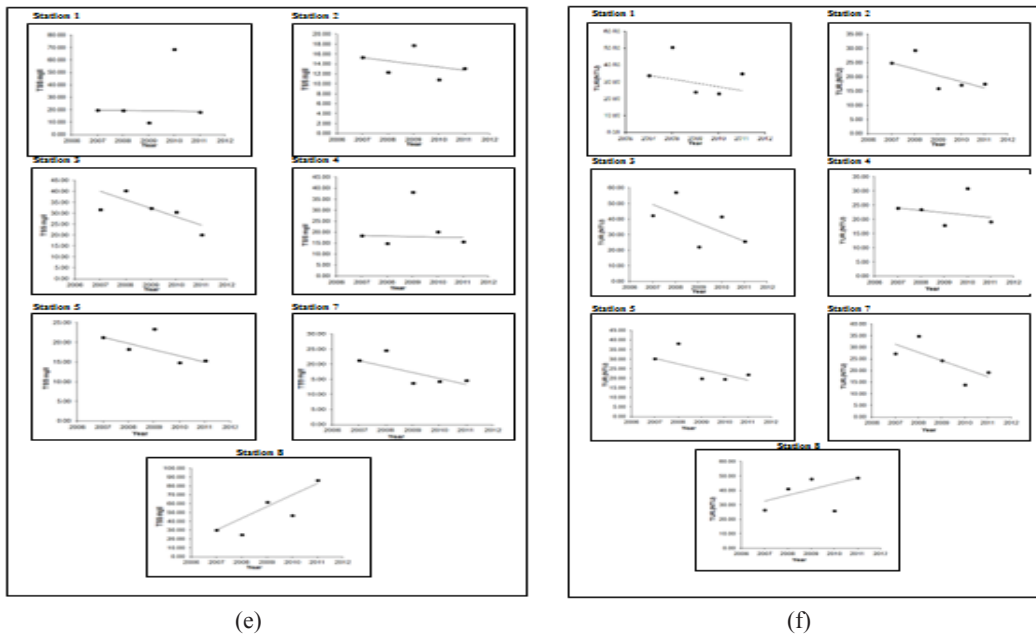


Figure 1. Linear lines for: (e) TSS; and (f) Turbidity

### Turbidity

In terms of turbidity, the analysis shows no trends exist at all station for the study period. By using Mann-Kendall method, probability for these stations is also more than 0.05 which means H<sub>0</sub> is accepted and there are no trends. Figure 1(f) shows all the data are distributed randomly. However, the quality of turbidity at stations 1, 2, 3, 4, 5 and 8 increased without any trend; while at station 7, TSS content decreased without any trend.

### Correlation among Parameters

Table 1 shows a weak correlation between BOD and DO. The rho's value = -0.298 indicates that when BOD is level is high, there is a decline in DO levels. The findings support the theory that when BOD levels are high, DO levels decrease. This is because the demand for oxygen by bacteria is high and they are taking that oxygen dissolved in water. If there is no organic waste

present in the water, there won't be as many bacteria present to decompose it and thus, BOD will tend to be lower and the DO level will tend to be higher. When BOD levels are high, DO levels decrease because the oxygen that is available in the water is consumed by the bacteria.

The second correlation is between Ammoniacal Nitrogen ( $\text{NH}_4\text{N}$ ) and Dissolved Oxygen (DO). Rho's value is -0.49. Negative sign means that when  $\text{NH}_4\text{N}$  is high, so DO will decrease. Ammoniacal Nitrogen ( $\text{NH}_4\text{N}$ ) indicates the presence of animal and human waste, domestic waste, urban and industrial as well as agricultural fertiliser. High concentration of  $\text{NH}_4\text{N}$  will enhance pulse, respiration rate and balance aquatic activities and affect metabolism. For example, Sungai Langat also suffers from  $\text{NH}_4\text{N}$  pollution caused by domestic, industrial and land use activities (Haslinur et al., 2012). Thus, when  $\text{NH}_4\text{N}$  is high, it means there is a lot of organic waste, and the bacteria will begin the process of breaking down this waste. The third correlation exists between BOD and COD. The Rho's value is 0.591 indicating a moderate correlation between BOD and COD. Positive value of Rho's value indicates that there is positive significance between BOD and COD. According to Byod (1990), it is possible if BOD and COD have same value, but the former should not be greater than COD.

The fourth correlation is between  $\text{NH}_4\text{N}$  and BOD. It is moderate correlation. The Rho's value is 0.572 and positive value of Rho's means there is positive significance between BOD and  $\text{NH}_4\text{N}$ . Ammoniacal Nitrogen ( $\text{NH}_4\text{N}$ ), as stated previously, is a major indicator of the presence of animal and human waste, domestic waste, urban and industrial as well as agricultural fertilizer. High concentration of  $\text{NH}_4\text{N}$  leads to increased pulse rate, respiration rate and affect aquatic life activities aquatic as well as affects metabolism. Microorganisms such as bacteria are responsible for decomposing organic waste. If there is a large quantity of it in the water. There is a lot of bacteria present working to decompose this waste and in this case, the demand for oxygen will be high and so the BOD level will be high.

The fifth correlation is between BOD and TSS. The Rho's value is 0.304 indicating a weak correlation between BOD and TSS. The positive value of Rho's value means that as TSS increased, so did the BOD level. This is confirmed by Tagarotop (2009) who concluded that BOD and TSS have high correlation. Total suspended solids (TSS) include all particles suspended in water which will not pass through a filter. The TSS consists of sanitary wastewater, soil erosion from agricultural and construction sites. As level of TSS increase, the water body begins to lose its ability to support a diversity of aquatic life. Microorganisms will begin to decompose organic waste which will directly increase the biochemical oxygen demand.

Besides, a correlation also exists between COD and  $\text{NH}_4\text{N}$ . The Rho's value is positive, =0.401, that indicates the positive relationship between COD and  $\text{NH}_4\text{H}$ . The COD is a measure of the amount of oxidisable matter present in the water. Sometimes, COD and NHN may come from similar sources such as industrial waste and agricultural fertiliser. Therefore, these two parameters have a positive relationship. Lastly, the correlation also exists between TSS and turbidity. The Rho's value is equal to 0.584. The correlation is positive and this result is parallel with Hannouche et al. (2011) who showed that the turbidity-TSS calibration relationship show good linearity regardless of weather conditions.

Table 1  
Correlation among parameter of water quality

Correlation	Rho value	P value	Hnull	Magnitude of Correlation
DO-BOD	-0.298	0.047	Rejected	weak
DO-NH <sub>4</sub> N	-0.49	0.01	Rejected	moderate
BOD-COD	0.591	0	Rejected	moderate
BOD-NH <sub>4</sub> N	0.572	0	Rejected	moderate
BOD-TSS	0.304	0.042	Rejected	weak
COD-NH <sub>4</sub> N	0.401	0.006	Rejected	moderate
TSS-TUR.	0.584	0	Rejected	moderate

## CONCLUSION

The results of this study showed that although almost all linear lines of parameters tend to represent the increase or decrease in water quality, only COD displayed a trend. This is because data plotted is distributed randomly with no trend. Although there are correlations among the parameters, it is weak. The correlation between the parameters is not strong because there are many other factors that affect water quality parameters.

## REFERENCES

- Boyd, C. E. (1990). Water quality in ponds for aquaculture. Alabama Agricultural Experiment Station, Auburn University. Alabama P462.
- Chang, N. B., Chen, H. W., & Ning, S. K. (2001). Identification of river water quality using the fuzzy synthetic evaluation approach. *Journal of Environmental Management*, 63, 293-305.
- Chau, K. W., Chuntian, C., & Li, C.W. (2002). Knowledge management system on flow and water quality modelling. *Journal of Expert Systems with Applications*, 22(4), 321-330.
- Cluis, D., Langlois, C., Vancoillie, R., & Laberge, C. (1989). Development of a software package for trend detection in temporal Series - application to water and industrial Effluent Quality Data for the St Lawrence River. *Environmental Monitoring and Assessment*, 13(2-3), 429-441.
- Gilbert, R. O. (1987). *Statistical methods for Environmental Pollution Monitoring*. New York: John Wiley & Sons, Inc.
- Hannouche, A., Chebbo, G., Ruban, G., Tassin, B., Lemaire, B. J., & Joannis, C. (2011). Relationship between turbidity and total suspended solids concentration within a combined sewer system. *Water Science and Technology*, 64(12), 2445-2452.
- Haslinur, M. D., Mohd, E. T., & Mazlin, M. (2012). Loading concentrations of pollutant in Alur Ilmu at UKM Bangi campus: Event Mean Concentration (EMC) approach. *Malaysian Journal of Analytical Sciences*, 16(3), 353-365.
- Kaprawi, N. (2000). *Quality of Working Life and Organisational Effectiveness in Public and Private Higher Education Institutions in Malaysia*. University of Manchester: Ph.D Thesis.

- Kovacs, G. (1986). Decision support systems for managing large international rivers. In: Vlachos, E., Mackenzie, L. D. and David, A. C. (2008). Introduction to environmental engineering 4<sup>th</sup> edition. New York: Mc Graw Hill.
- Nielsen, D. M. (Ed.). (2005). Practical handbook of environmental site characterization and ground-water monitoring. USA: CRC press.
- Rali, N. (2003). The relation between curriculum implementation with KUITTHO's Graduates's competency in civil engineering course. KUITTHO. Johor
- Tagarotop, R. (2009). *Correlation between Biological Demands*. Universitas Sumatera Utara: Degree Thesis.
- Wetzel, R. G. (2001). *Limnology: Lake and River Ecosystems*, 3<sup>rd</sup> Edition, Academic Press, USA, pp. 1006.



## Wind Characteristics and Outdoor Thermal Comfort Assessment in East Malaysia

Hanipah, M. H.<sup>1\*</sup>, Abdullah, A. H.<sup>1</sup>, Che Sidek, N. A.<sup>2</sup>, Yunus, R.<sup>1</sup>, Nagapan, S.<sup>1</sup>, Yassin, M. N.<sup>1</sup> and Muhammad Yazid, M. N. A. W.<sup>2</sup>

<sup>1</sup>Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia

<sup>2</sup>Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor, Malaysia

### ABSTRACT

Rapid urbanisation and industrialisation have had an adverse and deep impact on the environment contributing to global warming and climate change. These thermal environmental problems can be even more challenging to people living in regions with warm and humid climatic conditions throughout the year, such as Malaysia. This paper analyses wind characteristics and outdoor thermal comfort index at the hottest temperatures based on data recorded hourly between 2012 and 2014 for two cities in East Malaysia, namely Kuching (Sarawak) and Kota Kinabalu (Sabah). Wind characteristics were analysed using only wind velocity and direction, while the level of outdoor thermal comfort was measured using Universal Thermal Climate Index (UTCI). The results showed that hourly average wind velocities for Kuching and Kota Kinabalu were 1.84 m/s and 2.15 m/s respectively while the highest average wind velocities was 10.1 m/s and 12.4 m/s respectively. No wind movement (i.e. 0 m/s) was recorded for both locations. The prevailing annual wind flow is generally from South-Southeast (150°) in Sarawak and from East-Southeast (110°) in Sabah. It was also found that both Kuching and Kota Kinabalu experienced strong and extreme heat stress conditions with UTCI levels of 44.8°C and 49.8°C respectively. Thus, it can be concluded that, East Malaysia faces strong and extreme heat stress conditions. This study is an original contribution on the subject of outdoor thermal environment in Malaysia, Further research to

better understand outdoor thermal environmental problems is recommended.

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#### E-mail addresses:

hafizal@uthm.edu.my (Hanipah, M. H.),  
abdhalid@uthm.edu.my (Abdullah, A. H.),  
azwadi@fkm.utm.my (Che Sidek, N. A.),  
riduan@uthm.edu.my (Yunus, R.),  
sasi81@hotmail.com (Nagapan, S.),  
norazam@uthm.edu.my (Yassin, M. N.),  
mnafiqwitri@utm.my (Yazid, M. N. A. W)

\*Corresponding Author

*Keywords:* Outdoor thermal comfort, thermal stress, universal thermal climate index, warm and humid climate, wind direction, wind velocity

### INTRODUCTION

In recent years, there have been an increasing academic interest in issues regarding

urbanisation and climate change and their subsequent impact on global warming (Abd Razak et al., 2013; Ignatius et al., 2015; Jeong et al., 2016; Jihad & Tahiri, 2016; Martins et al., 2016; Sharmin et al., 2015). In Malaysia, thermal environmental problems have been extensively studied by researchers (Abdullah & Wang, 2012; Azizpour et al., 2013; Ghaffarianhoseini et al., 2015; Rajagopalan et al., 2014; Wang & Abdullah, 2011). In terms of global warming, temperatures have increased by 0.35°C per decade for the period 1969-2014 in Central Peninsular Malaysia (MetMalaysia, 2015). As a consequence, Malaysia's urban areas have become warmer which can adversely affect the internal and external thermal environment especially in urban areas. Furthermore, global warming can be harmful to human thermal comfort level. To date, only a few studies have tackled these issues focusing on the effects of urbanisation on outdoor thermal environment in Malaysia. Additionally, building arrangement parameters such as frontal area density ( $\lambda_f$ ), packing density ( $\lambda_p$ ), height-to-width ratio ( $\lambda_s$ ) etc., have accentuated the problem of heat stress as they have not been considered during the design stage of urban development (Abd Razak et al., 2013; Hang, Li, & Sandberg, 2011; Hang, Li, Sandberg, Buccolieri, & Di Sabatino., 2012; Kubota et al., 2008). Thus, this study examined the current wind characteristics and extreme outdoor thermal comfort index. Despite these promising results, further research should be undertaken to scientifically investigate the relationship between building design and outdoor thermal environment in warm and humid climate in order to improve the unfavourable thermal conditions.

## Study Area

The area of study is situated at coordinate of 2°30' North latitude and 112°30' East longitude. According to recent climatic data analysis, Malaysia experiences a wet and humid condition with daily temperature fluctuating between 24°C and 38°C (MetMalaysia, 2015). It is probable that wind velocity and prevailing wind in this area are influenced by three monsoon seasons, namely northeast monsoon, southwest monsoon and two short inter-monsoons.

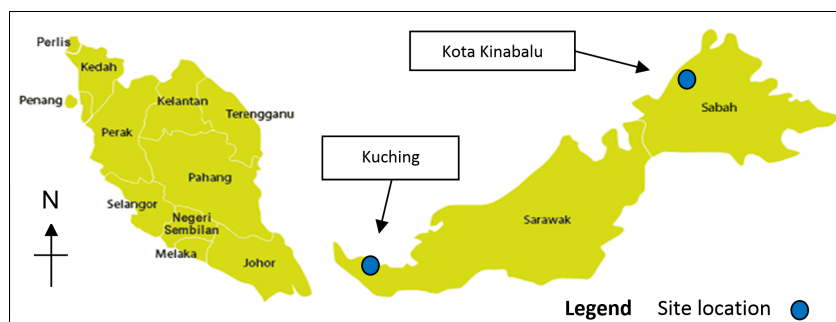


Figure 1. Map of Peninsular Malaysia showing the case study stations

During southwest monsoon season, wind velocity is below 8m/s. Meanwhile, for northeast monsoon season, the wind velocity is in the range of 5 to 10 m/s. Generally, wind velocity is light and inconsistent during inter-monsoons seasons. Annually, Malaysia experiences monthly

average relative humidity between 70% to 90%. Additionally, the country has around 6 hours of solar radiation per day on average (MetMalaysia, 2015). This study was aimed at enhancing our understanding of outdoor thermal environment in two different cities in East Malaysia, namely Kuching (i.e. Northwestern part of the Borneo island) and Kota Kinabalu (i.e. West coast of Sabah), as shown in Figure 1 and outlined in Table 1. The wind characteristics and outdoor thermal comfort levels were examined using weather data that correspond with the hot and humid tropical climate of Malaysia from two principal weather stations in Kuching and Kota Kinabalu.

Table 1  
*Location of weather stations*

Station	Latitude	Longitude	Height above sea level (m)
Kuching	1° 29' N	110° 21' E	20.90
Kota Kinabalu	5° 56' N	116° 03' E	2.10

## MATERIALS AND METHODS

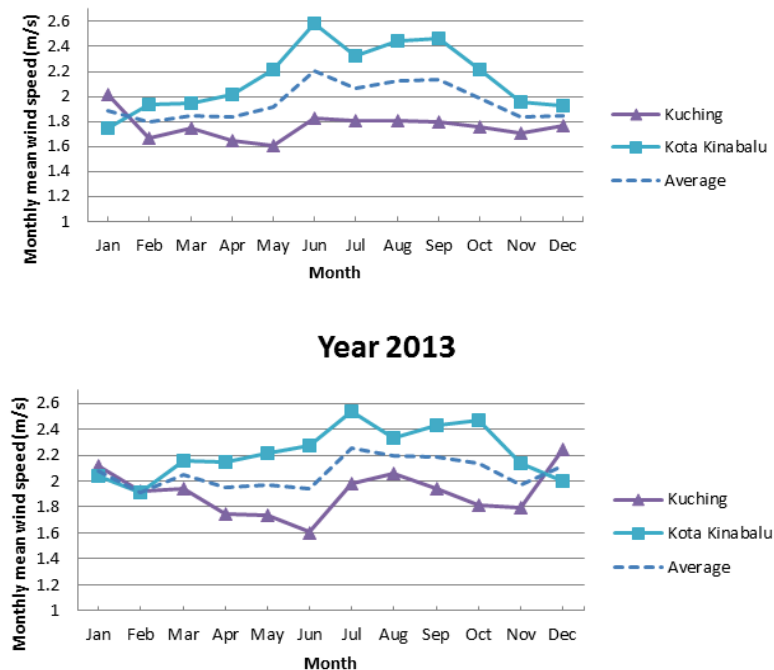
First, hourly weather data for 20 years (1994-2014) from Kuching and Kota Kinabalu weather stations were obtained and studied (MetMalaysia). The aim was to determine the hottest ambient temperature of the day throughout the 20 year period and to examine whether high heat stresses occur based on universal thermal climate index (UTCI) . Hourly wind velocity and wind direction data from 2012 to 2014 were analysed to examine wind characteristics. The wind velocity and direction at both weather stations were measured using rotating cup type anemometer and wind vane installed at the height of 10 m above the ground as suggested by Katsoulis (1993) for practical and climatological considerations. The hourly interval of wind velocity and directions were measured and stored in data logger. This study assesses the outdoor thermal comfort level using UTCI value which is calculated based on regression equation devised by International Society of Biometeorology Commission 6 by COST (European Cooperation in Science and Technology) Action 730 under the umbrella of the WMO Commission on Climatology (Jendritzky et al., 2012). Weather parameters taken into account for calculating UTCI (°C) consist of wind velocity (m/s), ambient temperature (°C), relative humidity (%) and solar radiation (W/m<sup>2</sup>) (Kjellstrom et al., 2015). The UTCI is suitable for thermal evaluation in all climates and seasons (Jendritzky et al., 2012).

### Universal Thermal Climate Index (UTCI)

The UTCI is classified into 10 different stress levels: thermal stress, 4 heat stress levels, and 5 cold stress levels (Glossary of Terms for Thermal Physiology, 2003). The UTCI is defined as the equivalent ambient temperature of a reference environment that causes the same physiological response of a reference person as well as the actual environment (Blazejczyk et al., 2012). It is based on Fiala multi-node model of human thermal regulation in combination with an adaptive clothing model (Fiala, Lomas, & Stohrer, 2008).

## RESULTS AND DISCUSSION

This section discusses wind characteristics and outdoor thermal comfort by analysing weather parameters over a three-year period (2012 to 2014), which comprise relative humidity, ambient temperature, average wind velocity, min-max wind velocity, wind direction, and solar radiation. Figure 2 shows the monthly average wind velocity in Kuching and Kota Kinabalu. On average, the windiest months were from July to October which recorded between 2.02 to 2.13 m/s due to the southwest monsoon. During inter-monsoons, the minimum average wind velocity of 1.89 m/s was recorded between April and November. From November to March, the average wind velocity was in the range of 1.90 to 2.06 m/s, where it reached the peak of 2.06 m/s in January due to northeast monsoon season. Moreover, the average wind velocity for Kuching and Kota Kinabalu was 1.84 m/s and 2.15 m/s respectively. Average wind velocity at both locations indicated only slight differences. The mode of wind velocity in Kuching was 1.2 m/s, which is considered as the dominant reading with 4.76% of frequency. Meanwhile, Kota Kinabalu demonstrated 1.7 m/s as the dominant reading with 4.88% of frequency. Moreover, the maximum monthly average wind velocity for Kuching and Kota Kinabalu were 2.14 m/s and 2.37 m/s respectively. In contrast, the lowest monthly average wind velocity in Kuching was 1.68 m/s, and it was slightly higher in Kota Kinabalu at 1.92 m/s. The highest wind velocity was 12.4 m/s in Kota Kinabalu on 16th July 2013 at 4.00 p.m., while Kuching's highest wind velocity was 10.1 m/s on 25<sup>th</sup> May 2012 at 4.00 p.m. As no wind movement (i.e. 0 m/s) can be considered as the lowest hourly wind velocity for both locations, Kuching showed the highest frequency of calmness at 3.75% as compared to that of Kota Kinabalu at only 0.9%. The variations of hourly average wind velocity were displayed by standard deviation values of 1.22 and 1.04 for Kuching and Kota Kinabalu respectively.





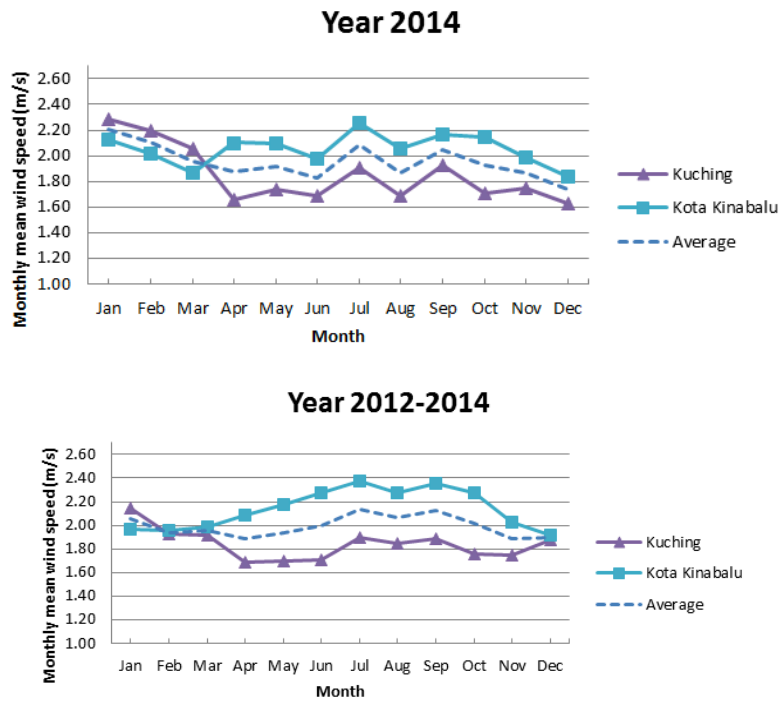
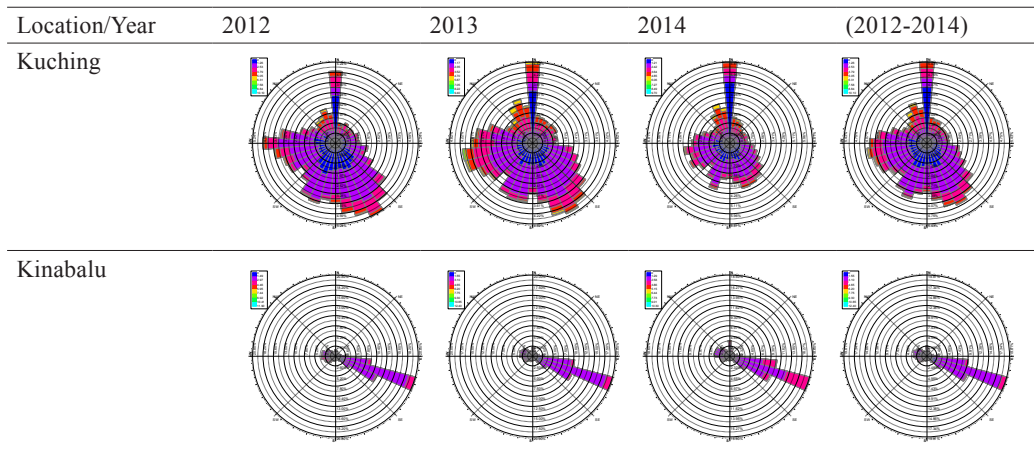


Figure 2. Monthly average wind velocities at 10 m height for the selected locations

Not only the values and trends of wind velocity, but the prevailing wind is also important in assessing the possibilities of outdoor thermal comfort conditions. The results of wind characteristic analysis can be very useful especially for design team to finalise their design of building orientation and position in relation to other surrounding buildings. This is particularly important in order to enhance building permeability for greater induction of wind that can reduce heat. Table 2 shows the trends of prevailing wind in Kuching from South-Southeast direction (150°), and from East-Southeast direction (110°) in Kota Kinabalu, with an average frequency of about 4.59% and 19.81% respectively. These results also indicated that both locations have different prevailing wind velocities throughout the years. However, their prevailing wind directions remained the same every year for each of the locations, except in 2014 where the prevailing wind direction in Kuching was from North (0°). In short, yearly weather data analysis for the three-year period show different wind directions. A more precise wind directions for both locations can be obtained if a longer study period is considered.

Table 2  
Annual wind rose distribution and frequency



Data was also analysed to determine worst heat stress scenarios. In general, as can be seen from Table 3, during the hottest temperatures, both locations experienced different levels of heat stress, where Kuching was slightly better than Kota Kinabalu. In 2012, Kota Kinabalu recorded the highest UTCI value of 49.8°C as it experienced extreme heat stress condition. In contrast, Kuching has the lowest UTCI value of 42.9°C as it experienced strong heat stress condition. In general, Kota Kinabalu experienced the most extreme heat stress condition as compared to Kuching. In short, UCTI values revealed that heat stress was a common problem in East Malaysia. It increased people’s level of thermal discomfort, particularly in dense urban areas. Global warming especially in urban areas are real issues due to higher solar radiations and inadequate wind velocity to wipe out the heat entrapped in and around a building.

Table 3  
Annual UTCI in the study at hottest temperature in 2012-2014 (3 years)

Location	Year	Time	Temperature (°C)	Relative Humidity (%)	Wind Velocity (m/s)	Solar Radiation (W/m <sup>2</sup> )	UTCI (°C)	Stress Category
Kuching	29.9.2012	1600	35.8	39	3.6	611.11	42.9	Very strong heat stress
	23.6.2013	1500	36.1	30	2.7	736.11	44.7	Very strong heat stress
	26.7.2014	1600	37.0	33	2.1	611.11	44.8	Very strong heat stress
Kota Kinabalu	19.5.2012	1400	34.9	68	2.1	916.67	49.8	Extreme heat stress
	23.9.2013	1400	35.2	54	1.3	936.11	49.0	Extreme heat stress
	7.5.2014	1500	36.1	53	1.4	797.22	48.4	Extreme heat stress

Table 4 shows extreme heat stress condition was recorded in Kota Kinabalu and Kuching. Kota Kinabalu recorded not only the highest UTCI value of 49.8°C but also the highest solar radiation intensity of 797.22 W/m<sup>2</sup>. Even though solar radiation in Kota Kinabalu was around 30% greater than that of Kuching, its UTCI values differed slightly around 8%. This is because wind velocity value of 2.1 m/s in Kuching was about 50% greater than that of Kota Kinabalu. It is almost certain that higher wind velocity would contribute to a positive effect on heat stress performance.

Table 4  
*UTCI index of the hottest temperature in 1994 to 2014 (20 years)*

Location	Year	Time	Temperature (°C)	Relative Humidity (%)	Wind Velocity (m/s)	Solar Radiation (W/m <sup>2</sup> )	UTCI (°C)	Stress Category
Kuching	26.7.2014	1600	37.0	33	2.1	611.11	44.8	Very strong heat stress
Kota Kinabalu	7.5.2014	1500	36.1	53	1.4	797.22	48.4	Extreme heat stress

## CONCLUSION

An analysis of weather data in Kuching and Kota Kinabalu over a 20-year period (2012-2014) showed that the average monthly mean wind velocities were 1.84 m/s and 2.15 m/s respectively; while the highest wind velocity for Kuching and Kota Kinabalu were 10.1 m/s and 12.4 m/s respectively. The results indicate that Kota Kinabalu experienced windier conditions compared with Kuching which showed the lowest frequency of calmness at 0.9%. In addition, the annual trend of prevailing winds in Kuching and Kota Kinabalu demonstrated a slight difference. The prevailing wind direction in Kuching was from South-Southeast (150°), and Kota Kinabalu was from East-Southeast (110°) with their average frequencies of about 4.59% and 19.81% respectively. Additionally, Kota Kinabalu recorded the most extreme heat stress condition as compared to Kuching. The UTCI values also pointed to extreme heat stress conditions in Kota Kinabalu, and very strong heat stress in Kuching. The present study was a preliminary investigation in evaluating the wind velocity and prevailing wind direction characteristics as a reason to have an inclusive wind data base. These findings have significant implication, particularly to researchers in evaluating a better prediction of outdoor thermal comfort in future work. Despite its exploratory nature, this study offers some insight and awareness on the current heat stress problem in East Malaysia. These findings would be useful for researchers, state authorities and country's policy makers. This should help improve predictions of current environmental issues as well as encourage a proper and well-planned strategies by incorporating suitable design parameters such as building geometry, building orientation, and building permeability; which can reduce heat in urban areas and thereby increase the level of outdoor thermal comfort, especially in warm and humid climate of Malaysia.

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## REFERENCES

- Abd Razak, A., Hagishima, A., Ikegaya, N., & Tanimoto, J. (2013). Analysis of airflow over building arrays for assessment of urban wind environment. *Building and Environment*, 59, pp. 56–65.
- Abdullah, A. H., & Wang, F. (2012). Design and low energy ventilation solutions for atria in the tropics. *Sustainable Cities and Society*, 2(1), 8–28.
- Azizpour, F., Moghimi, S., Salleh, E., Mat, S., Lim, C. H., & Sopian, K. (2013). Thermal comfort assessment of large-scale hospitals in tropical climates: A case study of University Kebangsaan Malaysia Medical Centre (UKMMC). *Energy and Buildings*, 64, 317–322.
- Blazejczyk, K., Epstein, Y., Jendritzky, G., Staiger, H., & Tinz, B. (2012). Comparison of UTCI to selected thermal indices. *International Journal of Biometeorology*, 56, 515–535.
- Dusan, F., Kelvin J. L., & Martin, S. (2008). Modeling in Physiology. Society, 82, 1522–1536. Fiala D, Lomas KJ, Stohrer M. A computer model of human thermoregulation for a wide range of environmental conditions: The passive system. *J Appl Physiol*. 1999, 87.
- Ghaffarianhoseini, A., Berardi, U., & Ghaffarianhoseini, A. (2015). Thermal performance characteristics of unshaded courtyards in hot and humid climates. *Building and Environment*, 87, 154–168.
- Glossary of Terms for Thermal Physiology (2003). *Journal of Thermal Biology*, 28, 5-106.
- Hang, J., Li, Y., & Sandberg, M. (2011). Experimental and numerical studies of flows through and within high-rise building arrays and their link to ventilation strategy. *Journal of Wind Engineering and Industrial Aerodynamics*, 99(10), 1036–1055.
- Hang, J., Li, Y., Sandberg, M., Buccolieri, R., & Di Sabatino, S. (2012). The influence of building height variability on pollutant dispersion and pedestrian ventilation in idealized high-rise urban areas. *Building and Environment*, 56, 346–360.
- Ignatius, M., Wong, N. H., & Jusuf, S. K. (2015). Urban microclimate analysis with consideration of local ambient temperature, external heat gain, urban ventilation, and outdoor thermal comfort in the tropics. *Sustainable Cities and Society*, 19, 121–135.
- Jendritzky, G., de Dear, R., & Havenith, G. (2012). UTCI-Why another thermal index? *International Journal of Biometeorology*, 56, 421–428.
- Jeong, M.-A., Park, S., & Song, G. -S. (2016). Comparison of human thermal responses between the urban forest area and the central building district in Seoul, Korea. *Urban Forestry and Urban Greening*, 15, 133–148.
- Jihad, A. S., & Tahiri, M. (2016). Modeling the urban geometry influence on outdoor thermal comfort in the case of Moroccan microclimate. *Urban Climate*, 16, 25–42.
- Katsoulis, B. D. (1993). *Theoretical and Applied Climatology*, 63.

- Kjellstrom T, Hyatt O, Lemke B, Otto M, Freyberg C, Hasson L, Clarke R. (2015, January 16). Analysis tools of heat stress. Retrieved from <http://www.climatechip.org/node/78>
- Kubota, T., Miura, M., Tominaga, Y., & Mochida, A. (2008). Wind tunnel tests on the relationship between building density and pedestrian-level wind velocity: Development of guidelines for realizing acceptable wind environment in residential neighborhoods. *Building and Environment*, 43(10), 1699–1708.
- Malaysian Meteorological Department, Malaysia. (2015, January 8). *Weatherwise Malaysia*. Retrieved from <http://www.met.gov.my>.
- Martins, T., Adolphe, L., Bonhomme, M., Bonneaud, F., Faraut, S., Ginestet, S., & Guyard, W. (2016). Impact of Urban Cool Island measures on outdoor climate and pedestrian comfort: simulations for a new district of Toulouse, France. *Sustainable Cities and Society*, 26, 9–26.
- Rajagopalan, P., Lim, K. C., & Jamei, E. (2014). Urban heat island and wind flow characteristics of a tropical city. *Solar Energy*, 107, 159–170.
- Sharmin, T., Steemers, K., & Matzarakis, A. (2015). Analysis of microclimatic diversity and outdoor thermal comfort perceptions in the tropical megacity Dhaka, Bangladesh. *Building and Environment*, 94, 734–750.
- Wang, F., & Abdullah, A. H. (2011). Investigating thermal conditions in a tropic atrium employing CFD and DTM techniques. *International Journal of Low-Carbon Technologies*, 6(April), 171–186.





## **Culture of the Traditional Malays: Usage of Sustainable Furniture in Internal Spaces of Traditional Malay Houses**

**Nabilah Zainal Abidin\*, Fawazul Khair Ibrahim and Raja Nafida Raja Shahminan**

*Department of Architecture, Faculty of Built Environment, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia*

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### **ABSTRACT**

This paper describes the culture of Traditional Malays, in particular the use of sustainable furniture inside a Traditional Malay House (TMH). The sample houses for this study were retrieved from archived reports, from the Centre for Built Environment in the Malay World (KALAM), Universiti Teknologi Malaysia (UTM). Data collected were analysed using Componential Analysis for the presence of components (based on drawings of archival reports as well as photographic evidence from site visits). The findings showed that the Malays used a variety of sustainable furniture in their houses. Additionally, their homes had built-in furniture, which indicated the houses were pre-designed based on its user.

*Keywords:* Malay culture, sustainable furniture, traditional Malay furniture, traditional Malay house, traditional Malays

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### **INTRODUCTION**

This paper aims to identify the different types of sustainable furniture that were used by the Traditional Malays. The objectives of this paper includes redefining the term ‘furniture’ as understood by Traditional Malays, which in turn helps to identify the various types of sustainable furniture available in a Traditional Malay House (TMH). The scope of this study was limited to samples selected from TMH of Melaka and from archived reports retrieved from KALAM, UTM.

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*E-mail addresses:*

[nabilah.nbza@gmail.com](mailto:nabilah.nbza@gmail.com) (Nabilah Zainal Abidin),

[strazawaf@gmail.com](mailto:strazawaf@gmail.com) (Fawazul Khair Ibrahim),

[jesz199@yahoo.co.uk](mailto:jesz199@yahoo.co.uk) (Raja Nafida Raja Shahminan)

\*Corresponding Author

### **Traditional Malays and Their Houses**

Traditional Malay Houses (TMH) commonly includes Islamic elements. Additionally, Malay homes are purely functional, reflecting

the family's needs while also expressing a deep symbolic meaning (Rodriguez & Siret, 2009). Almost all (TMH were built and designed by the occupants themselves reflecting the family lifestyles, while also portraying the builders' creativity and aesthetic skills. Ozaki (2002) and Hashim et al. (2009) reported that because of this mind-set, Malays have specific spaces that are for specific activities, hence, influencing the selection of furniture. Thus, houses become a home ground of cultural practices and traditions.

The TMH are commonly made of wood and are raised from the ground level on stilts. This is to protect the inhabitants from wild animals while also reducing the temperature of the interior of the house, providing sufficient and effective air ventilation for a comfortable environment in a humid climate (Yuan, 1987). Since this paper focuses on TMH in Melaka, the following table (Table 1) shows the main spaces as well as the furniture inside them.

Table 1  
Main spaces of TMH Melaka and its functions

Space	Functions
Tiled Staircase	Located at the front of the house, where guests are greeted and welcomed
<i>Anjung</i> (veranda)	Where unfamiliar guests are entertained. A relaxing area where the owner sits and watches the goings-on in the village.
<i>Serambi</i> (living area)	Male guests are entertained here. Equipped with low windows which allows for ventilation and effective cooling.
<i>Rumah Ibu</i> (private area)	The main female domain and core structure of the whole house. To express its importance, it has the highest head room and is the largest space in the house. Where most activities are conducted and includes the bedrooms.
<i>Selang</i> (passageway)	A closed passageway that acts as a link from the rumah ibu to the dapur.
<i>Dapur</i> (kitchen)	Situated at the very back of the house. Where meals are prepared and cooked.
Internal courtyard	An open area where clothes are washed and hung out to dry. Also considered as the children's play area.
<i>Loteng</i> (attic)	Located above the <i>rumah ibu</i> and acts as a storage of stuffs not in use.

Based on Table 1 above, it is evident that spaces available inside a TMH are very versatile and can be used for multiple functions or events, including special occasions (Tajuddin et al., 2005). Figures 1 shows how each space interact with one another (Hashim & Nasir, 2011) and the side elevation as well as the floor plan of a Melaka TMH.





Figure 1. Side elevation and floor plan of a Melaka TMH

It can be seen in Figure 1 that each space seems effortlessly from one to the next, starting from the front entrance right up to the kitchen at the back. Each space is also equipped with multiple windows and openings providing sufficient lighting and air flow.

### Sustainable Furniture of the Traditional Malays

Furniture is an important aspect of life and is considered part and parcel of any civilisation whether in the past, present, or future. Since the beginning of time, man has lived a nomadic life and rely on various equipment to store and carry their properties (Lucie-Smith, 1993). With advances in human civilisations, new raw minerals and materials gradually became the source of trading and barter. This eventually paved way for furniture to reflect symbol of social status, wealth and power (Joy, 1972).

We know that furniture is above all, functional and is considered an essential part of any home. Gibbs (1987) and Winstedt (1961) have stated that the Malays had a 'floor-culture', which means that they sleep, sit, eat, pray, etc. on the floor. They also observed that Traditional Malays had no furniture, because of this 'floor-culture'. This is one of the main misconceptions, which in reality is absolutely absurd, as reported by Lucie-Smith (1993) that furniture is part and parcel of any civilisation.

To understand this further, a deep understanding of what the Traditional Malays considered as furniture had to be identified, which means redefining the term 'furniture' as understood by them. We know for a fact that there are two types of furniture: built-in (permanent) furniture,

and loose furniture (Beard, 1985). Wahab et al. (2012) provided the following definition: “Furniture can be identified in two different types, which are built-in and loose. These two can then be categorized into two categories; usage and function. Usage of furniture includes body-supporting, storage or utility, and tools. Whereas the functions of the furniture would include sitting, sleeping and leaning, storing and keeping, and working.” Table 2 provides definition of furniture and its purpose.

Table 2  
*Definition of furniture*

Categories Usage	Function	Type
Body-supporting	Sitting, sleeping, leaning	Built-in & Loose
Storage/Utility	Storing/Keeping	
Tool	Working	

## MATERIALS AND METHODS

The samples for this research were selected houses in the Melaka region of Malaysia, retrieved from archival reports from the Centre for Built Environment of the Malay World (KALAM), Universiti Teknologi Malaysia (UTM). The Centre is considered as one of the most credible sources of data on architectural and built environment heritage of the Malay world which is done through continuous documentations and research. The reports contained detailed drawings of the selected houses, which in turn provided the author with enough evidence to locate and identify furniture available in each given space. Photographic evidence were also evaluated. Data was analysed using Componential Analysis, which used various variables to help the author identify Traditional Malay furniture, by indicating the presence of certain components.

## RESULTS AND DISCUSSION

The findings showed sustainable furniture were used by Traditional Malays. These furniture were environmentally friendly and made from materials that were not harmful to the environment as well as being durable; hence, reducing the need for the owner to throw it away, buy or make a new one. These furniture are also considered sustainable because of their multi-purpose or multi-function properties. One example of the said furniture is the coconut scraper, which is a seat and at the same time doubled as a working tool. Table 3 below states the various types of sustainable furniture that can be found inside a Melaka TMH in the category of built-in. Table 4 lists the various types of loose sustainable furniture inside a TMH.

Table 3  
Built-in sustainable furniture

Space	Activity	Furniture	Function	Material
<i>Anjung</i>	Sitting / Leaning	<i>Bendul</i> (Sill)	Body-supporting unit	Wood
		Seats	Body-supporting unit	Wood
	Tools	Light Fixture	Utility	Wood
Staircase	Sitting / Leaning	<i>Bendul</i> (Sill)	Body-supporting unit	Wood
		Stairs	Body-supporting unit	Tile / Concrete
	Daily Preparation	Well	Storage/Utility	Concrete
<i>Serambi</i>	Storing / Utensils / Tools / Equipment	Light Fixture	Utility	Wood
		Clothes Hanger	Utility	Wood / Antlers
		Partition	Utility / Furnishing	Wood
	Sitting / Leaning	<i>Bendul</i> (Sill)	Body-supporting unit	Wood
		Window Rail	Body-supporting unit	Wood

Based on Table 3, Traditional Malay furniture in the *Anjung* comprised of *Bendul* (beams) that were used by the inhabitants as seats. Light fixtures were also available and were used by the Traditional Malays as a place to hang their lanterns and lights during the time before electricity. The main tiled staircase of TMH of Melaka were seldom sat on, but Melaka TMH had wooden staircases at the side of the house together with a wooden bench. These staircases were considered as furniture because of the presence of a roof covering both the staircase and the bench, which indicated that the inhabitants used these stairs as a seat while chatting to guests or other inhabitants in the opposite bench. Wells were also located next to the stairs which were useful for drawing water to clean the feet of people before going into the house. The *Serambi* had the most built-in furniture as it is the main space where guests were entertained. These included light fixtures, fixed wooden clothes hangers carved from the main beam of the house, and also partitions that were used when extra separated rooms were needed. The *Bendul* were used as seats, while window railings were used for leaning while sitting near the window.

Table 4  
Loose sustainable furniture

Space	Activity	Furniture	Function	Material
Staircase	Daily Preparation	Flower Pots	Storage/Utility	Clay
		Wash Basin	Storage/Utility	Clay/Metal
		Shoe Rack	Storage/Utility	Wood
<i>Serambi</i>	Storing / Utensils / Tools / Equipment	Wardrobe	Storage/Utility	Wood
		Cupboard	Storage/Utility	Wood
		Clothes Hanger	Utility	Wood / Antlers
		Door Panel	Utility/Furnishing	Textile
	Sitting/Leaning	Mats	Body-supporting unit	Pandanus leaves / bamboo strips
	Daily Preparation	<i>Tikar mengkuang</i> (Mat)	Body-supporting unit	<i>Mengkuang</i> leaves
	Praying	<i>Sejadah</i> (Praying mat)	Body-supporting unit	Textile

Loose furniture of the Traditional Malays that were located at the staircases included flower pots, wash basins and shoe racks. They were used as storage or utility. Furniture in the *Serambi* consisted of wardrobes, cupboards and deer antlers that were used to hang clothes and headgears. These antlers also indicated that the occupant of the house was a hunter. Other than that loose furniture found in the *Serambi*, included door panels that were used for decoration, mats made from *mengkuang* or Pandanus leaves as well as praying mats. These mats come in various sizes and used for different occasions as well as different locations. For example, three layered squared seating mats were woven intricately with Pandanus leaves and were used by brides and grooms. Larger mats were used to cover the entire floor inside the TMH.

## CONCLUSION

By using Componential Analysis to identify the presence of certain components to determine the end product, the author was able to identify numerous furniture used by the Traditional Malays inside their houses. The furniture was significantly influenced by the culture and traditions of the traditional Malays. Therefore, certain spaces had certain types of furniture based on the activity that were carried out inside that specific space. Although this is true, the findings also indicated that because spaces functioned smoothly for multiple activities and events, the furniture were multi-functional as well. Thus, it is clear furniture in TMH homes was sustainable and environmentally friendly.

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## REFERENCES

- Beard, G. (1985). The national trust book of English furniture. *Penguin Books Ltd, England*. P. 79.
- Gibbs, P. (1987). Building a Malay House. *Oxford University Press*, 22.
- Hashim, A. H., Mohamad Ali, H., & Abu Samah, A. (2009). Urban Malays' user behaviour and perspective on privacy and spatial organization of housing. *International Journal of Architectural Research*, 3(1), 197-208.
- Hashim, W., & Nasir, A. H. (2011). The traditional Malay house, *Institut Terjemahan Negara Malaysia Berhad*, Kuala Lumpur.
- Joy, E. T. (1972). Furniture. *London: The Connoisseur Chestergate House*.
- Lucie-Smith, E. (1993). Furniture a concise history. *London: Thames and Hudson Ltd*.
- Ozaki R. (2002). Housing as a reflection of culture: Privatised living and privacy in England and Japan, *Housing Studies*, 17(2), 209 -227.
- Rodriguez, G., & Siret, D. (2009). The future of houses: What real-estate ads tell about the evolution of single-family dwellings? *International Journal of Architectural Research*, 3(1).
- Tajuddin, M. R., Kamaruddin, M. A., Syed Ahmad Iskandar, S. A., Ra'alah, M., & Gurupiah, M. (2005). The architectural heritage of the Malay world the traditional house. *Penerbit Universiti Teknologi Malaysia*, p 12.
- Wahab, M. H. A., Awang, M., & Awang Lah, N. A. (2012). Furniture in Negeri Sembilan traditional house kitchen. *International Proceedings of Economics Development and Research (IPEDR)*, 56, 4.
- Winstedt, R. (1961). The Malays a cultural history. *Routledge and Kegan Paul Ltd, London*. 174-175.
- Yuan, L. J. (1987). The Malay house rediscovering Malaysia's indigenous shelter system. *Institut Masyarakat, Pulau Pinang*, 88.



## **Drought Characterisation in Peninsular Malaysia Using DrinC Software**

**Md. Munir Hayet Khan<sup>1\*</sup>, Nur Shazwani Muhammad<sup>1</sup> and Ahmed El-Shafie<sup>2</sup>**

<sup>1</sup>*Department of Civil & Structural Engineering, Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor, Malaysia*

<sup>2</sup>*Department of Civil Engineering, Faculty of Engineering, University of Malaya (UM), 50603 Kuala Lumpur, Malaysia*

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### **ABSTRACT**

Prolonged drought conditions have adverse environmental and socio-economic impacts due to unmet water demands. Defining drought is difficult because of its onset and ending time. Therefore, characterisation of drought is essential for drought management operations. Thus, drought indices come in handy and are a practical approach to assimilate large amounts of data into quantitative information which can then be applied for drought forecasting, declaring drought levels, contingency planning and impact assessments. This study analyses drought events using indices, namely SPI and Deciles Index, computed with DrinC software program but are not popular in Malaysia. It is observed that both indices are identical and suitable for drought occurrences.

*Keywords:* DrinC, drought, indices, Malaysia, SPI & DI, water

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### **INTRODUCTION**

Drought is one of the extreme hydrological events that can cause great socio-economic and environmental damages. Drought and water scarcity have different causes. Table 1 shows timescale and causes of water scarcity and drought (Vlachos, 1982). According to some studies, one half of the world's population will face water crisis by 2025, particularly in South Asia, Middle East and Africa (Diwan, 2002). More than 10 million people have died in the last century between 1900 to 2005 (Wilhite, 2000; Below et al. 2007). In Malaysia, 1.8 million residents living around Kajang, Bangi and south of Kuala Lumpur City, were affected by severe droughts in

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*E-mail addresses:*

shihab.bd@gmail.com (Md. Munir Hayet Khan),

shazwani.muhammad@ukm.edu.my (Nur Shazwani Muhammad),

elshafie@um.edu.my (Ahmed El-Shafie)

\*Corresponding Author

1998. The water supplies came from upper Langat River basin. The drought also affected Sarawak, Sabah, Penang, Kedah and Kelantan.

Table 1  
*Timescale and causes of water scarcity, drought and related concepts*

Timescale		Short-term (days, weeks)	Mid-term (months, seasons, years)	Long-term (decades)
Causes	Natural	Dry Spell	Drought	Aridity
	Man-made	Water shortage	Water scarcity	Desertification

The complex climatic functions can be simplified using drought indices and which can also quantify anomalies of climatic conditions as for their frequency, severity and duration. Therefore, they are essential tools for characterisation and the monitoring of drought events. They are also very useful for communicating with the wider audiences by providing comprehensible information such as the severity of drought episodes (Tsakiris et al., 2007). As a common practice, the drought indices are calculated either by using tools designed for this purpose or by manual calculations following the corresponding equations and procedures. On the basis of the stated considerations above, DrinC - a software package was used in this study. This software program was developed at the Center for the assessment of natural hazards and proactive planning of the National Technical University of Athens, Greece. Currently, major river basins in Malaysia have limited quantifiable information of drought occurrence, frequency and severity. In addition, there is lack of sufficient and appropriate drought assessment and forecasting tools. To prepare for effective mitigation of drought risks in peninsular Malaysia, evaluation of drought conditions is vital. Thus, this study focuses primarily on drought characterisation.

## MATERIALS AND METHODS

### Standardized Precipitation Index (SPI)

The SPI is a drought defining and monitoring tool. It is specifically based on the probability of records for a given amount of precipitation and duration. The probabilities are standardised. When an index value is calculated as zero, it indicates the median precipitation amount. The SPI can easily be computed by dividing the difference between the normalised seasonal precipitation and its long-term seasonal mean by the standard deviation as given in equation (1). Thus,

$$SPI = \frac{x_{ij} - \bar{x}}{\sigma} \quad (1)$$

where,  $(x_{ij})$  is the seasonal precipitation at the  $i^{th}$  rain gauge and  $j^{th}$  observation,  $(\bar{x})$  is the long-term seasonal mean and  $(\sigma)$  is its standard deviation. This method requires only a set of precipitation data for 30 or more years. The most frequent time scales being 1, 3, 6, 12 and 24 months of duration. Table 2 shows the classification of drought levels according to SPI.



Table 2  
*Classification of drought conditions according to SPI (Mckee et al., 1995)*

SPI Values	Classification
2.0 or more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 or less	Extremely dry

### Deciles Index (DI)

Gibbs and Maher (1967) introduced Deciles' Index (DI) to improve the percentage of normal precipitation or precipitation anomaly index. Deciles are arranged from 1 to 10. The lowest values such as 1 and 2 show drier climate compared with average conditions, whereas greater values of deciles point to more wet & humid conditions. The amount of precipitation for the preceding three months are ranked against climatologic records. The ranking may fall within the lowest decile or highest decile depending on the historical distribution of 3-month totals (Kininmonth et al., 2000). The formula for DI calculation is given in equation (2):

$$P_i = \frac{I}{N+I} \times 100 \quad (2);$$

where,  $P_i$  is probability of rain in number  $i$ th and  $N$  is the number of rainfall data. The deciles are grouped into five classes as presented in Table 3 below.

Table 3  
*Classification of drought conditions according to deciles (Gibbs & Maher, 1967)*

Decile Class	Description
Deciles 1-2: Lowest 20%	Much below normal
Deciles 3-4: Next lowest 20%	Below normal
Deciles 5-6: Middle 20%	Near normal
Deciles 7-8: Next highest 20%	Above normal
Deciles 9-10: Highest 20%	Much above normal
-1.5 to -1.99	Severely dry
-2 or less	Extremely dry

The first decile denotes 10% of the lowest quantity of precipitation and the second decile denotes precipitation values ranging between 10 and 20%. Each group represents the level of dryness or humidity. The state of humidity marked as "Normal" (30-70%) in the original index has been classified as "Slightly lower than normal", "Normal" and "Slightly above normal". This classification was simplified and converted into a single category so that easier

comparison with other methods can be made as shown in Table 4 (Smakhtin & Hughes, 2004; McKee et al., 1995).

Table 4  
*Limit values for Standardised Precipitation Index (SPI), Deciles Index (DI)*

DI Values	SPI Values	Classification
> = 90	2.0 or more	Extremely wet
80 to 90	1.5 to 1.99	Very wet
70 to 80	1.0 to 1.49	Moderately wet
30 to 70	-0.99 to 0.99	Normal
20 to 30	-1.0 to -1.49	Moderately dry
10 to 20	-1.5 to -1.99	Severely dry
< = 10	-2 or less	Extremely dry

### **Drought Analysis Using DrinC Program**

Drought Indices Calculator abbreviated as “DrinC”, is a program that facilitates the calculation drought indices, especially in assessing the spatial distribution of indices. The main consideration was the broader applicability such as all types of meteorological, hydrological and agricultural drought and at different locations. It was noted that drought studies are particularly essential in semi-arid and arid lands, given that data availability is usually limited in those areas. Two indices developed recently, namely Reconnaissance Drought Index (RDI) and Streamflow Drought Index (SDI), were included in DrinC software as well as two more widely known indices such as Standardized Precipitation Index (SPI) and Deciles Index (DI). By default, the calculation period begins in October and the primary reference base in DrinC is the hydrological year (October-September). The main calculation steps are of 1-month, 3-month, 6-month, 9-month and annually. Therefore, DrinC may be useful for several real-world applications such as to study drought effects on specific crops to coincide with the crop growth period (Tigkas, 2008).

### **Study Area and Data Collection**

The selected catchment area in this study is Langat River and it is about 2350 sq.km and 200 km long. The basin is about 1854 sq.km from southern part of Selangor and about 450 sq.km from the western parts of Negeri Sembilan, the neighbouring state, with 41 sq.km covering Putrajaya and 5 sq.km covering Kuala Lumpur. Figure 1 shows the map of Langat river basin and Kampung Sungai Lui rainfall station.



Figure 1. Map of Langkat Basin

Sekolah Kebangsaan Kampung Sungai Lui was chosen in this study as one of the rainfall stations for Langkat river basin. The rainfall data was obtained from Drainage and Irrigation Department (DID, Malaysia). Figure 2 below shows the mean and median monthly rainfall recorded by Sekolah Kebangsaan Kampung Sungai Lui rainfall station. Dry months were generally observed between January and March and June to September in Malaysia.

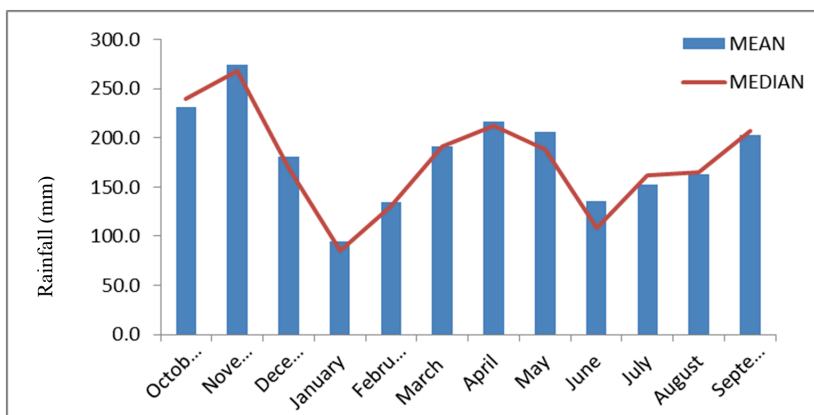


Figure 2. Mean and median monthly rainfall of Sekolah Kebangsaan Kampung Sungai Lui

## RESULTS AND DISCUSSION

This study used precipitation records of 43 years i.e. 1972-2014 from a rainfall station, Sekolah Kebangsaan Kampung Sungai Lui; SPI values (3, 6, 9 and 12-month) and DI values were calculated. The results are shown in Figures 3 to 10 below, with X-axis being the years and Y-axis being the SPI values. Figure 3 shows 3-month & 6-month SPI values having negative SPI levels from 1972-1973, 1976-1978, 1982-1983, 1986-1987, 1991-1992, 1997-1999, 2000-2001 and 2013-2014 years which indicate moderately dry and nearly normal conditions except for the period 1975-1977, 1986-1987, 1992, 1998, 2001-2002 when extreme dry conditions

were observed according to SPI values. In February 1998, the level of water of Langat dam came close to 14m above critical level (Shaaban & Sing, 2002), whereas, very wet conditions were observed in the years 1981-1983, 1994 and 2011-2012.

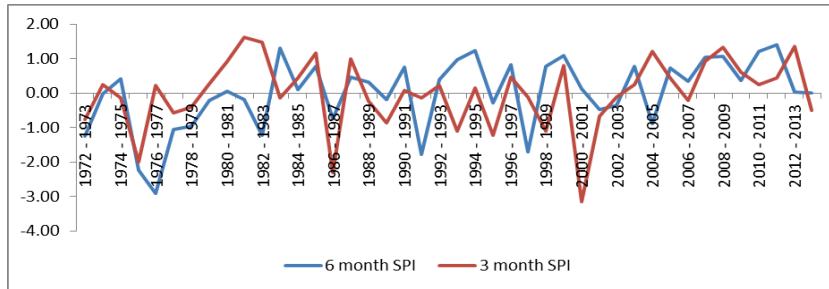


Figure 3. 3-month and 6-month SPI Values for Langat River Basin

There was a demand for extra water from the dam for abstraction downstream at km 18, Cheras treatment plant and Tampoi treatment plant in early April 1998. The water supply department (JBA) estimated water demand for Kuala Lumpur/Selangor in that year was 2658 million litres per day. However, the supplied amount was 2553 million litres per day (Shaaban & Sing, 2002). In 1976, for 6-month and 9-month SPI values, moderate and severe drought conditions were observed in 1976, 1977, 1992, and 1998 which were very similar to 3-month SPI values. As seen in Figure 4, for 12-month SPI values, moderate and severe drought conditions were observed in 1972, 1978, 1984, 1995 and 1997 which have similarity with 9-month SPI values. On the contrary, only 3-month SPI values showed drier conditions in 2014. As reported by Sanusi et al. (2014), longer periods of droughts were experienced especially in the urban areas of the south-western part of peninsular Malaysia in 2014.

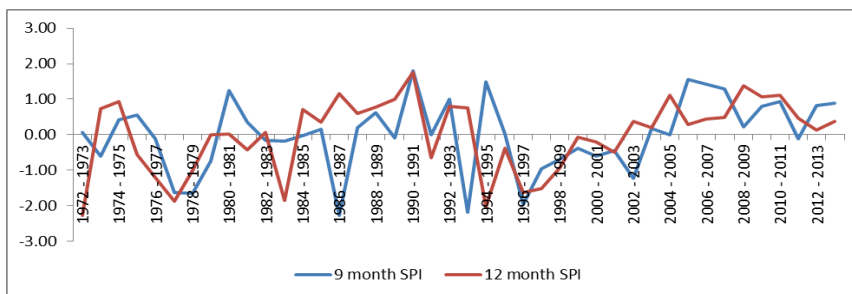


Figure 4. 9-month and 12-month SPI values for Langat River Basin

Based on the Decile Indices, 1972, 1976, 1978, 1987, 1988, 1992, 1997, 1998 and 2008 are in the decile class of 1-2 which means “Much below normal” and identical with the results for 3, 6, 9 and 12-month SPI values respectively as shown above. A previous similar study (Nohegar et al., 2015), compared three indices, SPI, DI & PNI, and they found the values of Decile Index (DI) and SPI values remained within closer characteristics at more than half of the time for drought index calculations.

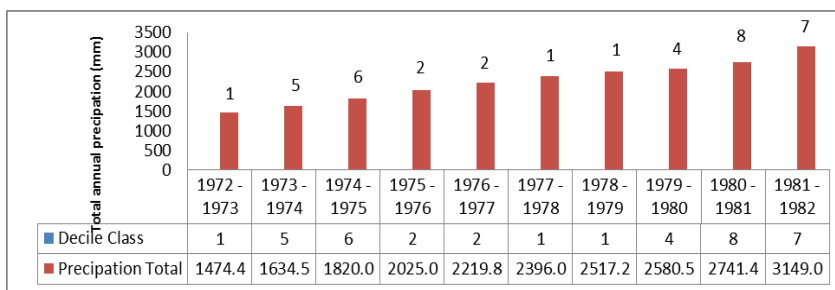


Figure 5. DI values for Langkat River Basin (1972-1982)

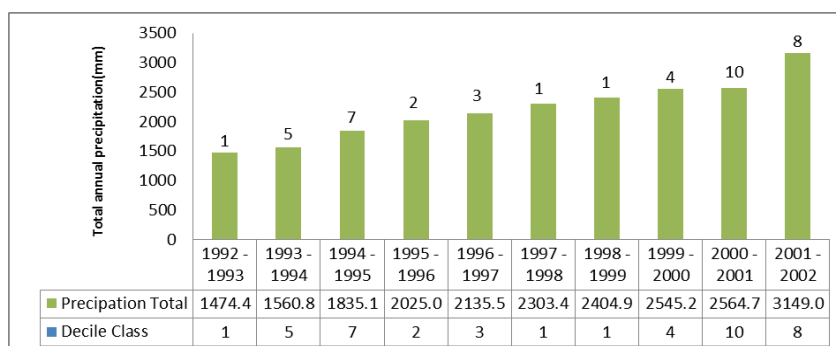


Figure 6. DI values for Langkat River Basin (1992-2002)

Figure 7 shows the frequency of decile classes. It can be observed that decile classes 1 and 2 (much below normal) equals to 34% of the whole events observed between 1972 and 2014 (rainfall data). It is found that among all SPI values calculated, the severely dry, moderately and extremely dry conditions equal to 26%.

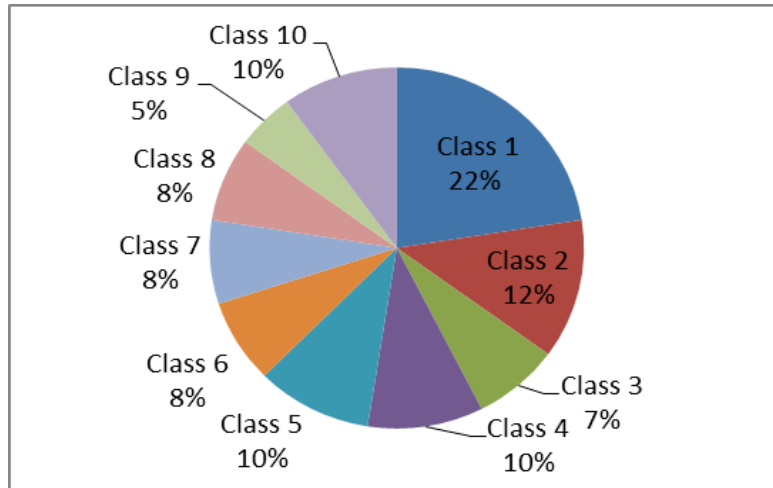


Figure 7. Frequency of decile classes (1 -10)

## CONCLUSION

Two drought indices, namely Deciles Index (DI) and SPI (Standardised Precipitation Index), were used in this study. Both indices were identical and suitable for describing drought occurrences in the chosen area of this study. A gradual increase has been observed using DrinC software to characterise and analyse droughts in many parts of the world. It can be used for assisting early estimation of drought consequences and mitigating future impacts.

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## REFERENCES

- Below, R., Grover-Kovec, E., & Dilley, M. (2007). Documenting drought-related disasters: A global reassessment. *The Journal of Environment & Development*, 16(3), 328–344.
- Diwan, P. L. (2002). Water, Environment & Drought. Proceedings: *All India Seminar on Water & Environment- Issues and challenges*, October 2002, IIT, Roorkee, India 21-185.
- Gibbs, W. J., & Maher, J. V. (1967). Rainfall deciles as drought indicators. Bureau of Meteorology Bulletin no. 48. Commonwealth of Australia, Melbourne.
- Kininmonth, W. R., Voice M. E., Beard G. S., Hoedt, G. C., & Mullen, C.E. (2000). Australian climate services for drought management. In: D.A. Wilhite (ed.) *Drought, a global assessment*. Routledge, pp. 210-222.
- McKee, T. B., Doeskin, N. J., & Kleist, J. (1995). Drought Monitoring with Multiple Time Scales. *Conference of Applied Climatology*, American Meteorological Society, Boston, pp. 179-184.

- Nohegar, A., Mahmoodabadi, S., & Norouzi, A. (2015). Comparison the suitability of SPI, PNI and DI drought index in Kahurestan watershed (Hormozgan Province/South of Iran). *Journal of Environment and Earth Science*, 5(8), 71-76.
- Sanusi, W., Jemain, A. A., Zawiah, W., Zin, W., & Zahari, M. (2014). The drought characteristics using the first-order homogeneous markov chain of monthly rainfall data Peninsular Malaysia. *Water Resources Management*, 29, 1523–1539.
- Shaaban, A. J., & Sing, L.K. (2002). The 1998 drought in the Kuala Lumpur-Bangi-Kajang Conurbation: Characterisation and impacts. *International Conference on Urban Hydrology*, 14-18 October 2002, Kuala Lumpur.
- Smakhtin, V. U., & Hughes, D. A. (2004): Review, automated estimation and analyses of drought Indices in South Asia. Working Paper 83, *Drought Series Paper 1*.
- Tigkas, D. (2008). Drought characterization and monitoring in regions of Greece. *European Water*, 23/24, 29-39.
- Tsakiris, G., Pangalou, D., & Vangelis, H. (2007). Regional drought assessment based on the reconnaissance drought index (RDI). *Water Resources Management*, 21(5), 821-833.
- Vlachos, E. C. (1982). Drought Management interfaces. *Annual ASCE Meeting*, Las Vegas, Nevada, 15.
- Wilhite, D. A. (2000). *Drought: A Global Assessment*. Volume I and II. London/New York: Routledge.







## **Localisation for E-Learning Website of Comprehensive Universities in Malaysia**

**Aslina Baharum<sup>1\*</sup>, Grace Jelang Anak Thomas<sup>1</sup>, Nurul Hidayah Mat Zain<sup>2</sup>,  
Nordaliela Mohd. Rusli<sup>1</sup> and Jason Teo<sup>2</sup>**

<sup>1</sup>*Faculty of Computing and Informatics, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia*

<sup>2</sup>*Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Kampus Jasin, 77300 Merlimau, Melaka, Malaysia*

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### **ABSTRACT**

An e-learning website is very useful, especially for students and lecturers, as this platform is very efficient for blended learning. Thus, the main objective of this research was to determine the user expectations of e-learning websites of comprehensive universities through localisation based on user preferences. This research showed how users interact with e-learning websites and indicated the patterns that can be used as standard guidelines to design the best e-learning websites. It was found localisation of e-learning websites was scarce and slow interaction with e-learning websites has inconvenienced users. Additionally, too many web objects on the user interface of e-learning websites have a tendency to confuse users. A mixed method approach was used in this study, namely content analysis (qualitative) and localisation (quantitative). Thus, this research contributes to knowledge by guiding users on localising their web objects according to their preferences and hopefully allow for an easy and quick information search for e-learning websites.

*Keywords:* E-learning, localisation, user expectations, web objects

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*E-mail addresses:*

aslinabaharum@gmail.com (Aslina Baharum),  
grayz.weeh@yahoo.com (Grace Jelang Anak Thomas),  
nurulmz@tmsk.uitm.edu.my (Nurul Hidayah Mat Zain),  
daliela@ums.edu.my (Nordaliela Mohd. Rusli),  
jtwteo@ums.edu.my (and Jason Teo)

\*Corresponding Author

### **INTRODUCTION**

An e-learning website allows sharing of materials for teaching and learning outside of the classroom such as slideshows, notes, documents, PDFs, and videos. Additionally, some e-learning websites allow one to communicate with others who are online. Thus, e-learning websites save time for both lecturers and students. Lecturers can also make online assessments for their students.

There have been various studies of localisation of websites, such as library websites, informational websites, and e-commerce websites. However, none has been on e-learning user interface design (UID). This research was motivated by attempts to find a solution to problems related to slow e-learning UID (Fitchen et al., 2009). Next is the complexity of e-learning UID (Fitchen et al., 2009). No standard web objects make the UID complex and complicated (Aslina, 2016).

E-learning provides a cost-effective and improved learning experiences beyond those available in the classroom (Misra, 2013). Students facing economic, family, physical, or geographical constraints can take advantage of opportunities provided by online learning (Misra, 2013). In addition, students learning in the classroom can augment their learning outcomes by participating in hybrid or fully online courses. Moreover, e-learning provides students with the ability to fit learning in their lifestyles, effectively allowing even the busiest person to pursue careers and gain new qualifications. This research will first determine the standard web objects of e-learning before localising them according to user expectations. All the results are recorded. This paper is organised as follows: a discussion of related localisation of user interface is contained in section 2, the experimental setup is presented in section 3 while discussions are in section 4. The final section summarises the paper.

## **Related Works**

Most users would judge a website based on its interface design. According to Marcus (2013), on web implies availability and access to knowledge-based products among people around the world. Successful web-based products developed for markets in different countries and of different cultures consist of partially universal or general solutions to the design of user interface (Aslina & Azizah, 2014). Thus, by managing the user experience with common structures and processes, as well as user preferences and expectations, user interface and information visualisation designers can achieve compelling forms that allow for easy use.

## **E-Learning**

E-learning refers to the deliberate use of networked information and communications technology (ICT) in teaching and learning (Naidu, 2009). It also includes online learning, virtual learning, distributed learning, network, and web-based learning. Referring to the educational processes that utilise ICT to mediate asynchronous as well as synchronous learning and teaching activities, Naidu (2009) stated that the growing interest in e-learning seems to come from several directions including organisations that have traditionally offered distance education programmes in either single-mode settings, dual or mixed. Besides, e-learning is also attracting residential campus-based educational organisations because they see e-learning as a way to improve access to their programmes and also as a way to take advantage of the growing market niche. In addition, the major obstacle to the growth of e-learning is the lack of access to necessary technology infrastructure (Naidu, 2009).

## User Interface Design

User interface design (UID) for e-learning is different from a normal website for certain purposes. Since e-learning is an educational-based website, studies have looked at how to make a good and attractive website exclusively for its usability. E-learning interface design is critical for effectiveness of learning and interface design is largely intertwined (Delf, 2013). Besides, Delf (2013) added that the trend among large companies has led to the usability-first way of thinking about e-learning design, where ease of use is considered as a top design priority. In addition, designers follow the rules, which are required to make a design principle in which the method is to focus mainly on making a product easy to use. Delf (2013) also suggested that e-learning interface should be a core, integrated component of the overall design of e-learning products and the interface design should be determined by how people learn and the need to implement this program. There are four guiding principles in building a good interface for e-learning. It can vary from individual to individual since it is preferable to match e-learning closely to the clients' brand guidelines or to other pre-existing e-learning courses and materials (Webster, 2015). The first guiding principle is un-obstructive in which the user interface should not overpower the content so the end users will barely notice that it is there at all. Second, it is intuitive for which users need little explanation on how to navigate a course and use the user interface. Next, the flexibility in which the content of the course is not known at design time, but it is a safe guess that there will be a lot of variety in the content. Lastly, it must be simple and clean whereby being able to execute a simple and clean design with particular attention to detail is the mark of a skilled designer (Webster, 2015). Although expert opinion on designing a user interface for e-learning websites vary, there are similarities in which they want users to understand the websites in a simpler way. Thus, an e-learning website should be based on its usability.

## Localisation

The theory of localisation is the process of adapting a product or service to a particular language, culture, and desired by the locals in certain countries (Cyr & Trevor-Smith, 2004). In the localisation of products, in addition to idiomatic language translation, such as time zones, currencies, local colour sensitivities, product or service names, gender roles and geographic examples must all be considered (Cyr & Trevor-Smith, 2004). Thus, they argue successfully that localised service or product is one developed in the context of local culture. Previous research has proven that localisation is beneficial for both user and work efficiency (Aslina & Azizah, 2013; Reinecke, 2010). Somehow, current localisation methods disregard the many facets of the typical user's culture by simply adapting to a certain country (Aslina & Azizah, 2014). User interface designs are a matter of taste as preferences vary from person to person. According to Nisbett (2003), people considered belonging to the same cultural group also perceive and process information in similar ways. Therefore, the design of user interfaces in different countries indicates that culture bundles a variety of these partialities, such as concerning a number of colours, navigational support, or information density and that many

preferences are collectively shared by certain cultural groups. Many companies have also started to adapt their user interfaces to foreign markets in order to gain customer loyalty and increase their market share (Nisbett, 2003).

Most of the previous studies conducted on localisation were for user interface of e-commerce websites (Adkisson, 2002; Bernard, 2000, 2001, 2002; Bernard & Sheshadri, 2004; Costa, 2010). Localisation in UID is to provide a technologically, linguistically, and culturally neutral platform to launch global e-commerce initiatives while allowing a framework that incorporates local content and functionality (Aslina & Azizah, 2015; Shannon, 2000). Then, visual design aids the viewer in establishing a system to structure information where this structure is created by the use of icons, symbols, or other navigational tools. Furthermore, persuasive power of design elements on an e-commerce website offers a set of guidelines to web designers based on elements such as navigation or optimal presentation of information as they appeal to user's logic, emotions, and credibility (Winn & Beck, 2002). Winn and Beck (2002) stated that with the number of online users on the Web steadily increasing, there are both social and business reasons to seek a better understanding of user preferences related to design elements.

This research will localise selected web objects from comprehensive universities in Malaysia according to what users among lecturers and students from UMS preferred. Previous studies have described the localisation of user interface designs but somehow none of them has localized web objects of e-learning websites. Apart from that, web objects need to localise the interface of e-learning websites. The web objects from the literature will be used to compare the e-learning websites of the chosen universities. This research will also focus on students and lecturers from UMS as users. Besides, effective UID toward e-learning websites is very important. Thus, this study will localise the web objects for e-learning user interface website. Before localising a website, web objects will be recognised first, so that localisation can be done. Web objects, which are also known as elements of a web page, include text, graphics, scripts, and URLs of a web page. The Web has expanded the set of objects with which users interact, such as representations of people, apartments, locations, flight itineraries, and products but somehow the Web lacks standardised type and tools for such semantically rich objects (Pham, 2013).

## **MATERIALS AND METHODS**

### **Experimental Set-up**

This research used a mixed method of qualitative and quantitative methodology. A qualitative methodology using content analysis was adopted which is the identifications of web objects in comprehensive universities in Malaysia. The web objects on e-learning websites of four comprehensive universities in Malaysia, which are also known as educational universities, were reviewed. They are Universiti Teknologi Mara (UiTM), Universiti Malaysia Sarawak (UNIMAS), Universiti Islam Antarabangsa Malaysia (IIUM) and Universiti Malaysia Sabah (UMS). Next, a quantitative methodology using survey by distributing questionnaires was conducted. The UMS was used as a case study for data collection. The questionnaires

were adapted from Bernard (2000) and Aslina and Azizah (2013). The sample size of the questionnaires was 70 random participants among UMS students and lecturers. The questionnaires were distributed to 20 lecturers and 50 students. There are two sections of the questionnaires; the first section (Section A) is demographic questions of the respondents; and the second section (Section B) is the user expectations of the location of web objects. The localisation of web objects used as grid the study was done by Aslina and Azizah (2013) who used 7x6 geometric grid square. For easy naming of the location for each object, the geometric grid square was also divided into nine sections, which are Top Left, Top Centre, Top Right, Centre Left, Centre, Centre Right, Bottom Left, Bottom Centre, and Bottom Right (Figure 1). The location of each web object consisted of four best options based on the content analysis done in the first methodology. So, the list localisation of the selected web objects was then determined. Next, respondents were asked to select the best location of the web objects in the second methodology. Finally, the localisation of the web objects was confirmed.

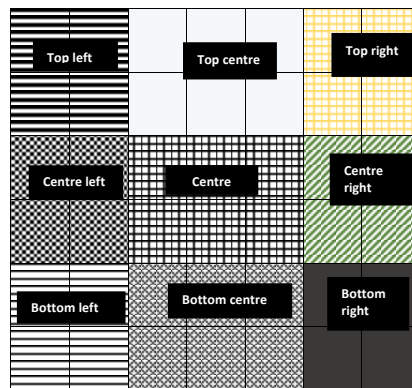


Figure 1. Geometric 7x6 grid square (Aslina & Azizah, 2013)

## RESULTS AND DISCUSSION

There are 14 web objects selected for localisation in this research based on the review of four universities: Logo, Log In, External Links, News & Announcements, Advertisements, Search Courses, Helpdesk, Navigation, Main Menu, Home, Calendar, Course Categories, Faculty Categories, and Feedback. The web objects were divided into two sections, which are confirmed web objects and selected web objects. The confirmed web objects were those that appeared three or four times on each e-learning website of the comprehensive universities. The confirmed web objects were Logo, Log In, External Links, News & Announcements, Advertisements, Search Courses, Helpdesk, Navigation, Main Menu, and Home. The selected web objects appeared once or twice only on certain e-learning websites of the comprehensive universities. They were Calendar, Course Categories, Faculty Categories, and Feedback. Localisation of selected web objects was collected using 7x6 geometric grid method proposed by Aslina and Azizah (2013). The darker the shade in the region, the greater the number of times that the particular web objects selected by respondents to localise the web objects (Figure 2).

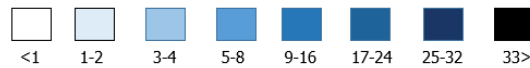


Figure 2. Scale of shades

The first section of the questionnaires is on demographics. A total of 44% of the respondents were male. The questionnaires were distributed to 20 lecturers and 50 students from UMS. About 57% of the respondents were in the age group between 20 and 24, 10% were between 25 and 29, 4% were in the age range of 30-34 years old, 14% were 35-39 years old, 3% were 40-44 years old, 4% were 45-49 years old, 3% were 50-54 years old, 4% were 55-59 years old, and none was 60 years old and above. Since this research used mainly students as a sample, the highest percentage age group was between 20 and 24 years old and therefore, most of the respondents were undergraduate students. The 14 web objects were localized according to user expectations. The percentage of respondents who localised the 14 web objects was recorded and analysed. Figure 3 to Figure 16 show the results.

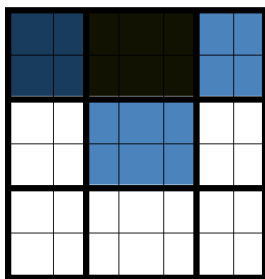


Figure 3. Logo

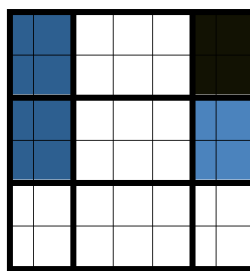


Figure 4. Log In

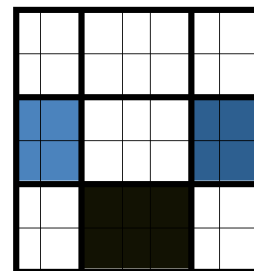


Figure 5. External Links

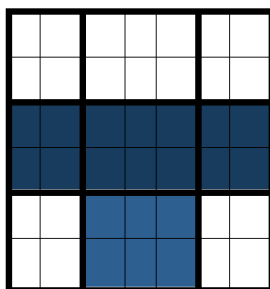


Figure 6. News & Announcements

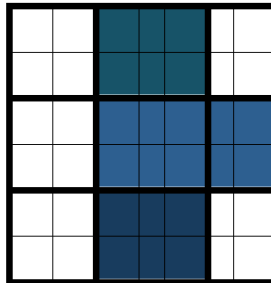


Figure 7. Advertisements

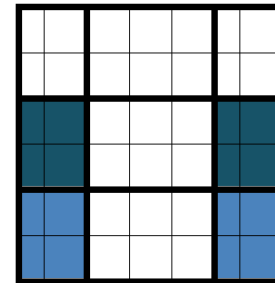


Figure 8. Search Courses

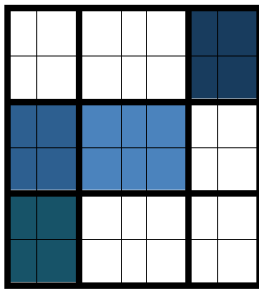


Figure 9. Helpdesk

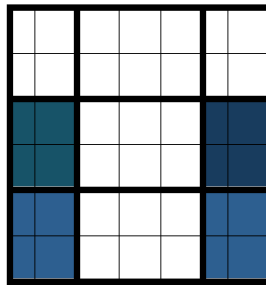


Figure 10. Navigation

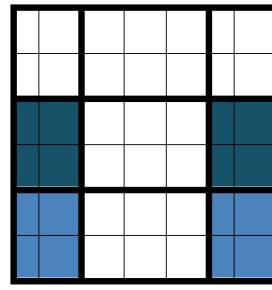


Figure 11. Main Menu

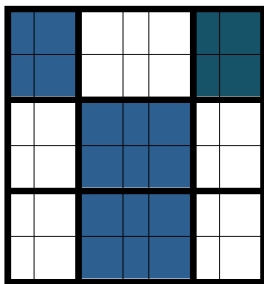


Figure 12. Home

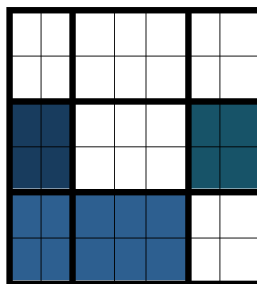


Figure 13. Calendar

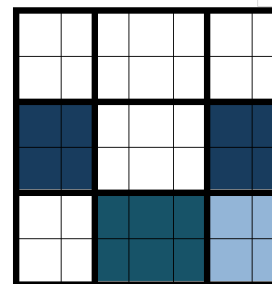


Figure 14. Course Categories

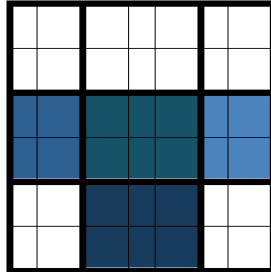


Figure 15. Faculty Categories

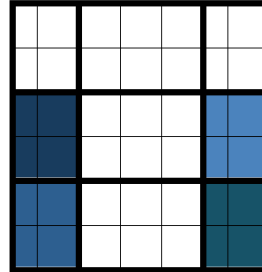


Figure 16. Feedback

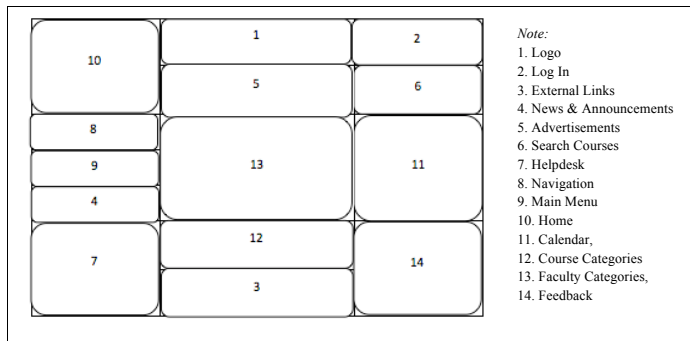


Figure 15. Localisation of web objects for e-learning website

## CONCLUSION

In conclusion, the proposed guideline (Figure 17) for the UID of e-learning websites has been obtained based on localisation. By using user expectations, it will be easier for users to use the e-learning websites. Most of the web objects are localised based on user's need. Thus, it is hoped that it will help users to easily access the information and details that they need. The Ministry of Education (MOE) has indicated Malaysia's intention to expand on massive open online courses (MOCC) as a way to take advantage of technology to improve quality and widen access to education where MOOC is being used as an online learning approach that offers benefits for Malaysia. The MOCC refers to what a good e-learning should be; where, an interactive and engaging environment encourages a high-degree of collaboration and international interactions. The guidelines enable users to easily engage in learning tasks. Future research can focus on usability testing or by using tools such as eye-tracking technology which are based on (Nurul-Hidayah et al., 2011; Aslina and Azizah, 2014b) efficiency, effectiveness, and satisfaction to measure and verify the proposed guidelines.

## REFERENCES

- Adkisson, H. P. (2002). Identifying de-facto standards for e-commerce Web sites. *Proceedings. IEEE International Professional Communication Conference*. IEEE.
- Aslina, B., & Azizah, J. (2013). Users' Expectation of Web Objects Location: Case study of ASEAN Countries. In *Springer International Publishing Switzerland 2013*, H. Badioze Zaman et al. (Eds.): IVIC 2013, LNCS 8237, pp. 383-395.
- Aslina, B., & Azizah, J. (2014a). Investigating adaptive ASEAN cultural diversity through users' mental models for user interface design. *Journal of Theoretical and Applied Information Technology (JATIT)*, 61(3), 617-629.
- Aslina, B., & Azizah, J. (2014b). Evaluation of ASEAN mental models pattern of web user-centered interface design using eye-tracking technology. *Journal of Computer Science*, 10(10), 2492-2506.
- Aslina, B., & Azizah, J. (2015). Web user interface: Local websites versus users' mental model pattern for ASEAN. *ARPN Journal of Engineering and Applied Sciences*, 10(23), 18046-18053.
- Aslina, B. (2016). *Localisation of web objects for user interface design through users' mental model pattern*. (Unpublished doctoral thesis). Universiti Kebangsaan Malaysia.
- Bernard, M. (2000). Examining user expectations of the location of web objects. (3.3): *Article-Conceptual User Interface*, 1-6.
- Bernard, M. (2001). User expectations for the location of web objects. CHI '01 Extended abstracts on human factors in computer systems - CHI '01, 171. doi:10.1145/634164.634171
- Bernard, M. (2002). Examining user expectations for the location of common e-commerce web objects. *Usability News*, 4(1).
- Bernard, M., & Sheshadri, A. (2004). Preliminary examination of global expectations of users' mental models for e-commerce Web Layouts. *Usability News*, 6(2), 1-9.
- Costa, C. (2010). Cultural factors and usability user expectations for the location of e-commerce web Objects, 1-20.



- Cyr, D., & Trevor-Smith, H. (2004) Localisation of web design: An Empirical comparison of German, Japanese and U.S. Website Characteristics. *American Society for Information Science and Technology*, 55(13), 1-10.
- Delf, P. (2013). Designing effective eLearning for healthcare professionals. *Radiography*. Volume 19. Issue 4. pp. 315-320. Doi: 10.1016/j.radi.2013.06.002.
- Marcus, A. (2013). Cross-cultural user-experience design. In proceeding of SIGGRAPH Asia 2013 Courses (SA '13), Article No. 8.
- Misra, P. (2013). Pedagogical quality enrichment in OER based courseware: Guiding principles. *Open Praxis*, 5(2), 123-134.
- Naidu, S. (2009). Pedagogical affordances of technology. In S. Misra (Ed.), *E-learning (STRIDE Handbook 8)*. New Delhi, IGNOU.
- Nisbett, R. E. (2003). The influence of culture: Holistic versus analytic perception. *TRENDS in Cognitive Sciences*, 9(10), 467-473.
- Nurul-Hidayah, M. Z., Fariza-Hanis, A. R., Azizah, J., & Mohd-Firdaus, Z. (2011). Eye tracking in educational games environment: Evaluating user interface design through eye tracking patterns. In *Visual Informatics: Sustaining Research and Innovations, Springer Berlin Heidelberg*, pp: 64-73.
- Pham, H. (2013). *User interface handles for web objects*. Doctoral thesis. Massachusetts Institute of Technology
- Reinecke, K. (2010). *Culturally adaptive user interfaces*. Doctoral dissertation. University of Zurich, Department of Informatics, Zurich
- Shannon, P. (2000). Including language in your global strategy for B2B e-commerce, *World Trade*, 13(9), 66-68.
- Shaikh, B. A. D., & Lenz, K. (2006). Where's the search? Re-examining user expectations of web objects. *Usability News* 8(1), 2-6.
- Vasantha, R. N., & Harinarayana, N.S. 2011. *Identifying the location of web objects: A study of library web sites*. Paper presented at 8<sup>th</sup> International Caliber, pp. 28-39.
- Webster, J. (2015). Designing an e-Learning GUI. In proceeding of the 7<sup>th</sup> European Conference e-Learning., W., and Beck, K. (2000). The persuasive power of design elements on an e-commerce web site. *Technical Communication*, 49(1), 17-35.



## **Effect of Batu Pahat Soft Clay (BPSC) Concentrations on the Physical and Rheological Properties of Asphalt Binder**

**Mohd Idrus Mohd Masirin<sup>1\*</sup>, Allam Musbah Al Allam<sup>2</sup> and Ahmed Suliman Bader Ali<sup>1</sup>**

<sup>1</sup>*Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia*

<sup>2</sup>*Research Centre for Soft Soils (RECESS) Malaysia, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia*

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### **ABSTRACT**

The major aim of this research was to investigate the addition of BPSC on the physical and rheological properties of asphalt binder. In this study, addition of five different percentages of BPSC compositions were studied, namely (2, 4, 6 and 8%). The impact of modifier on the rheological and physical properties was determined using conventional tests, such as softening point, ductility and penetration, and measurements from a dynamic shear rheometer. Based on the results, it was observed that the addition of BPSC has a significant impact on the rheological properties of asphalt binder and would improve rutting resistance at high temperatures. Meanwhile, results related to physical properties indicated that a decrease in penetration and increase in softening points results in stiffness of BPSC. The results showed that BPSC reduced temperature susceptibility and increased stiffness and elastic behaviour in comparison to unmodified asphalt binder. This means BPSC would increase the resistance of permanent deformation (rutting). Finally, BPSC could be considered as an appropriate additive to modify the properties of asphalt binder.

*Keywords:* Amplitude sweep, Asphalt binder, DSR, physical properties, soft clay, superpave parameter (rutting)

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*E-mail addresses:*

[idruse@uthm.edu.my](mailto:idruse@uthm.edu.my) (Mohd Idrus Mohd Masirin),

[alallm84@yahoo.com](mailto:alallm84@yahoo.com) (Allam Musbah Al Allam)

\*Corresponding Author

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### **INTRODUCTION**

In principle, asphalt binder plays a critical role in enhancing the quality of hot mix asphalt. Thus, pavement engineers should have a comprehensive understanding of the behaviours of asphalt binder (Zaniewski & Pumphrey, 2004). Airey (1999) found that the performance of asphalt binder has become increasingly more complicated with increased

utility of PMB in the asphalt pavement industry. Traditionally, asphalt binder has been widely used as cementing materials in the construction of flexible pavements (Kamal et al., 2012). This is in order to improve the performance of pavement based on the specifications for asphalt mixtures and binders (Kennedy & Harrigan, 1990). In recent years, modified asphalt binder has been applied in the asphalt pavements ( Hasham et al., 2013). A recent study (Patted et al., 2013) showed that rheological is a very strong instrument for quantifying material properties, as well as, the rheological properties of asphalt binder . Several indexes methods have been proposed to assess the low and high-temperatures performance of asphalt binders respectively (Shan et al., 2015).

Similarly, researchers have showed that rheological behaviour relies on the structure of pure and chemical composition of modified binder (de Camargo Forte et al., 2004). One of the most important challenges for researchers is proposing an effective method to improve the properties of asphalt binder to provide longer service life ( Muniandy et al., 2013).

## **MATERIALS AND METHODS**

### **Materials**

In this research, 80/100 of penetration grade was used in order to prepare all the test samples; the specific gravity of the asphalt binder is 1.03. The physical properties of asphalt binder are shown in Table 1.

### **Sample Preparation**

BPSC particles at various concentrations (2, 4, 6 and 8%) was added to asphalt binder (bitumen was prepared using a high shear mixer). The material was then stirred for 60 minutes at speed of 3000 rpm while maintaining a temperature of 165°C to ensure that the soft clay particles were homogeneous during the process of mixing and well dispersed inside the medium of bitumen binder.

### **Experimental Procedures**

**Physical Properties of Asphalt Binder.** Before conducting physical properties tests, prior tests such as softening point, ductility and penetration are vital (see Table 1). The DSR measurements were done according to ASTM specifications in order to ensure reproduction changes of BPSC. The penetration test value is to determine the stiffness of asphalt binder while the softening point is where asphalt binder starts to become a fluid while the ductility test value is measure the distance in centimetres which is a standard briquette of asphalt binder.

Table 1  
*The physical properties of asphalt binder*

Physical Properties	units	Limits	Specification
Penetration@ 25°C, 0.1mm	0.1mm	80-100	ASTM D 5
Softening Point, °C	°C	45-52	ASTM D 36
Ductility @ 25°C, cm	cm	≥ 100	ASTM D 113
Specific Gravity, g/cm <sup>3</sup>	-	1.01-1.05	ASTM D 70

**Rheological tests.** It has been recently established that the rheological properties of the asphalt binder impact on the performance of asphalt binder (Shafabakhsh & Ani, 2015).

**Dynamic shear rheometer.** The SHRP Superpave performance grade binder specifies lowest values for  $G^*/\sin \delta$  of 1000 Pa for original asphalt binder. After placing the sample into the DSR device, HAKE software was used in order to perform the test oscillation. Basically, the Superpave specification of rutting parameter ( $G^*/\sin \delta$ ), provides a measure of rutting resistance of asphalt binder, as well as identify a term to be used for high and intermediate temperature performance. Procedures for the DSR are given in AASHTO 315.

**Rutting performance.** The resistance of asphalt binder versus rutting was determined using dynamic shear rheometer test. In order to determine the permanent deformation (rutting) resistance, DSR test was done on unaged asphalt blend. Temperatures at 46°C, 52°C, 58°C, 64°C and 72°C were used to determine the permanent deformation tests (rutting) accurately.

## RESULTS AND DISCUSSIONS

### Physical Properties of Asphalt Binder

The effect of different ratios of BPSC on the physical properties of asphalt binder, such as softening point, ductility and penetration test, is shown in Table 2.

### Penetration

The penetration test is defined as an empirical test, used to determine the consistency of asphalt binder (Leng et al., 2014). The test was conducted at 25°C and according to ASTM D 5. As per Figure 1, the addition of soft clay constrictions to base asphalt show declared reduction in penetration for up to 4% of BPSC.

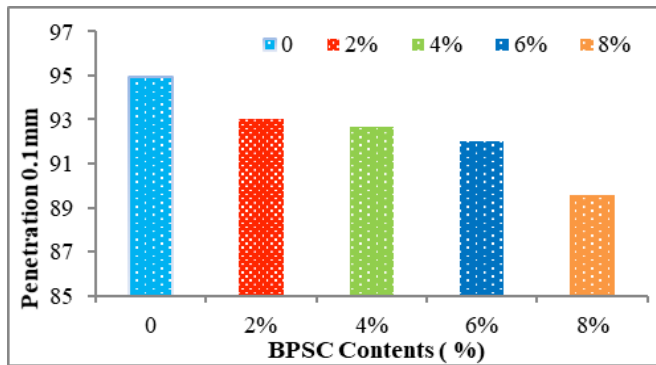


Figure 1. Penetration test at 25°C

### Softening Point

This test is defined as the temperature at which an asphalt binder cannot support the weight of a steel ball and begins to soften. The test is conducted using ball and ring process in accordance with ASTM D36. Reciprocally, an increment in the softening point happens up to 4% of BPS, followed by a decrease in other concentrations as shown in Figure 2.

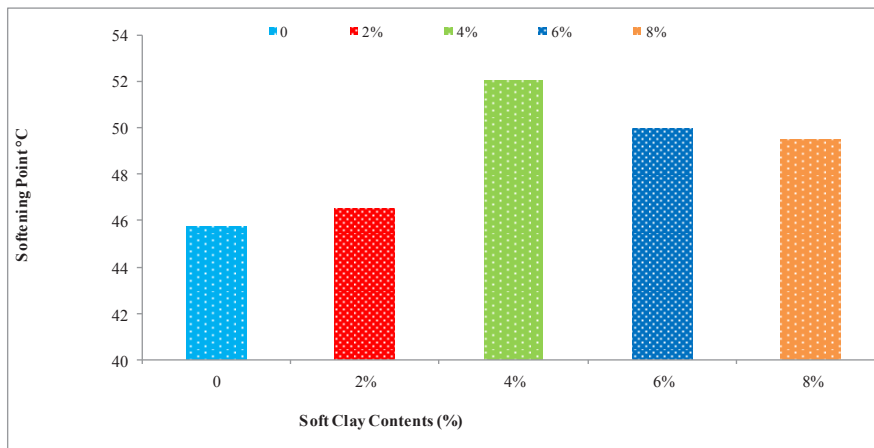


Figure 2. Softening test

### Ductility

The Ductility test, run in accordance with ASTM D113, is shown in Figure 3. The ductility of asphalt binder is observed to progressively reduce as BPS percentages increase that lead to increase in the stiffness of BPS.

### Effect of Batu Pahat Soft Clay (BPSC)

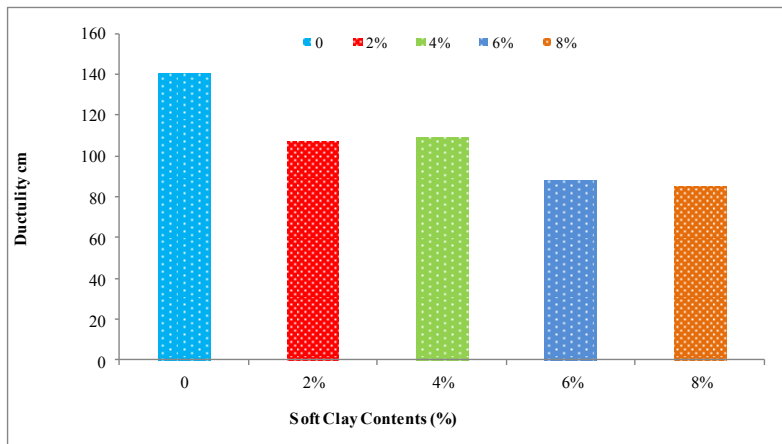


Figure 3. The ductility test

Table 2

*The physical properties of asphalt binder*

Asphalt Binder Contents	Ductility @ 25°C, cm	Softening Point, °C	Penetration@ 25°C, 0.1mm
0	140	45.75	94.93
2%	107	50	93.03
4%	109	52	92.67
6%	88	46.5	92.02
8%	85	49.5	89.54

### DSR

The DSR is used to measure rheological prosperities of asphalt binders at intermediate and high temperatures. Moreover, dynamic shear rheometer evaluates the complex shear modulus ( $G^*$ ) value and phase angle ( $\delta$ ) of the binder at the desired temperature and loading frequency (Cao et al., 2009). Moreover, the higher value of  $G^*$  means higher resistance to rutting of asphalt binder, while lower value of  $\delta$  shows means increased elasticity and makes the asphalt binder more resistant to permanent deformation.

#### Rutting Performance

The  $G^*/\sin \delta$  describes the rutting resistance of an asphalt binder at high temperature. According to Superpave requirement for conducting the rutting of an unaged specimen, the parameter of  $G^*/\sin \delta = 1\text{kPa}$  ( Amirkhanian et al., 2014). It uses 25 mm diameter spindle with a gap of 1000-lm' with high and intermediate temperatures ranging from 46, 52, 58, 64 and 72°C. Furthermore, the test was conducted at fixed frequency sweep and applied 1rad/sec which is equivalent (nearly 0.1592 Hz) in accordance to Superpave specification. Figure 4 shows that the lowest value of  $G^*/\sin \delta$  was gained via use of e unmodified binder and that the 4% BPSC has the highest value of  $G^*/\sin \delta$ . A greater value of  $G^*/\sin \delta$  indicates that the pavement has good rutting resistance.

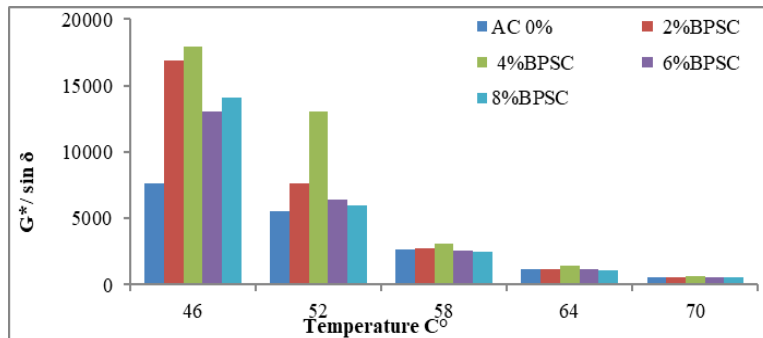


Figure 4. Influence of temperatures on the permanent deformation (rutting) of modified and unmodified binder

### Complex Modulus ( $G^*$ )

$G^*$  could be considered as the overall resistance of the asphalt binder to permanent deformation when frequently clipped. As shown in Figure 5, base binder has a lower complex modulus  $G^*$  than other percentages of BPSC at the tested temperatures, thus exhibiting high elastic properties compared with the original binders.

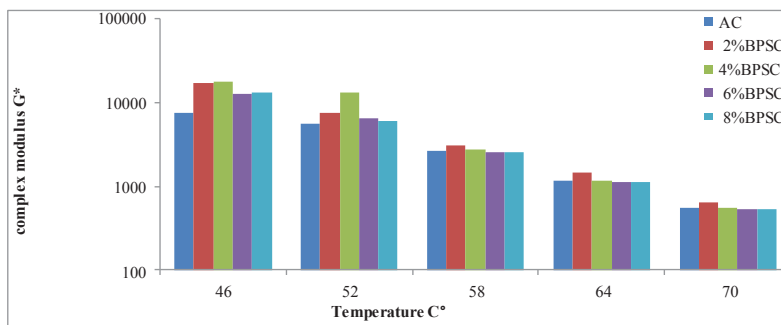


Figure 5. Complex Modulus ( $G^*$ ) against Temperature

### Phase Angle ( $\Delta$ )

Phase angle ( $\delta$ ) is defined as the time lag among stress and strain under the traffic loading and also is extremely dependent on the temperature and frequency of loading. Also, it could be applied as an index of elasticity and viscosity of asphalt binders (Punith et al., 2013). Figure 6 shows the performance and grade type of the asphalt binder, unmodified binder has higher phase angle compared with other percentages which display lower viscous and elastic properties.



### Effect of Batu Pahat Soft Clay (BPSC)

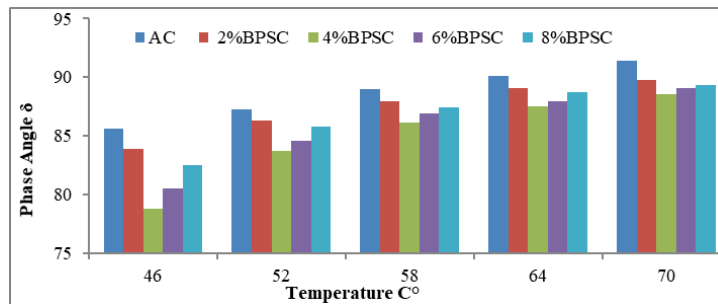


Figure 6. Phase angle ( $\delta$ ) against temperature

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### CONCLUSION

Based on the test outcomes of this study, the following findings and conclusions can be drawn with respect to applications.

According to conventional tests for physical properties, such as softening point, penetration and ductility, it was confirmed that the hardness of asphalt binder was enhanced. The results of the permanent deformation (rutting) parameter show it could be complemented that the usage of BPSC as asphalt binder modifier could enhance the resistance versus rutting at high temperatures. An excellent result was reported for 4% BPSC. Hence, this ratio can be considered as the optimum BPSC-modifier content. Mostly, the asphalt binder influences the ( $G^*$ ) and ( $\delta$ ) values when it has decreased shear stress. Therefore, the elastic properties are also influenced by a shear stress for different concentrations of BPSC particles.

### REFERENCES

- Airey, G. (1999). Dynamic shear rheometry, fluorescent microscopy, physical and chemical evaluation of polymer modified bitumens. *Proceedings of the 7th Conference on Asphalt Pavements for Southern Africa*.
- Chen, M., Binbin, L., Shaopeng, W., & Yang, S. (2014). Physical, chemical and rheological properties of waste edible vegetable oil rejuvenated asphalt binders. *Construction and Building Materials*, 66, 286-298.
- Chetana, J., Amit, P., Archana, M. R., & Amarnath, M. S. (2013). Determining the rheological properties of asphalt binder using dynamic shear rheometer (DSR) for selected pavement stretches. *International Journal of Research in Engineering and Technology*, 11, 192-196.

- Feiping, X., Punith, V.S., Serji, A., & Putman, B. J. (Rheological and chemical characteristics of warm mix asphalt binders at intermediate and low performance temperatures. *Canadian Journal of Civil Engineering*, 40(9), 861-868.
- Feiping, X., Serji, A., Hainian, W., & Peiwen, H. (2014). Rheological property investigations for polymer and polyphosphoric acid modified asphalt binders at high temperatures. *Construction and Building Materials*, 64, 316-323.
- Hafeez, I., Ahmed Kamal, M., Ahadi, M. R., Shahzad, Q., & Bashir, N. (2012). Performance Prediction of Hot Mix Asphalt from Asphalt Binders. *Pakistan Journal of Engineering and Applied Sciences*, 11, 104-113.
- Kennedy, T. W., & Harrigan, E. T. (1990). The SHRP asphalt research program products. *Journal of the Association of Asphalt Paving Technologists*, 59.
- Mahdi, L. M. J., Muniandy, R., Yunus, R., Hasham, S., & Aburkaba, E. E. (2013). Effect of short term aging on organic montmorillonite nanoclay modified asphalt. *Indian Journal of Science and Technology*, 6(10), 5434-5442.
- Muniandy, R., Lamya, M. J., Yunus, R., Hasham, S., & Aburkaba, E. (2013). Effect of organic montmorillonite nanoclay concentration on the physical and rheological properties of asphalt binder. *Australian Journal of Basic and Applied Sciences*, 7(9), 429-437.
- Shafabakhsh, G., & Ani, O. J. (2015). "Experimental investigation of effect of Nano TiO<sub>2</sub>/SiO<sub>2</sub> modified bitumen on the rutting and fatigue performance of asphalt mixtures containing steel slag aggregates. *Construction and Building Materials*, 98, 692-702.
- Shutang, L., Weidong, C., Jianguo, F., & Shujie, S. (2009). Variance analysis and performance evaluation of different crumb rubber modified (CRM) asphalt. *Construction and Building Materials*, 23(7), 2701-2708.
- Socal Da Silva, L., De Camargo Forte, M. M., De Alencastro Vignol, L., & Cardozo, N. S. M. (2004). Study of rheological properties of pure and polymer-modified Brazilian asphalt binders. *Journal of Materials Science*, 39(2), 539-546.
- Xiolin, L., Lian, S., & Yique, T. (2015). Analysis of different indices for high-and low-temperature properties of asphalt binder. *Construction and Building Materials*, 83, 70-76.
- Zaniewski, J. P., & Pumprey, M. E. (2004). Evaluation of performance graded asphalt binder equipment and testing protocol. *Asphalt Technology Program*, 107.



## Evaluating Bus Running Time Variability in High-Frequency Operation Using Automatic Data Collection Systems

Seyed Mohammad Hossein Moosavi<sup>1\*</sup>, Amiruddin Ismail<sup>1</sup> and Ardalan Balali<sup>2</sup>

<sup>1</sup>*Sustainable Urban Transport Research Centre (SUTRA) / Department of Civil and Structural Engineering, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia*

<sup>2</sup>*Department of Civil and Structural Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*

### ABSTRACT

Bus services usually tend to be irregular and their level of irregularity depends on various factors, such as crowding level, terminal departure behaviour, passengers' behaviour, operator behaviour, traffic and weather condition and etc. High-frequency bus routes have shorter headways (usually headway less than 10 to 15 minutes) and higher passenger demand compared with normal routes. Therefore, level of irregularity can be even higher in bus service at high-frequency operation. Running time variability comes from both systematic changes in ridership and traffic levels at different times of the day, which can be accounted for in service planning, and the inherent stochasticity of homogeneous periods, which must be dealt with through real-time operations control. This study evaluated impact of ridership changes and traffic condition through time of the day on running time variability, using Automatic Vehicle Location system (AVL) and Automatic Fare Collection system (AFC). All data extracted and collected from RapidKL Company for route U32, which is a high-frequency route in downtown of Kuala Lumpur. Descriptive analysis on data showed a high variation in running times, especially in morning peak hours. A liner regression model also proved that crowding level (extracted from AFC data), number of stops and congestion zones have relatively high impact on running time variation.

*Keywords:* AFC, AVL, bus service, high-frequency, running time, variability

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#### *E-mail addresses:*

[mhmoosavi@siswa.ukm.edu.my](mailto:mhmoosavi@siswa.ukm.edu.my)

(Seyed Mohammad Hossein Moosavi),

[abim@eng.ukm.my](mailto:abim@eng.ukm.my) (Amiruddin Ismail),

[ardalan.balali@gmail.com](mailto:ardalan.balali@gmail.com) (Ardalan Balali)

\*Corresponding Author

### INTRODUCTION

Malaysia has high private vehicle ownership and only urban travel is by public transport (Kamba et al., 2007). Thus, providing a productive and sufficient service that is reliable for the public is an important challenge for transport authorities and agencies (Lee & Vuchic, 2005). One of the most significant

features of transit service quality is reliability. In addition, it is a major concern for transit agencies and passengers (Daganzo & Pilachowski, 2011). Running time variability is one the indicators of bus service reliability and the essential resources to a high-frequency route reliably (Diab & El-Geneidy, 2013). Automated data collection systems, such as AVL, which provide very large observation samples at low marginal costs, enable the development and use of new data-driven analysis tools that can potentially enhance performance monitoring abilities, and ultimately lead to improved resource allocation and effectiveness.

Running time is the amount of time that a bus spends travelling from one point to another on a chosen route in the service of travellers. One important factor that can worsen transit service reliability is increase in the variation in run time for a given mean run time (El-Geneidy et al., 2011). Higher levels of variation in service for travellers are directly related to increases in waiting time at bus stops, which intensify travellers' stress levels and diminish their perceived ease and comfort, lessening the appeal of bus service (Bates et al., 2001; Berrebi et al., 2015; Perk et al., 2008). Previous studies have shown that the value commuters place on travel time and travel time variation are nonlinear (Pinjari & Bhat, 2006). The cost of travel time variation might actually be higher than the cost of standard travel time (Chen et al., 2003; Perk et al., 2008), significantly impacting decision making and day-to-day time scheduling procedures (Nam et al., 2005; Noland & Polak, 2002). Studies have shown that commuters are more interested in reliable service with fewer deviations than in services with shorter headway (Balcombe et al., 2004; Daskalakis & Stathopoulos, 2008). Researchers have found that improving reliability of service in terms of running time and running time variation is strongly related to increasing passenger satisfaction levels and responding to demand (Boyle, 2006; Hollander, 2006).

Passenger behaviour variables such as boarding and alighting percentages influence run-time variation (Lin & Bertini, 2004; Tirachini et al., 2013). Moreover, studies have identified various factors that can impact bus running time, including the distance involved, geometric conditions (such as the number of signalised intersections), tardiness at the beginning, time of day, number of real stops made, environmental factors (such as rain and snow), and traffic conditions (El-Geneidy et al., 2011; Mahudin et al., 2012). In this study, descriptive analysis on running times was carried out to determine current situation of route and level of variability. A linear model was developed to evaluate and understand the factors which significantly impact running time variation.

## **MATERIALS AND METHODS**

RapidKL is owned by Prasarana Berhad, a government-owned company. It was established in 2004 as a provide solution to public transport woes affecting Kuala Lumpur and its surrounding cities. For reporting and analysis purposes, RapidKL uses automatically collected data to estimate the route ridership per hour. This data can be used to predict total route ridership to be distributed at each key stop (schedule time points and stops with high passenger demand). The primary data source for evaluating this study is the raw automatically collected data from Automatic Vehicle Location (AVL) and Automatic Fare Collection (AFC) systems. Data is stored at the RapidKL database, when the bus refuels, which is useful to identify running times

and terminal departure behaviour (in response to schedule deviation). The AFC system creates a record for each fare transaction using smart media or magnetic stripe fare media; cash paying and non-paying passengers (e.g. children) are not recorded. This study uses Route U32 as a case in point. It is a high-frequency route due to high passenger demand in downtown Kuala Lumpur (Figure 1). This route has 59 bus stops (almost 30 stops in each direction). Table 1 shows route U32 specifications and table 2 shows list of key stops in each direction. The study duration was between October and November 2015 (including weekends and holidays). As described in Table 2, this route has four key stops in each direction. Therefore, each direction consists of three segments (segment is the distance between two key stops). Accordingly, segment 1 is between HUB TMN DANGANG and BLTN KG PANDAN, segment 2 is between PANDAN and Majestic and segment 3 is between Majestic and HSBC/ 7 ELEVEN.

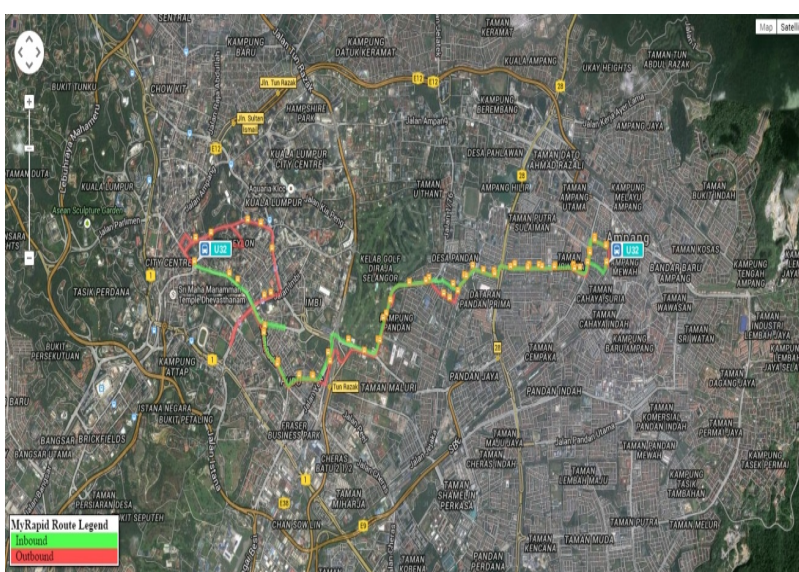


Figure 1. Route U32 layout and location

Table 1  
Route U32 specifications

Route	Origin	Destination	Distance	No. of Buses	No. of bus stops
U32	TAMAN DANGANG	BUKIT BINTANG	20.565 Km	9	59

Table 2  
Route U32 key stops (Outbound)

Stop ID	Stop Name	Order	Zone	Distance
1000970	HUB TMN DAGANG	1	3	0
1000360	BLTN KG PANDAN	21	3	5347
1001846	MAJESTIC/LRT PUDU	24	3	7561
1000958	HSBC/7 ELEVEN	28	2	9375

## RESULTS AND DISCUSSION

Running time variability is one of the main causes of unreliability in bus routes (Moosavi et al., 2015). A descriptive analysis was used in this study. When examining variability by segment, the time range of data for analysis must be consistent across segments (figure 2). Similarly, when examining variability by time of day, data must be spatially consistent across times of day. Based on the scope of this study, only one direction of route U32 is considered for further analysis. Figure 3 illustrates running time variability by time of day. All running times are demonstrated in seconds.

Running time variability differs based on time. As Figure 3 shows, this variability reaches its maximum during morning and afternoon peak hours. The analysis will measure variability within homogeneous periods, aggregating observations from different days of the week and weeks of the year only if they are considered to represent the same operating environment.

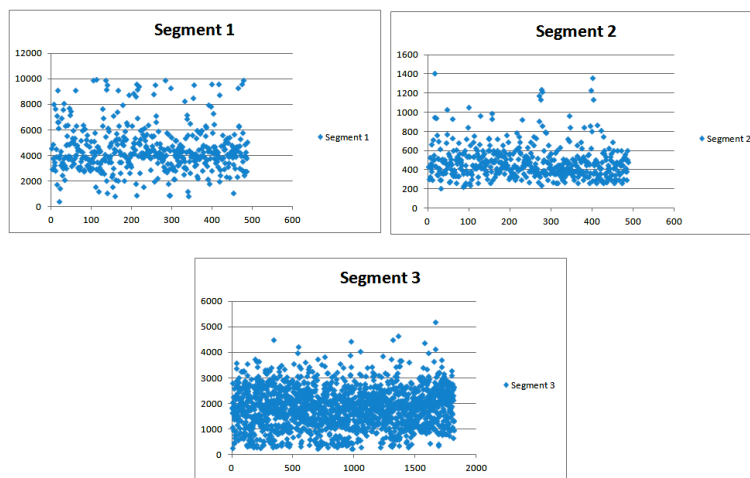
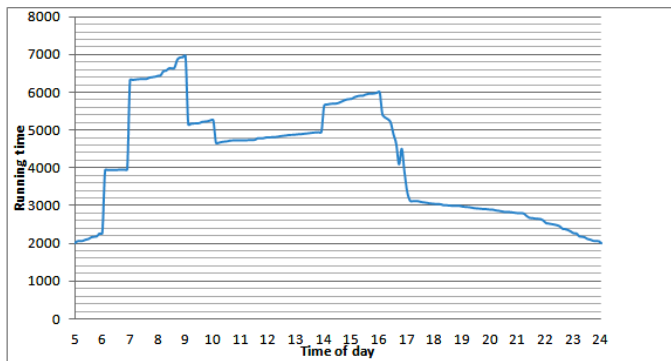


Figure 2. Running time variation for each segment separately

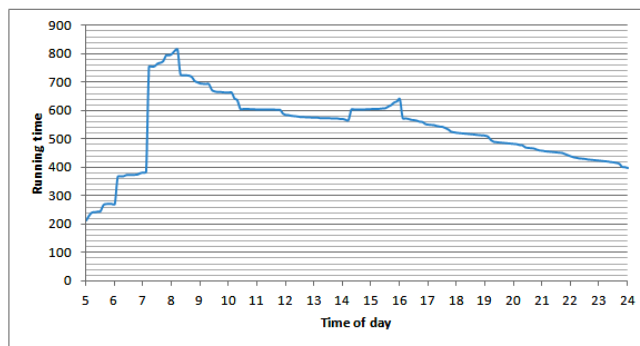
Table 3  
Route U32 running time records

	Morning peak				Afternoon peak			
	Min	Max	Mean	Stdev	Min	Max	Mean	Stdev
Segment 1	0:08:58	1:31:50	0:57:17	0:029:47	0:07:24	1:12:43	0:46:32	0:27:33
Segment 2	0:03:31	0:23:20	0:07:21	0:3:32	0:03:45	0:23:32	0:07:32	0:3:11
Segment 3	0:04:04	1:09:07	0:21:06	0:5:43	0:04:53	1:09:08	0:39:12	0:4:56

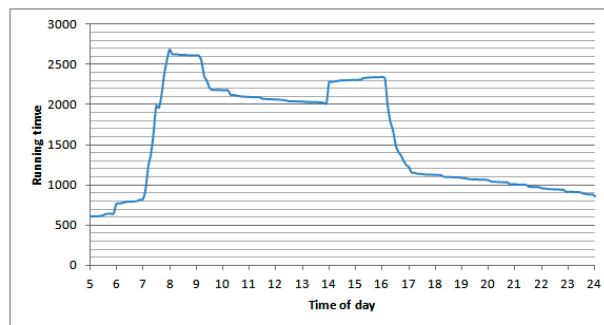
### Running Time Variability in High-Frequency



(a)



(b)



(c)

Figure 3. Running time variability (sec) by time of day: (a) Segment 1; (b) Segment 2; and (c) Segment 3

### Linear Model of Median Running Time

A linear model is specified with median running time as a function of distance, number of stops, average crowding level, and dummy variables for segments entering the congestion zone in down town of Kuala Lumpur. In this study, areas around Kuala Lumpur, especially streets and area around BUKIT BINTANG, are considered as congestion zone. Automatic Fare Collection



(AFC) data was used to obtain the average crowding level at key stops. Table 4 shows the regression results for this model. The signs of all the parameter estimates agree with general experience: longer running times are related to segments going through the congestion zone, greater run distances, greater number of stops, and greater ridership. The statistical significance of the estimates is very high, and the overall fit, with  $R^2 \approx 0.81$ , is moderately high. The average number of boarding per trip is a better characterisation of how busy the operating environment is in comparison with morning peak and afternoon peak dummy variables (not included in this model) because it captures pattern-specific characteristics.

Table 4  
*Linear regression on running time*

Coefficient	Estimate	Std. Error	T value	Pr (>  t )
Distance	1.52E-3	1.93E-4	8.01	1.64E-9
No. of stops	3.53	0.91	3.67	7.04E-3
Average crowding level	0.18	0.03	8.64	8.68E-9
Congestion zone	3.68	0.99	3.88	1.43E-2

Residual standard error: 7.409 on 236 degrees of freedom

$R^2$ : 0.81

F-statistic: 126.8 on 6 and 246 DF, p-value: < 2.3E-15

## CONCLUSION

A descriptive analysis carried out to understand current situation of route U32 in term of running time variability. The results showed a very high variation in running times in this route. In order to gain better insights on running time variation, homogeneous sets of running time were prepared (morning peak, afternoon peak and off-peak hours). Results showed that morning peak hours (6am to 9am) has the highest variation with standard deviation of almost 30 minutes. A linear model was developed with the goal of finding general patterns of route characteristics leading to higher or lower typical running times and running time variability. Segments entering central Kuala Lumpur tend to have higher and more variable running times. Distance, number of stops, and ridership all contribute to higher and more variable running times as well. Obviously, there are other factors not explored here such as driving running time variability. Variables such as traffic, weather conditions, corridor characteristics, road work, ridership patterns (at a disaggregate level), operator behaviour at the terminal and mid-route, and even fleet size itself could have significant impact on variability.

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## REFERENCES

- Balcombe, R., Mackett, R., Paulley, N., Preston, J., Shires, J., Titheridge, H., Wardman, M., & White, P. (2004). The demand for public transport: a practical guide. *TRL Report*.
- Bates, J., Polak, J., Jones, P., & Cook, A. (2001). The valuation of reliability for personal travel. *Transportation Research Part E: Logistic and Transportation Review*, 37, 191–229.
- Berrebi, S. J., Watkins, K. E., & Laval, J. A. (2015). A real-time bus dispatching policy to minimize passenger wait on a high frequency route. *Transp. Res. Part B Methodol.* 81, pp. 377–389.
- Boyle, D. K. (2006). Fixed-route transit ridership forecasting and service planning methods. *Transportation Research Board*.
- Chen, C., Skabardonis, A., & Varaiya, P. (2003). Travel-time reliability as a measure of service. *Transp. Res. Rec. J. Transp. Res. Board*, 74–79.
- Daganzo, C. F., & Pilachowski, J. (2011). Reducing bunching with bus-to-bus cooperation. *Transp Res. Part B Methodol.* 45, 267–277
- Daskalakis, N. G., & Stathopoulos, A. (2008). Users' perceptive evaluation of bus arrival time deviations in stochastic networks. *Jornal Public Transportation*, 11, 2.
- Diab, E. I., & El-Geneidy, A. M. (2013). Variation in bus transit service: Understanding the impacts of various improvement strategies on transit service reliability. *Public Transp.* 4, 209–231.
- El-Geneidy, A. M., Horning, J., & Krizek, K. J. (2011). Analyzing transit service reliability using detailed data from automatic vehicular locator systems. *Journal Advanced Transportation*, 45, 66–79.
- Hensher, D. A., Stopher, P., & Bullock, P. (2003). Service quality—developing a service quality index in the provision of commercial bus contracts. *Transp. Res. Part A Policy Pract.* 37, 499–517.
- Hollander, Y. (2006). Direct versus indirect models for the effects of unreliability. *Transp. Res. Part A Policy Pract.* 40, pp. 699–711.
- Kamba, A. N., Rahmat, R., & Ismail, A. (2007). Why do people use their cars: A case study in Malaysia. *J. Soc. Sci.* 3, 117–122.
- Lee, Y. -J., & Vuchic, V. R. (2005). Transit network design with variable demand. *J. Transp. Eng.* 131, 1–10.
- Lin, W., & Bertini, R.L. (2004). Modeling schedule recovery processes in transit operations for bus arrival time prediction. *J. Adv. Transp.* 38, 347–365.
- Mahudin, N. D. M., Cox, T., & Griffiths, A. (2012). Measuring rail passenger crowding: Scale development and psychometric properties. *Transp. Res. part F traffic Psychol. Behav.* 15, 38–51.
- Moosavi, S. M. H., Ismail, A., & Golzadfar, A. (2015). Development of simulation model to improve bus service reliability at high-frequency operation. *J. Teknol.*, 74.
- Nam, D., Park, D., & Khamkongkhun, A. (2005). Estimation of value of travel time reliability. *J. Adv. Transp.* 39, 39–61.
- Noland, R. B., & Polak, J. W. (2002). Travel time variability: A review of theoretical and empirical issues. *Transp. Rev.* 22, 39–54.

- Perk, V., Flynn, J., & Volinski, J. M. (2008). Transit ridership, reliability and retention.
- Pinjari, A., & Bhat, C. (2006). Nonlinearity of response to level-of-service variables in travel mode choice models. *Transp. Res. Rec. J. Transp. Res. Board*, 67–74.
- Tirachini, A., Hensher, D. A., & Rose, J.M.. (2013). Crowding in public transport systems: Effects on users, operation and implications for the estimation of demand. *Transp. Res. Part A Policy Pract.* 53, 36–52.
- Yin, Y., Lam, W. H. K., & Miller, M. A. (2004). A simulation-based reliability assessment approach for congested transit network. *J. Adv. Transp.* 38, 27–44.

## The Influence of *Sulphate Reduction Bacteria* on the Durability of Concrete in Seawater Condition

T. Teddy<sup>1</sup>, JM. Irwan<sup>1\*</sup> and N. Othman<sup>2</sup>

<sup>1</sup>*Jamilus Research Centre for Sustainable Construction (JRC), Faculty of Civil and Environmental Engineering, University Tun Hussein Onn, 86400 Parit Raja, Johor, Malaysia.*

<sup>2</sup>*Micropollutant Research Centre (MPRC), Faculty of Civil and Environmental Engineering, University Tun Hussein Onn, 86400 Parit Raja, Johor, Malaysia*

### ABSTRACT

Strength and durability are important characteristics of concrete and desired engineering properties. Exposure to aggressive environment threatens durability of concrete. Previous studies on bio-concrete using several types of bacteria, including sulphate reduction bacteria (SRB), had to increase durability of concrete have shown promising results. This study used mixtures designed according to concrete requirement for sea water condition with SRB composition of 3%, 5% and 7% respectively. The curing time were 28, 56 and 90 days respectively. The mechanical properties, namely compressive strength and water permeability, were tested using cube samples. The results showed compressive strength had higher increase than the control at 53.9 Mpa. The SRB with 3% composition had maximum water permeability. Thus, adding SRB in concrete specimens improves compressive strength and water permeability. This is particularly suitable for applications using chloride ion penetration (sea water condition) where corrosion tends to affect durability of concrete constructions.

*Keywords:* Compressive strength, durability, permeability, sea water, sulphate reduction bacteria

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*E-mail addresses:*

hf140033@siswa.uthm.edu.my (T. Teddy),

irwan@uthm.edu.my (JM. Irwan),

norzila@uthm.edu.my (N. Othman)

\*Corresponding Author

### INTRODUCTION

An archipelago is an area with a long coastline surrounded by sea. This creates challenges to civil engineers to choose appropriate and robust construction material to withstand sea water corrosion. The materials of choice for concrete should be able to resist extreme weather conditions or exposure to environment-related chemicals such as sulphates, chlorides and salt; for example, sulphate is present in both soil and

groundwater originating from fossil fuel and biomass combustion. This increases acidity of the area, threatening the concrete structure around the area. Interactions of concrete with other external influences also decrease its durability. Other factors such as freezing and thawing, abrasion, corrosion of steel, chemicals may deteriorate quality of concrete (Bajza et al., 2001).

In general, chemical corrosion refers to acid attack, alkali attack, carbonation, chloride attack, leaching or sulphate attack (ACI 201). Thus, concrete durability influences the selection of appropriate material. Crack formation is a typical example of concrete durability. Large cracks hamper structural integrity and smaller sub-millimetre sized cracks may result in durability problems as connected cracks increase matrix permeability (Jonkers, 2012). Concrete in general can lead to fluctuations in temperature and moisture without deterioration, and under adverse exposure conditions, most concrete will fail by following causes: alkali-aggregate reaction, sulphate attack, freeze-thaw cycles and reinforcement corrosion. These three factors may occur individually or simultaneously, leading to expansion and development of cracks in concrete. Alkali-silica reaction, sulphate attack (Aguiar et al., 2008) and freeze-thaw cycle (Muynck et al., 2008) are common culprits. Deterioration can also occur due to corrosion of reinforcement. Corrosion risk is higher for structures exposed to aggressive environment (seawater) or de-icing salts. In short, corrosion has emerged as the most important factor affecting reinforced concrete structures.

Basheer (1996) had pointed out that the deterioration of concrete due to sulphates, chlorides, salts can damage its structure (Choi et al., 2015). Thus, bio-concrete has been introduced as an alternative material to overcome these problems. The application of microorganisms in concrete decreases pores in concrete as well as seals cracks (Aguiar et al., 2008). The bacteria also reduces mass variation, volume variation (higher age) and water absorption (Basheer, 1996). Earlier studies have shown that application of bioconcrete results in higher durability of concrete structures (Jonkers, 2012; Muynck et al., 2008). Therefore, an attempt to explore bioconcrete at aggressive environment is timely. In this research, sulphate reducing bacteria, previously isolated with specific behaviour to tolerate with alkaline and anaerobic condition, are tested (Alshalif et al., 2015). This research, hence, was aimed at examining the influence of Sulphate Reduction Bacteria (SRB) on concrete in aggressive condition (high salt/sodium) by testing on its compressive strength and water permeability.

## **MATERIALS AND METHODS**

### **SRB Preparation**

The SRB that was previously isolated (Alshalif et al., 2015) was acclimatised in 3% NaCl condition. Prior to acclimatisation, the growth curve of the SRB was monitored to determine the optimum enrichment condition. This process was to ensure survival of the SRB added in aggressive condition concrete. The amount of SRB prepared was based on the amount of water calculated in casting process. The SRB would be as partial replacement of water by 3%, 5% and 7%. respectively.

## Material

The concrete mix design was calculated using DOE and is shown in Table 1. The samples were prepared based on G35 using DOE method. The fabrication of concrete was done according to BS 1881-125:2013 (British Standard, 2013). In simulating aggressive environment, the samples were removed after 24 hours and kept air dry until tests were conducted.

## Test Procedure

Two tests were conducted, namely compressive strength and water penetration. The compressive strength and water penetration test were performed according to BS EN 12390-3:2009 (British Standard, 2009) and BS EN 12390-8:2009 (British Standard, 2009) respectively. In this study, cubes 150 mm × 150 mm × 150 mm, were used. The tests were conducted using three samples that were immersed for 28 days in a solution containing 3% NaCl.

Table 1  
*Amount of materials prepared for fabrication*

Material	Cement (kg)	Sand (kg)	Aggregate (kg)	Water (kg)	Sulphate reduction bacteria (kg)
Control	65.10	149.0	91.3	29.3	-
3% *SRB	65.10	149.0	91.3	27.8	1.5
5% *SRB	65.10	149.0	91.3	27.3	2.0
7% *SRB	65.10	149.0	91.3	26.37	2.93

## RESULTS AND DISCUSSION

### The SRB Bacteria

The volume of SRB was stirred and kept aside for 14 days before being used in the casting process. In this study, only SRB strain that was acclimatised in 3% of sodium chloride was used to ensure good survival in an aggressive environment.

### Compressive Strength

The compressive strength results are shown in Table 2 and Figure 1. In general, compressive strength of bio-concrete is higher compared with control. The highest compressive strength after 28 days of curing were for samples added with 7% of SRB. After 90 days, maximum compressive strength of 24.4% was achieved compared with control s for specimens with 5% of SRB addition. The results revealed that adding significant amount of SRB improved compressive strength. The findings are consistent with those of earlier studies on bio-concrete on the enhancement of concrete properties (Jonkers, 2012), (Muynck et al, 2008). The addition of specific bacteria group with specific enzyme functions to precipitate calcium carbonate at the pore of the concrete (Muynck et al., 2008). The process of plugging in the pores at the binder matrix improves compressive strength.

Table 2  
Results related to compressive strength

Days	0% SRB		3% SRB		5% SRB		7% SRB	
	Samples (MPa)	Average (Mpa)	Samples (Mpa)	Average (Mpa)	Samples (Mpa)	Average (Mpa)	Samples (Mpa)	Average (Mpa)
28	44.7		47.3		49.0		48.5	
	40.0	42.2	46.3	46.4	45.2	46.6	46.8	47.2
	42.0		45.7		45.6		46.3	
	42.2		50.7		51.2		48.0	
	40.8	41.0	49.2	49.5	49.0	49.9	47.7	47.6
56	40.1		48.5		49.4		47.0	
	44.2		44.8		56.4		48.5	
	44.9	43.3	46.4	47.0	55.1	53.9	48	48.5
90	40.8		49.7		50.1		49	

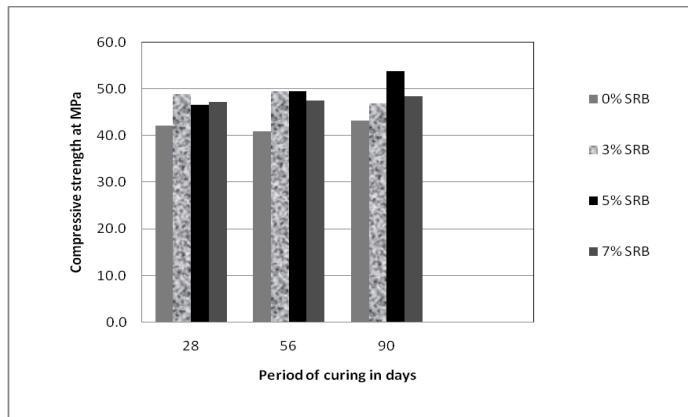


Figure 1. Influence of different concentrations of bioconcrete containing SRB

### Permeability Concrete Test

The test results showed reduction in water permeability when bioconcrete is used by adding SRB at 3%, 5% and 7% concentration respectively compared with control as seen in Figure 2. Maximum reduction of water permeability after 28 days was seen for samples with 7% SRB concentration. After 90 days, the results for maximum reduction of water permeability were for specimens with 5% SRB. The presence of bacteria in concrete with capability to deposit calcium salt at concrete pores allow less water to penetrate it. Therefore, it increases the durability of concrete as it would prevent water seeping and causing carbonation of steel to affect the structure of the entire building (BS, 2014). In this study, reduction of water seeping also minimise penetration of sodium chloride that is already dissolved in curing water. This reduces the possibility of chloride attack leading to an aggressive environment. Nilsson et al. (2014) had pointed out that chloride corrodes any steel material in concrete structure, thus reducing its durability (Nosouhian et al., 2015).

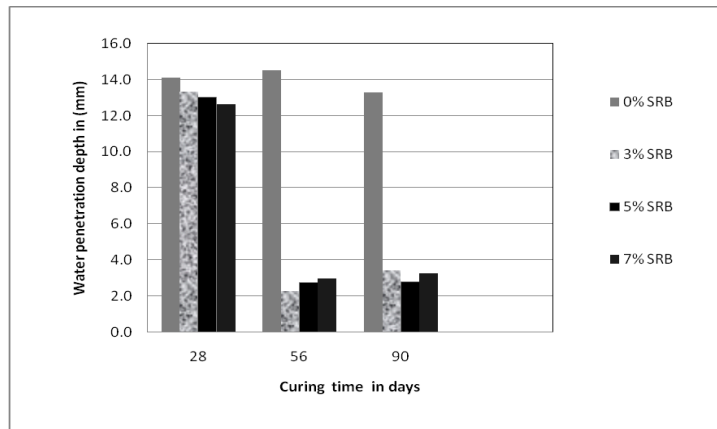


Figure 2. Permeability concrete of different concentrations of bioconcrete containing SRB

## CONCLUSION

The concrete added with 3%, 5% and 7% SRB respectively showed positive results in increasing compressive strengths and decreasing water penetration. The results proved that bacteria improve the durability of concrete also in addition to minimising chloride ingress when exposed to an aggressive environment (sea water condition).

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## REFERENCES

- ACI Committee 201. Quid to durable concrete, *American Concrete Institute, Report of ACI Committee*, ACI 201.2R-7.
- Aguiar, J. B., Camões, A., & Moreira, P. M. (2008). Performance of concrete in aggressive environment. *International Journal of Concrete Structures and Materials*, 2(1), 21-25.
- Alshalif, A. F., Irwan, J. M., Othman, N., & Anneza, L. H. (2016). Isolation of sulphate reduction bacteria (srb) to improve compress strength and water penetration of bio-concrete. *International Conference on Civil and Environmental Engineering for Sustainability*, 47. doi:10.1051/mateconf/20164701016
- Basheer, P. A. M., Chidiact, S. E., & Long, A. E. (1996). Predictive models for deterioration of concrete structures. *Construction and Building Materials*, 10(1), 27-37.
- British Standard Institution. (2009). Part 3: *Compressive strength of test specimens*, London. BS EN 12390-3.
- British Standard Institution. (2009). *Testing hardened concrete: Part 8: Depth of penetration of water under pressure*. London BS EN 12390-8
- British Standard Institution. (2013). *Testing Concrete: Part 125: Methods for mixing and sampling fresh concrete in the laboratory*. London, BS 1881-125.

- British Standard Institution. (2014). *Products and systems for the protection and repair of concrete structures –test methods-measurement of chloride ion ingress*, European committee for standardization, BS EN 13396
- Jonkers, H. M. (2012). Bacteria-based self-healing concrete, *Heron Journal*, 56(1/2).
- Muynck, W. D., Cox, K., Belie, N. D., & Verstraete, W. (2008), Bacterial carbonate precipitation as an alternative surface treatment for concrete. *Construction and Building Materials*, 22, 875–885.
- Nanukuttan, S. V., Basheer, P. A. M., McCarter, W. J., Tang, L., Holmes, N., Chrisp, T. M., Starrs, G., & Magee, B. (2015). The performance of concrete exposed to marine environments: Predictive modelling and use of laboratory/on site test methods. *Construction and Building Materials*, 93, 831-840.
- Nilsson, L-O., Poulsen, E., Sandberg, P., Sorensen, H. E., & Klinghoffer, O. (1996). HETEK, chloride penetration into concrete, state-of-the-art-, transport processes, corrosion initiation, test methods and prediction models. *Report No. 53*, p. 58.
- Nosouhian, F., Mostofinejad, D., & Hasheminejad, H. (2016). Concrete durability improvement in a sulphate environment using bacteria, *Journal of Materials in Civil Engineering*, 28(1).
- Zivica, V., & Bajza, A. (2001). Acidic attack of cement based materials - A review: Part 1. Principle of acidic attack. *Construction and Building Materials*, 15(8), 331-340.





## **Effect of Eco-Innovation Practices on Sustainable Business Performance**

**Salmah Omar<sup>1\*</sup>, Norfaridatul Akmaliah Othman<sup>2</sup> and Juhaini Jabar<sup>2</sup>**

*<sup>1</sup>School of Technology Management and Logistics, Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia*

*<sup>2</sup>Faculty of Technology Management and Technopreneurship, Universiti Teknikal Malaysia Melaka, Durian Tunggal, 76100 Melaka, Malaysia*

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### **ABSTRACT**

The evolution of ‘sustainability’ reflects a crucial change in global thinking, which is forcing firms to re-evaluate their approach in measuring organisational performance. The objectives of this study are to examine the extent of eco-innovation practices and their effects on sustainable business performance of chemical companies in Malaysia. The results show a moderate to a considerable extent of eco-innovation practices among the companies.

*Keywords:* Chemical industry, eco-innovation, organisational performance, performance, sustainable performance

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### **INTRODUCTION**

In the past, environmental issues have been considered burden to business, associated with costs and restrictions which impede companies’ competitiveness. However, in recent times, the environmental agenda has been found a place among richer economies to see the emergence of proactive environmental strategies. The importance of green competitiveness has been recognised and it goes beyond business.

Unfortunately, the problems related to environmental pollution are yet to be solved. Industrial development and rapid urbanisation are responsible for major environmental problems; among them, disposal of hazardous and communal waste, pollution of air and water. The chemical industry, without proper environmental management, has poses a challenge on sustainability. Thus, many chemical companies have been at the forefront

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*E-mail addresses:*

salmah@uum.edu.my (Salmah Omar),  
norfaridatul@utem.edu.my (Norfaridatul Akmaliah Othman),  
juhaini@utem.edu.my (Juhaini Jabar)

\*Corresponding Author

of adopting innovative technologies and state-of-the-art environmental management practices. As a result, adoption of eco-innovation in this sector is very significant.

At the macro level, sustainable development was popularised in a report published by the World Commission on Environment and Development in 1987. Also known as the Brundtland report, it defines sustainable development as “development which meets the needs of the present without compromising the ability of future generations to meet their own needs” (Murphy & Drexhage, 2012). Sustainable development embodies three principles: environmental integrity, social equity, and economic prosperity. At the organisational level, a sustainable business has been defined as one that ‘meets the needs of its stakeholders without compromising its ability also to meet their needs in the future (Hockets, 2001). Introducing the concept of sustainability into organisational thinking has implications for business strategy, which, in turn, affect how firms measure performance. At the moment, an organisation’s sustainability indicators do not indicate any clear or consistent approach – the items suggested are not well justified from a conceptual perspective. This study adopts the Sustainable Balance Scorecard (SBSC) introduced by (Hubbard, 2009) for the purpose of measuring sustainable business performance, which is beyond triple bottom line (TBL).

The reasons behind the proposed relationship between eco-innovation practices and sustainable performance are based on several factors. First, an eco-innovation practice is about the efficient use of raw materials, resulting in lower costs for raw materials and disposal of waste (Hart & Ahuja, 1996). (Porter, Linde, & Porter, 1995) argue that firms that consider resource productivity, process change, and product innovation as priorities can achieve competitive advantage by having lower costs or offering differentiated products (Hart & Ahuja, 1996; Porter et al., 1995). Second, it may lead them to convert waste into usable products and continue to find new ways of converting that provide additional revenues. Third, it offers the potential to cut emissions well below required levels, reducing the firm’s compliance and liability costs (Hart, 1997). Fourth, it helps firms to improve their environmentally based leadership reputation relative to competitors. Since reputation is in itself a source of market advantage, this should result in enhanced cash flow and enhanced sustainable performance. The objectives of this study are:

- To show the extent of eco-innovation practices among chemical companies in Malaysia.
- To examine the effect of eco-innovation practices on sustainable business performance.

### **Impact of Eco-Innovation Practices on Sustainable Performance**

Eco-innovation, which is defined as “the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources used (including energy use) compared to relevant alternatives” (Kemp & Pearson, 2007). Given that this study focuses on the chemical industry, the eco-innovations practices of the companies have been integrated with the responsible care code of practice to make it more convenient and reliable. Eco-innovation initially promoted safer chemicals and protection of the environment, but at the same time introduced the principles of energy efficiency, atom economy in chemical processes

with reduction of waste. Some governments introduced lower taxes for industries which applied voluntary alternative “greener” methodologies (Moiseev, 2011; Centi & Perathoner, 2009; Iles, 2008). The issues of energy generation, storage, and transport are all intrinsically linked to the materials that are used, and these materials need to be designed and manufactured using the principles of Green Chemistry (Moiseev, 2011). Considering the effect of eco-innovation practices on sustainability in chemical industry, the hypothesis of this study is as follows:

HA: There is a positive and significant relationship between eco-innovation practices (EIP) and sustainable performance (PER).

## **MATERIALS AND METHODS**

A cross-sectional survey method was employed. Field study refers to non-experimental scientific inquiries designed to discover the relationship among variables in real social structures, such as communities, institutions, and organisations (Kerlinger, 1992).

The population of this study consisted of chemical companies in Malaysia. The sample was drawn from the directory of Federation of Malaysian Manufacturers (FMM). A total of 500 questionnaires were distributed to various chemical companies, and 76 was returned which translated into a response rate 15.2%.

The PLS-SEM was used for data analysis. PLS is a soft modelling approach to SEM with no assumptions about data distribution. Thus, PLS-SEM is a more robust approach and can be used to analyse data with non-normality distribution. Using PLS-SEM, data normality is not important because PLS uses calibration mechanisms, which transform any non-normal data into data that adheres to the central limit theorem (Chin & Dibbern, 2010).

### **Measurement for Endogenous Variable**

Sustainable performance acts as an endogenous variable in this research. Sustainability concepts have dramatically widened the scope of measurement options and leading organisations are grappling with sustainability reporting, but there is no sign of consensus on a common reporting standard and the competing frameworks are impossibly complex. This study adapts stakeholder-based, Sustainable Balanced Scorecard (SBSC) framework by (Hubbard, 2009).

### **Measurement for Exogenous Variable**

The definition of eco-innovation was stretched to include 12 principles of green chemistry (Anastas & Warner, 1998). The 12 principles were then translated into practices which incorporated responsible care code of practices. Responsible Care is an initiative of the chemical industry and adopted by chemical companies to improve continuously safety, health and environmental performance of their operations and products in a manner responsible to public concerns. Chemical Industries Council of Malaysia (CICM) is the Malaysian steward for the Responsible Care initiative of the global chemical industry. At the heart of the Responsible Care, the initiative is the Six Codes of Management Practices, which focus on specific areas of chemical manufacturing, transportation, research, and handling. This study, however, simplified the practices into four categories of eco-innovation practices.

## RESULTS AND DISCUSSION

After the preliminary scrutiny, all 73 usable cases were loaded into SPSS version 20 software for the following reasons: 1) generating descriptive statistical reports; and 2) generating exploratory analyses on every variable to check for missing or invalid data. For PLS-SEM analysis purposes, Smart PLS 3.0 was used to analyse the measurement and structural models. Using SmartPLS, data was transformed into an Excel CVS file to generate raw input for the application.

### Descriptive Statistic of Variables

The mean and standard deviation of each construct are presented in Table 1. The mean ( $\bar{x}$ ) value range from 3.489 to 3.890 out of a possible value 5.0 on the scale, reflect a moderate to a considerable extent of implementation of eco-innovation practices. This result answer the first research objective: to reveal the extent of eco-innovation practices implementation. Furthermore, the mean ( $\bar{x}$ ) value range from 3.589 to 4.03 out of a possible value 5.0 indicates the ability of the respondent firms in showing better sustainable performance. More specifically, the highest score is for social performance, followed by environmental performance, customer, and internal process, financial, and learning and growing.

Table 1  
*Descriptive statistic of variables*

	Mean	
	( $\bar{x}$ )	SD
<b>Eco-innovation practices</b>		
Pollution prevention	3.667	.522
Product and process stewardship	3.489	.545
Distribution	3.890	.473
Employee and public health and safety	3.684	.429
<b>Sustainable Performance</b>		
Financial	3.726	.445
Internal process	3.734	.415
Customer	3.750	.455
Learning and growing	3.589	.387
Environmental	3.982	.431
Social	4.030	.521

### Path Coefficients ( $\beta$ ) in Structural Model

Within the structural model, each path connecting two latent variables represent a hypothesis. The analysis conducted on the structural model shows the conformation of each hypothesis as well as the strength of the relationship between dependent and independent variables. Table

2 lists the path coefficients, observed statistics, and significance level for the hypothesized path. Using the results from the path assessment, the acceptance or rejection of the proposed hypotheses is determined. The result is found to support the hypothesis.

Table 2  
*Path coefficients, observed t-statistics, significant level*

Hypothesis	Path coefficient ( $\beta$ )	Sample Mean (M)	SD	T-Statistics	P-Values	Sig.
EIP -> PER	0.349	0.349	0.129	2.701	0.004	Yes

According to (Hair, Ringle, & Sarstedt, 2011), the path coefficients should have standardised values between -1 and +1. The value close to +1 represents strong positive relationships and vice versa for the negative value. Very low values close to 0 are usually not significant. The significance of path coefficient was assessed using bootstrapping analysis. Critical values for one-tailed test are 1.645 (significant level = 5%).

## CONCLUSION

From the results of the study, the mean ( $\bar{x}$ ) value range from 3.489 to 3.890 out of a possible value 5.0 on the scale, indicates a moderate to a considerable extent of implementation of eco-innovation practices among Malaysia chemical companies. The Path Coefficients ( $\beta$ ) supported the hypothesis of this research. Therefore, it can be concluded that there is the positive and significant relationship between eco-innovation practices and sustainable business performance among chemical companies in Malaysia. As such, the study provides empirical evidence indicating that firms can benefit by implementing eco-innovation practices. The result is consistent with those of earlier studies (Cheng, Yang, & Sheu, 2014; Maletic & Dahlgaard, 2014; Özşahin, Sezen, & Çankaya, 2013; Yu & Ramanathan, 2015).

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## REFERENCES

- Anastas, P. T., & Warner, J. C. (1998). *Green Chemistry: Theory and Practice*.
- Centi, G., & Perathoner, S. (2009). From green to sustainable industrial chemistry. *Sustainable Industrial Chemistry*, (January 2001), 1–72. Retrieved from <http://doi.org/10.1002/9783527629114.ch1>
- Cheng, C. C. J., Yang, C. L., & Sheu, C. (2014). The link between eco-innovation and business performance: A Taiwanese industry context. *Journal of Cleaner Production*, 64, 81–90. Retrieved from <http://doi.org/10.1016/j.jclepro.2013.09.050>

- Chin, W. W., & Dibbern, J. (2010). *Handbook of partial least squares. Handbook of Partial Least Squares*. Retrieved from <http://doi.org/10.1007/978-3-540-32827-8>
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. *The Journal of Marketing Theory and Practice*, 19(2), 139–152. Retrieved from <http://doi.org/10.2753/MTP1069-6679190202>
- Hart, S. (1997). Beyond greening: Strategies for a sustainable world. *Harvard Business Review*, 75(1), 66–67.
- Hart, S. L., & Ahuja, G. (1996). Does it pay to be green? An empirical examination of the relationship between emission reduction and firm performance. *Business Strategy and the Environment*, 5(1996), 30–37. Retrieved from [http://doi.org/10.1002/\(SICI\)1099-0836\(199603\)5:1<30::AID-BSE38>3.0.CO;2-Q](http://doi.org/10.1002/(SICI)1099-0836(199603)5:1<30::AID-BSE38>3.0.CO;2-Q)
- Hocketts, K. (2001). Corporate sustainability management-towards controlling corporate ecological and social sustainability. In *Igarss 2001*, 2, 1–5. Retrieved from <http://doi.org/10.1007/s13398-014-0173-7.2>
- Hubbard, G. (2009). Measuring organizational performance: Beyond the triple bottom line. *Business Strategy and the Environment*, 191(December 2006), 177–191. Retrieved from <http://doi.org/10.1002/bse>
- Iles, A. (2008). Shifting to green chemistry: The need for innovations in sustainability marketing. *Business Strategy and the Environment*, 17, 524–535. Retrieved from <http://doi.org/10.1002/bse.547>
- Kemp, R., & Pearson, P. (2007). Final report MEI project about measuring eco-innovation. *European Environment*, 120. Retrieved from <http://www.oecd.org/env/consumption-innovation/43960830.pdf>
- Maletic, M., & Dahlgaard, J. (2014). The relationship between sustainability-oriented innovation practices and organizational performance: Empirical evidence from Slovenian organizations. *The Relationship between Sustainability – Oriented Innovation Practices and Organizational Performance*, 47(1), 3–13. Retrieved from <http://doi.org/10.2478/orga-2014-0001>
- Moiseev, I. (2011). “Green chemistry”–a new paradigm for the basic organic chemical industry. *Theoretical and Experimental Chemistry*, 46(6), 360–369. Retrieved from <http://www.springerlink.com/index/D327T343569895X4.pdf>
- Murphy, J., & Drexhage, D. (2012). Sustainable Development : From Brundtland to Rio 2012. *United Nations*, (September 2010), 26. Retrived from <http://doi.org/10.1007/s13398-014-0173-7.2>
- Özşahin, D. M., Sezen, B., & Çankaya, S. Y. (2013). Effects of Green manufacturing and eco-innovation on sustainability performance. *Procedia - Social and Behavioral Sciences*, 99, 154–163. Retrieved from <http://doi.org/10.1016/j.sbspro.2013.10.481>
- Porter, M. E., Linde, C. Van Der, & Porter, M. E. (1995). Green and competitive: Ending the stalemate. *Long Range Planning*, 28(6), 128–129. Retrieved from [http://doi.org/10.1016/0024-6301\(95\)99997-E](http://doi.org/10.1016/0024-6301(95)99997-E)
- Yu, W., & Ramanathan, R. (2015). An empirical examination of stakeholder pressures, green operations practices and environmental performance. *International Journal of Production Research*, 53(21), 6390–6407. Retrieved from <http://doi.org/10.1080/00207543.2014.931608>



## Optimisation of *Botryococcus* sp. Growth Using Synthetic Media (N: P) for Biodiesel Production

R. Wellson<sup>1</sup>, N. Othman<sup>1\*</sup> and HM. Matias-Peralta<sup>2</sup>

<sup>1</sup>Micropollutant Research Centre, Faculty of Civil and Environmental Engineering, University Tun Hussein Onn, 86400 Parit Raja, Johor, Malaysia

<sup>2</sup>Department of Technology and Heritage, Faculty of Science, Technology and Human Development, University Tun Hussein Onn, 86400 Parit Raja, Johor, Malaysia

### ABSTRACT

Algae biodiesel is undeniably very promising as an energy substitute for fossil fuel. Its mass cultivation though requires huge capital investment. The aim of this study was to find a simple, inexpensive and tolerable media for algae growth. The optimal growth conditions for algae growth were studied. *Botryococcus* sp. was isolated from Sembrong Dam in Johor, Malaysia. In this study, two media were used, namely Bold's basal medium (BBM) and synthetic media from nitrogen and phosphorus compound. The synthetic media consisted of ammonium chloride and monopotassium phosphate that were blended together and modified into desired ratios. The N: P ratio of 1.5:1 yielded the highest chlorophyll-a concentration and the optimal growth conditions of algae for both media were at 6000 Lux, pH 7 and 30 rpm. The BBM had the highest algae growth,  $3.25 \times 10^7$  cell/ml while the synthetic media yielded a maximum cell concentration of up to  $1.025 \times 10^7$  cell/ml which is 68.5% lower compared with BBM. The findings of this study point to the importance of large scale production of algae useful for industrial production of biodiesel.

*Keywords:* Algae, biodiesel, *Botryococcus* sp., growth media

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#### E-mail addresses:

[wellsonrichter@gmail.com](mailto:wellsonrichter@gmail.com) (R. Wellson),

[norzila@uthm.edu.my](mailto:norzila@uthm.edu.my) (N. Othman),

[hmp1229@gmail.com](mailto:hmp1229@gmail.com) (HM. Matias-Peralta)

\*Corresponding Author

### INTRODUCTION

In recent years, there has been notable development of microalgae biodiesel for fuel in western countries, such as America and Brazil because of the dwindling of fossil fuel stock. Therefore, there is an urgent need to stop dependency on fossil fuels and find alternative ways for renewable fuel production. Researchers have discovered the commercial value of microalgae as it can



produce more oil compared with other feedstock which is 3-35 times higher than terrestrial plants in terms of oil content (Mata et al., 2010). The large scale culturing microalgae for mass production of biodiesel is usually associated with high cost in terms of execution and maintenance. The use of algae growth media is quite expensive for large scale production of microalgae (Lim et al., 2012).

Many algae growth media have been introduced, yet, the high culturing cost impede the development of algal biodiesel production except the mass culturing in ponds where nutrients are supplied by the fish or shrimp through their life cycle (Lim et al., 2012). As the available commercial media growth is made of several chemicals is a complicated process and not a cost-effective one, there is a quest for cheaper yet efficient media growth. In this study, media growth is due to most important nutrients for algae growth, nitrogen and phosphorus (Hu et al., 2004). Ammonium ion ( $\text{NH}_4^+$ ) is easier for microalgae to absorb than ammonia ( $\text{NH}_3$ ), according to Harold (1966). Most algae has high amounts of phosphate as polyphosphate granules important for plant growth and animal tissue as well use to synthesize protein in them while phosphorus is an essential nutrient in converting sunlight into usable energy and vital for cellular growth and reproduction. In this study, two different types of media were compared which are N:P media and Bold's Basal Medium (BBM). The ammonium source ( $\text{NH}_4\text{Cl}$ ) and phosphate ( $\text{KH}_2\text{PO}_4$ ) were used to produce synthetic media and the ratio between them was adjusted for its effectiveness vis a vis algae growth. Favourable environment parameters such as intensity of light, pH culture and bioreactor speed also need to be controlled for ensuring the culture results in optimal growth.

## MATERIALS AND METHODS

### The Selection of Synthetic Media Grow

In this study, several ratios of N: P were tested to stimulate nutrient strength (0.6:0.2, 0.8:0.4, 1:0.6, 1.2:0.8, 1.5:0.8, 1.5:0.9, 1.5:1, 2:1, 2:1.5). The ratio selections were based on strength of N: P in Sembrong Dam water in which the average ammonia content was 1.14 mg/L of ammonia and total phosphate is 1.05 mg/L. The ammonium chloride ( $\text{NH}_4\text{Cl}$ ) and monopotassium phosphate ( $\text{KH}_2\text{PO}_4$ ) were diluted according to desired concentration. All samples were prepared in triplicate. 250 ml of Erlenmeyer flasks were used with the initial algae concentration of 1000 cells/ml for all samples. The *Botryococcus* sp. used was isolated from the Sembrong Dam (Wellson et al., 2016). *Botryococcus* sp. was cultured under the light of white fluorescent bulbs of  $4000 \pm 100$  lux (photoperiod of 16:08 h light dark). The cultures were shaken gently manually twice a day for 20 days and exposed to room temperature at  $27^\circ\text{C} \pm 2$ .

### Optimization of *Botryococcus* sp.

**Light Optimisation.** The light intensity varied based on previous studies (Lavens & Sorgeloos., 1996; Yan Li., 2005; Stuart et al., 2011). The light intensities were 4000, 6000, 8000 and 10000 Lux. 100 ml of synthetic media was used for every sample in 250ml of conical flask. The samples were prepared in triplicate with initial inoculation of 1000 cells/ml for all sample



and shaken gently by hand twice per day and exposed to room temperature at  $26^{\circ}\text{C} \pm 2$  and cultured for 20 days. The initial pH of cultures was set at 7 and manually shaken twice per day.

**Initial pH Optimization.** The pH values adapted were 6, 7, 8 and 9 based on previous study (Lavens & Sorgeloos, 1996; Yan Li., 2005; Stuart et al., 2011). The hydrochloric acid (HCl) and sodium hydroxide (NaOH) were used to adjust the pH to meet the desired pH values. The initial inoculation cell was 1000 cells/ml under the white compact fluorescent bulb of 23 watts of  $6000 \pm 100$  lux with 16:08 photoperiod. The other conditions were set the same for optimal light.

**Shaking Speed Optimization.** The rotational speed for culturing *Botryococcus* sp. is essential in order to provide an adequate air mixture and uniformity of nutrients in the cultures. Three different speeds were adapted, 30, 40 and 50 rpm by using laboratory orbital shaker. The inoculation cells, lux, temperature were set at same pH optimisation and the initial pH was set at 7 pH.

## RESULTS AND DISCUSSION

### Synthetic Media

Based on the result of chlorophyll-a for 9 different of N:P ratios, the highest concentration of chlorophyll-a recorded was at ratio 1.5:1 with  $98 \mu\text{g/L}$ . The second highest is 1.5:09 with  $74 \mu\text{g/L}$  and the third highest with ratio 2:1.5 yielding  $68 \mu\text{g/L}$ . Therefore, the best ratio of N:P is of 1.5:1 and ensures good synthetic media optimisations. The culture with N:P nutrients ratio were cultured for 20 days. Based on observation, the algae was able to live and tolerate the synthetic media even though its biomass was not as high compared with using BBM media growth (as in Figure 1).



Figure 1. Cultures of 1.5:1 NP ratio at 20 days

### Optimisation of Light

Over a period of 20 days, the cell concentration of all cultures was counted everyday using haemocytometer in the unit cell/ml (Paran, 2014). Figure 2 shows that growth of algae increased with time and reached optimum level between 16<sup>th</sup> and 18<sup>th</sup> day within the stationary phase. The lag phase occurred from 1<sup>st</sup> to 11<sup>th</sup> day and the exponential growth was between 11<sup>th</sup> and

16<sup>th</sup> day. Generally, the death phase occurred within 17<sup>th</sup> to 20<sup>th</sup> day. The result showed that the growth of *Botryococcus* sp. is optimal under the illumination of 6000 lux. For both synthetic and BBM media at 6000 lux the optimal algae concentration was  $1.025 \times 10^7$  cell/ml and  $3.25 \times 10^7$  cell/ml respectively. Using synthetic media results in algae concentration being 68.5% lower than commercial media BBM. This shows that the use of simple and cheap synthetic will not able to give abundant *Botryococcus* sp. as much as using BBM but the former can still be used as a cheap media for experimental purposes. The synthetic media also represent the nutrient strength in actual water source with pollutant loading. The second highest peak cell concentration is at illumination 8000 lux yielding  $925 \times 10^4$  cell/ml equivalent to 30.8% of the peak concentration using BBM which is  $3000 \times 10^4$  cell/ml. Additionally, under the 10000 lux, the peak concentration is  $900 \times 10^4$  cell/ml equivalent to 32.7% of the highest cell concentration using BBM which is  $2750 \times 10^4$  cell/ml. The light intensity of 4000 lux produces the least cell concentration compared with the rest; light intensity is only reached at the peak of  $800 \times 10^4$  cell/ml or 40% of the Bbm ( $2000 \times 10^4$  cell/ml). This is consistent with the findings of Sharma (2011) who pointed out the optimum range for light is between 5000-7500 lux, and 6000 lux is the optimal for growth of *Botryococcus* sp. Other researchers cultured the botryococcus with light intensity in the range of 6000-7000 Lux (Stuart et al., 2011; Nagaraja et al., 2014).

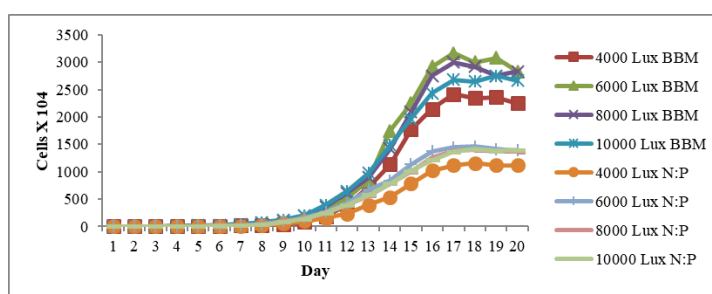


Figure 2. Graph of optimal light intensities

### pH Optimisation

The growth of algae is also influenced by the pH level of the media (Mata et al., 2010). Based on Figure 3, the trend of graph is similar to light optimisation. *Botryococcus* sp. grows under optimal conditions of pH 7 with maximum cell concentration of  $1100 \times 10^4$  cell/ml or 56% less than the peak cell concentration using BBM ( $2500 \times 10^4$  cell/ml). Furthermore, the graph for pH 7 and pH 8 is almost the same at 15<sup>th</sup> day, in which the cell concentration at pH 8 is higher than pH 7 until the 14<sup>th</sup> day before it declines. The peak cell concentration for pH 8 was  $1050 \times 10^4$  cell/ml or 45.5% at the maximum cell concentration using BBM ( $2250 \times 10^4$  cell/ml). The peak cell concentration of algae cultured in N:P media with pH 9 yields  $900 \times 10^4$  cell/ml equivalent to 45% of the peak cell concentration of using BBM ( $2000 \times 10^4$  cell/ml). The

*Botryococcus* sp. grew slowly at pH 6 as the maximum yielding concentration was  $775 \times 10^4$  cell/ml or 59% than the peak cell concentration using BBM ( $1600 \times 10^4$  cell/ml). The optimal pH range for the cultivation of microalgae of all species is between 7 and 9 (Huo et al., 2011; Sharma, 2011). It will be easier for microalgae to capture carbon dioxide in the atmosphere when the growing condition is alkaline, which can produce greater biomass (Zang et al., 2011). The *Botryococcus* sp. is not suitable to be cultured under the pH below 7. Based on the study by Nagaraja et al. (2014), the *Botryococcus* sp. optimal growth was at pH of 6.5 using BBM.

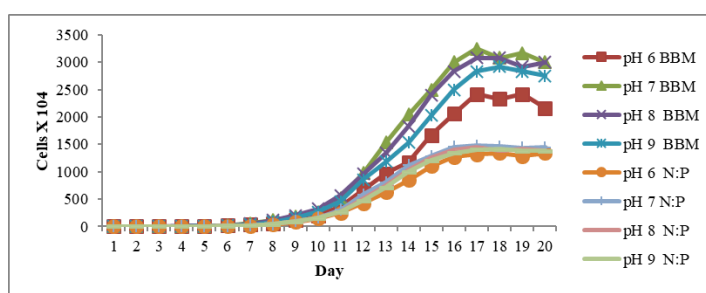


Figure 3. Graph of pH optimisation

### Shaking Speed Optimisation

Mixing is necessary for microalgae cultivation to prevent sedimentation and to ensure all cells receive equal amount of light and nutrients. Figure 4 shows a less cell concentration is yielded when cultured under continuous rotating orbital shaker and the growth curve of algae has the same trend of light and pH optimisation. As the rpm speed declined the cell concentration increased. The speed at 30 rpm yields the highest cells concentration,  $157.5 \times 10^4$  cell/mL or 52.5% of the peak concentration using BBM ( $300 \times 10^4$  cell/ml) while speed at 40 rpm yields  $150 \times 10^4$  cell/ml equivalent to 54% of the highest concentration using BBM ( $275 \times 10^4$  cell/m). The greater the speed of rpm the less concentration of cells is observed. At 50 rpm, the cultures were only able to reach a peak with  $145 \times 10^4$  cell/ml or 58% of the peak cell concentration using BBM ( $250 \times 10^4$  cell/ml). The rotation at 60 rpm gives the lowest peak concentration, which is  $137.5 \times 10^4$  cell/ml or 61%, than the peak cell concentration using BBM ( $225 \times 10^4$  cell/ml). Under continuous rotation, *Botryococcus* sp. was seen accumulated at the centre of the flask as a result of centrifugal forces. Eroglu, Okada and Melis (2011) reported the same scenario with *Botryococcus braunii* when the orbital shaker were set continuously at a greater rpm.

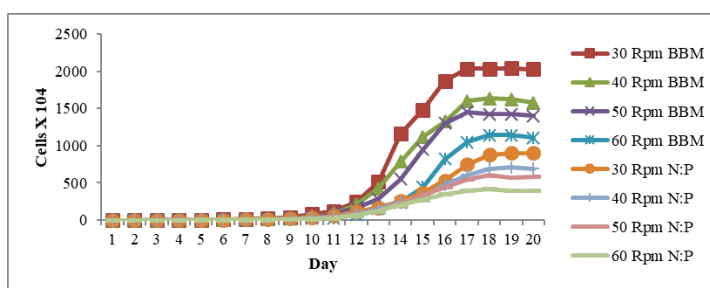


Figure 4. Graph of optimal shaking rate

## CONCLUSION

In conclusion, BBM to grow *Botryococcus* sp. is more promising compared with synthetic media which provides 68.5% lower yield than the cell concentration using BBM. *Botryococcus* sp. can be cultured in synthetic media by adjusting N: P ratio of 1.5:1 to produce moderate cells concentration and stimulate the actual condition of *Botryococcus* sp. growth. The optimal growth is observed under the exposure of 6000 lux of light, pH 7 and shaking rate of 30 rpm. The N:P can be further studied, improved and blended with some other nutrients for better performance.

## REFERENCE

- Chisti Y. (2007). Biodiesel from microalgae. *Biotechnology Advances*, 25(3), 294–30.
- Eroglu, E., Okada, S., & Melis, A. (2011) Hydrocarbon productivities in different *Botryococcus* strains: Comparative methods in product quantification. *Journal Application Phycology*, 23(4), 763–775.
- Harold, F. M. (1966). Inorganic polyphosphate in biology: Structure, metabolism, and function. *Bacteriological Reviews*, 30, 772-794.
- Hu, Q. (2004). Environmental Effects on Cell Composition. *Handbook of Microalgal Culture: Biotechnology and Applied Phycology*; Richmond, A., Ed.; Blackwell: Oxford, UK, 83–93.
- Huo, S., Dong, R., Wang, Z., Pang, C., Yuan, Z., Zhu, S., & Chen, L. (2011). Available resources for algal biofuel development in China. *Energies*, 4, 1321–1335.
- Juren, P. (2014). *The production of biofuel from microalgae after phycoremediation*. Master Thesis Report. University Tun Hussein Onn Malaysia:
- Lavens, P., & Sorgeloos, P. (1996). Manual on the production and use of live food for aquaculture. *FAO Fisheries Technical Paper*, No. 361, Rome, 295
- Li, Y., Wang, B., Wu, N., & Lan, C. Q. (2008). Effects of nitrogen sources on cell growth and lipid production of *Neochloris oleoabundans*. *Applied Microbiology and Biotechnology*, 81(4), 629–636.
- Lim, D. K. Y., Garg, S., Timmins, M., Zhang, E. S. B, Thomas-Hall, S. R., Schuhmann, H., Li, Y., & Schenk, P.M. (2012). Isolation and evaluation of oil producing microalgae from subtropical coastal and brackish waters. *PLoS ONE* 7(7): e40751. doi: 10.1371/journal.pone.0040751.

- Mata, T. M., Martins, A. A., & Caetano, N. S. (2010). Microalgae for biodiesel production and other Applications. *Renewable and Sustainable Energy Reviews*, 14(1), 217-32.
- Nagaraja, Y. P., Biradar, C., Manasa, K. S., & Venkatesh, H. S. (2014). Production of biofuel by using microalgae (*Botryococcus braunii*). *International Journal of Current Microbiology and Applied Science*. 3(4), 851-860.
- Sharma, O. P. (2011). *Series on diversity of microbes and cryptogams: Algae*. New Delhi: Tata McGraw Hill Education Private Limited.
- Stuart, B. J., Csavina, J. L., Riefler, R., & Vis, M. L. (2011). Growth optimization of algae for biodiesel production. *Journal of Applied Microbiology*, 111, 312-318.
- Wellson, R., Othman, N., & Matias-Peralta. (2016). The characterization of chlorophyll-a and microalgae isolation process of wastewater collected at Sembrong dam. IOP Conf. Series: *Materials Science and Engineering*, 136. 012062. doi:10.1088/1757-899X/136/1/012062.
- Yan, L and Qin, J. (2005). Comparison of growth and lipid content in three *Botryococcus braunii* strains. *Journal of Applied Phycology*, 17(6), 551-556.
- Zang, C., Huang, S. and Wu, M. (2011). Comparison of relationship between pH, dissolve oxygen and chlorophyll a for aquaculture and non aquaculture water. *Water, Air and Soil Pollution*, 219 (1-4), 157-174





## Optimisation of Water Soluble Essential Oil from Lemongrass Leaves using Steam Distillation

S. F. Lim\*, P. Y. L. Pah, S. N. David Chua and H. T. Nicholas Kuan

*Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak Malaysia*

### ABSTRACT

Lemongrass leaves are often under-utilised and unexploited. In this study, lemongrass leaves were used to produce water soluble essential oil using a steam distillation system. Water steam was passed through the lemongrass leaves which were placed and supported on a grid above the water in a distiller. The steam distillation system was fabricated and optimised using Response Surface Methodology (RSM). The maximum oil yield with optimal relative citral content is obtained at 6.69 of plant-to-water ratio, 26.68 minutes of distillation time using air-dried lemongrass leaves left under the shade for two days. At the optimum conditions, the predicted oil yield was 0.6719% of lemongrass (*C. citratus*) oil which contains 71.79% of citral content.

*Keywords:* Essential oil, lemongrass leaves, optimisation, steam distillation

### INTRODUCTION

Hussin et al. (2013) reported that there are more than 100 hectares of lemongrass farm in Malaysia producing about 200 tonnes of dry bagasse (leaves) per year. The lemongrass plant which is widely cultivated in tropics and subtropics is well-known for its traditional sweet and savoury flavouring in Asian cuisines (Nambiar & Matela, 2012). All parts of the lemongrass plant are lemon-flavoured with citral functional group as a main compound, approximately 78% (Chomchalow, 2002; Negrelle & Gomes, 2007; Ranitha et al., 2014; Rocha et al., 2014; Tajidin et al., 2012). Hutton (2013) stated that the part used in cooking and edible is the basal part of the leaf sheath (stalk), while the top part (blade) of the lemongrass has coarse, broad leaves which are not used in cooking. According to Ranitha et al. (2014), lemongrass plant which includes its sheath and blade contains 1-2% of essential oil. The

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##### *E-mail addresses:*

[sflim@unimas.my](mailto:sflim@unimas.my) (S. F. Lim),

[paulinpahyenling@gmail.com](mailto:paulinpahyenling@gmail.com) (P. Y. L. Pah),

[csndavid@unimas.my](mailto:csndavid@unimas.my) (S. N. David Chua),

[khtnicholas@unimas.my](mailto:khtnicholas@unimas.my) (H. T. Nicholas Kuan)

\*Corresponding Author

oil is extracted and used as raw material in food, cosmetic, and pharmaceutical industries (Orji, 2012; Firdaus et al., 2016). Thus, lemongrass leaves rather than being a part of agro-waste, can be turned into valuable products by extracting its essential oil compound (Masamba et al., 2003).

Generally, steam distillation method is preferred for essential oil extraction because it is cheap, flexible, versatile, and does not lead to decomposition of the essential oil (Milojevi et al., 2008; Amenaghawon et al., 2014). The steam distillation is an extraction method to extract essential oil from plant leaves and herbs whereby water steam is passed through the plant materials which are placed and supported on a perforated grid above the water in the distiller (Hunter, 2009; Mohamed, 2005). Moreover, steam distillation using water as solvent does not require any involvement of organic solvent during the extraction process. This process is temperature dependent which influences the kinetic of the extraction (Ana et al., 2016). Therefore, the production system is green and environmentally friendly (Hamzah et al., 2014).

In this study, a steam distillation system was fabricated and optimised to produce essential oil from lemongrass leaves. The extracted essential oil was analysed using a Gas Chromatography Mass Spectrometry (GC-MS) for the relative citral content.

## MATERIALS AND METHODS

### Materials

Fresh lemongrass (*Cymbopogon citratus*) leaves were collected from Kota Samarahan, Sarawak. All lemongrass leaves were freshly cut, approximately 10cm long from the root of the plant. The leaves were rinsed with tap water to remove soil and dust. Three categories of lemongrass leaves were produced i.e. fresh without drying, air-dried under shade for 2 days, and oven-dried at 45°C for 1 day. Prior to use for essential oil extraction, the leaves were then cut into small pieces at approximately 2 cm long each.

### Fabrication of Steam Distillation System

A steam distillation system was designed and fabricated by modifying a pressure cooker as a steam distiller (it is low in cost). The distillation system consists of heat source (using an electric hotplate), distiller (using a modified pressure cooker), condenser, and collection tank. The schematic flow diagram of the steam distillation system is shown in Figure 1.

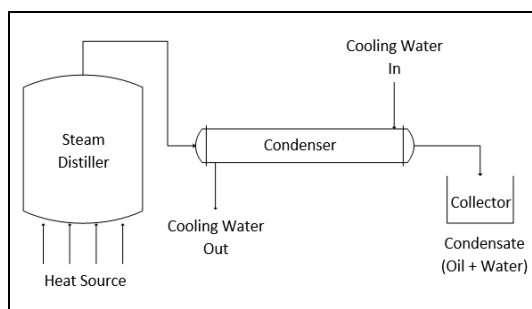


Figure 1. Schematic flow diagram of the steam distillation system



## Design of Experiment

A split plot optimal design from Response Surface Methodology (RSM) using Design-Expert v10 (free trial) by Stat-ease was used to determine the optimum parameters to extract lemongrass (*C. citratus*) essential oil by steam distillation. As seen in Table 1, three independent variables which consist of two numeric and one categorical variables, namely plant-to-water ratio (4:1-10:1, factor A), distillation time (10-40 min, factor B), and plant drying condition (fresh, air-dried, and oven-dried, factor C), were studied for their influence on the extraction process which directly affected the oil yield and quality. The plant-to-water ratio was manipulated by varying the mass of plant material subjected to the same volume of distilled water which is 1L. The experiment was carried out at maximum temperature of 100°C under atmospheric pressure. The extracted essential oils were stored in sealed vials at low temperature (4°C) before analysis. The percentage yield of the essential oil is calculated using Equation 1.

$$\% \text{Essential oil yield} = \frac{\text{Weight of essential oil (g)}}{\text{Weight of plant sample (g)}} \times 100\% \quad [1]$$

## Gas Chromatography Mass Spectrometry (GC-MS)

The relative citral content (%) in the lemongrass essential oil was analysed using GC-MS. The analysis was performed using Shimadzu GCMS QP2010 (Japan) which is equipped with splitless injector at 280°C using a BPX-5 column (30 m x 0.25 mm, column diameter 0.25 µm). The operating temperature was programmed to start at 80°C, hold for 2 minutes and increased to 260°C at a rate of 10°C/min. The operating temperatures for injector and detector were at 280°C. Helium gas was used as a carrier gas at a flow rate of 0.97 mL/min. The identification of the chemical components was carried out by comparing with the peaks of the NIST05 and WILEY8 libraries search data.

## RESULTS AND DISCUSSION

Using the design of experiment concept for optimisation, 22 runs were performed for the three independent variables (plant-to-water ratio, distillation time, and plant drying condition) and the corresponding responses (oil yield and relative citral content). The optimal design for the three uncoded independent variables and the corresponding responses for each run are tabulated in Table 1.

Table 1  
*Optimal design with uncoded independent variables and corresponding response*

Run No.	Experimental Parameters			Response	
	Plant-to-Water Ratio, A	Distillation Time, B (min)	Plant Drying Condition, C	Oil Yield (%)	Relative Citral Content (%)
1	7.00	35.80	Fresh	0.2730	84.3000
2	7.00	25.00	Ovendry	0.4480	32.5500
3	10.00	10.00	Fresh	0.1000	77.2400
4	7.00	25.00	Ovendry	0.5250	31.7300
5	7.24	18.85	Fresh	0.2679	74.7100
6	7.24	18.85	Fresh	0.2389	74.6600
7	4.00	40.00	Ovendry	0.7600	24.6600
8	10.00	37.90	Airdry	0.3600	77.3600
9	10.00	10.00	Ovendry	0.7400	38.9800
10	4.00	26.05	Airdry	0.5760	64.2200
11	4.30	40.00	Airdry	0.5117	68.2500
12	10.00	40.00	Fresh	0.1200	77.2400
13	7.21	40.00	Airdry	0.4614	79.0800
14	4.00	26.05	Airdry	0.5920	66.4100
15	7.00	25.00	Ovendry	0.4200	29.8500
16	4.00	10.00	Ovendry	0.5040	32.9600
17	10.00	23.80	Airdry	0.3500	75.4800
18	4.00	16.00	Fresh	0.2840	74.8800
19	6.79	10.00	Airdry	0.4889	73.7200
20	6.79	10.00	Airdry	0.4753	68.8000
21	10.00	40.00	Ovendry	1.0800	22.3600
22	4.00	31.45	Fresh	0.5640	80.3500

The final model in terms of coded factors and actual factors for the oil yield response in the analysis is presented in Equations 2, 3, 4, and 5. The final equation in terms of coded factors is:

$$\begin{aligned} \log_{10}(\text{Oil yield}) = & -0.35 - 0.081 * A + 8.956 \times 10^{-3} * B - 0.18 * C[1] + 0.17 * C[2] \\ & - 0.026 * AB - 0.16 * AC[1] - 5.690 \times 10^{-3} * AC[2] + 0.046 * A^2 \\ & - 0.14 * B^2 + 0.084 * A^2B - 0.098 * A^2C[1] - 0.20 * A^2C[2] \end{aligned} \quad [2]$$

The final equation in terms of actual factors is:

*Fresh:*

$$\begin{aligned} \log_{10}(\text{Oil yield}) = & -1.52725 + 0.23467 * \text{Ratio} + 0.065762 * \text{DistillationTime} \\ & - 9.27935 \times 10^{-3} * \text{Ratio} * \text{DistillationTime} - 0.021381 * \text{Ratio}^2 \\ & - 6.13740 \times 10^{-4} * \text{DistillationTime}^2 \\ & + 6.21987 \times 10^{-4} * \text{Ratio}^2 * \text{DistillationTime} \end{aligned} \quad [3]$$

*Air-dry:*

$$\begin{aligned} \log_{10}(\text{Oil yield}) = & -2.08221 + 0.44351 * \text{Ratio} + 0.065762 * \text{DistillationTime} \\ & -9.27935 \times 10^{-3} * \text{Ratio} * \text{DistillationTime} - 0.032731 * \text{Ratio}^2 \\ & -6.13740 \times 10^{-4} * \text{DistillationTime}^2 \\ & +6.21987 \times 10^{-4} * \text{Ratio}^2 * \text{DistillationTime} \end{aligned} \quad [4]$$

*Oven-dry:*

$$\begin{aligned} \log_{10}(\text{Oil yield}) = & 0.094647 + 0.27755 * \text{Ratio} + 0.065762 * \text{DistillationTime} \\ & -9.27935 \times 10^{-3} * \text{Ratio} * \text{DistillationTime} + 0.022747 * \text{Ratio}^2 \\ & -6.13740 \times 10^{-4} * \text{DistillationTime}^2 \\ & +6.21987 \times 10^{-4} * \text{Ratio}^2 * \text{DistillationTime} \end{aligned} \quad [5]$$

The final model in terms of coded factors and actual factors for the relative citral content response in the analysis are presented in Equations 6, 7, 8, and 9. The final equation in terms of coded factors is:

$$\begin{aligned} \text{Relative Citral Content} = & 60.16 + 2.24 * A - 0.21 * B + 17.66 * C[1] + 12.06 * C[2] \\ & -2.26 * AB - 2.75 * AC[1] + 4.06 * AC[2] + 4.18 * BC[1] + 1.84 * BC[2] \end{aligned} \quad [6]$$

The final equation in terms of actual factors is:

*Fresh:*

$$\begin{aligned} \text{Relative Citral Content} = & 63.61735 + 1.08452 * \text{Ratio} \\ & +0.61626 * \text{DistillationTime} \\ & -0.050235 * \text{Ratio} * \text{DistillationTime} \end{aligned} \quad [7]$$

*Air-dry:*

$$\begin{aligned} \text{Relative Citral Content} = & 46.01151 + 3.35541 * \text{Ratio} \\ & +0.46071 * \text{DistillationTime} \\ & -0.050235 * \text{Ratio} * \text{DistillationTime} \end{aligned} \quad [8]$$

*Oven-dry:*

$$\begin{aligned} \text{Relative Citral Content} = & 29.86364 + 1.56587 * \text{Ratio} \\ & -0.063688 * \text{DistillationTime} \\ & -0.050235 * \text{Ratio} * \text{DistillationTime} \end{aligned} \quad [9]$$

Hence, the optimum process parameters for the steam distillation process were plant-to-water ratio of 6.69, distillation time of 26.68 minutes, and use of lemongrass air-dried leaves under shade for 2 days. The distillation time was shorter than the results reported by Desai and Parikh (2015) which is 45 minutes. At the optimum conditions, the predicted oil yield is 0.6719% of lemongrass (*C. citratus*) oil which contains 71.79% of citral content. Figure 2 shows the optimised parameters generated by the RSM.

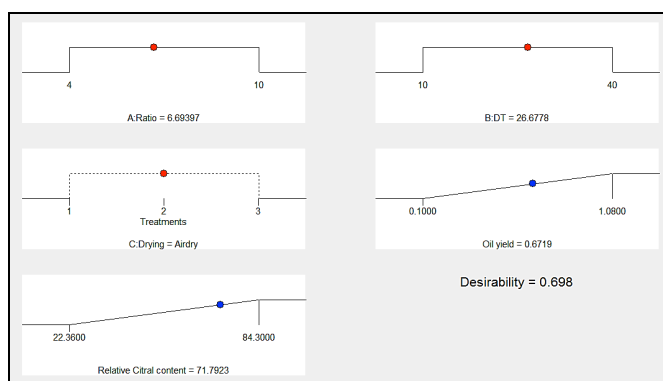


Figure 2. Optimised parameters for the steam distillation process

## CONCLUSION

A steam distillation system for producing water soluble lemongrass leaf essential oil is fabricated by modifying a conventional pressure cooker. Optimisation study was performed on the steam distillation process for extraction of the essential oil using response surface methodology. The optimum process parameters were plant-to-water ratio of 6.69, distillation time of 26.68 min, and use of lemongrass air-dried under shade for 2 days. These optimum operating conditions yielded 0.6719% of lemongrass (*C. citratus*) oil which contained 71.79% of citral content.

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## REFERENCES

- Amenaghawon, N. A., Okhueleigbe, K. E., Ogbiede, S. E., & Okieimen, C. O. (2014). Modelling the kinetics of steam distillation of essential oils from lemon grass (*Cymbopogon* Spp.). *International Journal of Applied Science and Engineering*, 12(2), 107–115.
- Ana, B.-K., Sovova, H., Planinic, M., & Tomas, S. (2016). Temperature dependent kinetics of grape seed phenolic compounds extraction: Experiment and model. *Food Chemistry*, 136(3-4), 1136–1140.
- Chomchalow, N. (2002). Production of Herbs in Asia : An Overview. *Assumption University Journal of Technology*, 6(2), 95–108.
- Desai, M. A., & Parikh, J. (2015). Extraction of essential oil from leaves of lemongrass using microwave radiation: Optimization, comparative, kinetic, and biological studies. *ACS Sustainable Chem. Eng.*, 3(3), 421–43.
- Firdaus, M. Y. N., Osman, H., Metselaar, H. S. C., & Rozyanty, A. R. (2016). *Cymbopogon citratus* Ash Calcined at Different Temperature. *BioResources*, 11(1), 2839–2849.

- Hamzah, M. H., Che Man, H., Zainal Abidin, Z., & Jamaludin, H. (2014). Comparison of Citronella Oil Extraction Methods from *Cymbopogon nardus* Grass by Ohmic-heated Hydro-distillation, Hydro-Distillation, and Steam Distillation. *BioResources*, 9(1), 256–272.
- Hunter, M. (2009). *Essential oils: Art, agriculture, science, industry and entrepreneurship (A Focus on the Asia-Pacific region)*, 1. New York: Nova Science Publishers.
- Hussin, H., Salleh, M. M., Chong, C. S., Naser, M. A., Abd-Aziz, S., & Merican Al-Junid, A. F. (2013). Eco-friendly bioconversion of lemongrass biomass leaves to biovanillin using *Phanerochaete chrysosporium*. In *International Symposium on Biotechnology Advances*.
- Hutton, W. (2013). *A Cook's Guide to Asian Vegetables*. Tokyo, Japan: Tuttle Publishing.
- Masamba, W. R. L., Kamanula, J. F. M., Henry, E. M. T., & Nyirenda, G. K. C. (2003). Extraction and analysis of lemongrass (*Cymbopogon citratus*) oil: An essential oil with potential to control the Larger Grain Borer (*Prostephanus truncatus*) in stored products in Malawi. *Malawi Journal of Agricultural Sciences*, 2(1), 56–64.
- Milojevi, S. Z., Stojanovi, T. D., Palic, R., Lazic, M. L., & Veljkovic, V.B., (2008). Kinetics of distillation of essential oil from comminuted ripe juniper (*Juniperus communis* L) berries. *Biochemical Engineering Journal*, 39, 547-553.
- Mohamed, N. A. B. (2005). *Study on important parameters affecting the hydro-distillation for ginger oil production*. Universiti Teknologi Malaysia.
- Nambiar, V. S., & Matela, H. (2012). Potential functions of lemon grass (*Cymbopogon citratus*) in health and disease. *International Journal of Pharmaceutical & Biological Archives*, 3(5), 1035–1043.
- Negrelle, R. R. B., & Gomes, E. C. (2007). *Cymbopogon citratus* (DC.) Stapf: Chemical composition and biological activities. *Brazilian Journal of Medicinal Plants*, 9(1), 80–92.
- Orji, O. A. (2012). Extraction and formulation of perfume from lemongrass leaves. Caritas University.
- Ranitha, M., Nour, A. H., Sulaiman, Z. A., Nour, A. H., & Thana Raj, S. (2014). A comparative study of lemongrass (*Cymbopogon Citratus*) essential oil extracted by microwave-assisted hydrodistillation (MAHD) and conventional hydrodistillation (HD) method. *International Journal of Chemical Engineering and Applications*, 5(2), 104–108.
- Rocha, R. P., Melo, E. D. C., Barbosa, L. C. A., Santos, R. H. S., Cecon, P. R., Dallacort, R., & Santi, A. (2014). Influence of plant age on the content and composition of essential oil of *Cymbopogon citratus* (DC.) Stapf. *Journal of Medicinal Plant Research*, 8(37), 1121–1126.
- Tajidin, N. E., Ahmad, S. H., Rosenani, A. B., Azimah, H., & Munirah, M. (2012). Chemical composition and citral content in lemongrass (*Cymbopogon citratus*) essential oil at three maturity stages. *African Journal of Biotechnology*, 11(11), 2685–2693.





## **Bio-Asphalt Concrete: From Waste Product to Green Aggregate Replacement**

**Resdiansyah<sup>1\*</sup>, Amidah Mohd Ujang<sup>2</sup> and Zarinah Zaini<sup>2</sup>**

<sup>1</sup>*Universitas Pembangunan Jaya, 15413 Bintaro Jaya, Banten, Indonesia*

<sup>2</sup>*Politeknik Sultan Salahuddin Abdul Aziz Shah, Persiaran Usahawan, Seksyen U1, 40150 Shah Alam, Selangor, Malaysia*

### **ABSTRACT**

Malaysia has over 5 million hectares of land planted with palm oil, divided almost equally between peninsula Malaysia and East Malaysia. This paper presents a laboratory evaluation of the performance of the waste product palm kernel shell (PKS) in creating plant-based asphalt concrete (bio-asphalt concrete). PKS aggregate partially replaced granite aggregate in preparing the mixes (10%, 30%, and 100%) in the range of 5mm-14mm in ACW 14 mixed with 5% to 7% of bitumen content. 35 blows and 50 blows compaction of mixes was used to evaluate the potential of palm kernel shells in the preparation of bitumen to deal with light to medium traffic. Results showed that PKS aggregate can be used up to 30% PKS replacement for the light traffic design and only 10% PKS replacement was potential to be used in medium traffic design.

*Keywords:* Bio-asphalt concrete, green aggregate replacement, oil palm, palm kernel shell

### **INTRODUCTION**

The production of flexible pavement relies on the availability of mineral aggregate (stone) the most important ingredient behind the rising cost of pavement structure. This has led to interest in finding suitable replacement material as a substitute for natural stone. Using waste materials

as an alternative can help in conserving natural resources, disposal of waste materials, and making land available for other economic benefit (Sherwood, 1995). Wastes generally have no commercial value and does not compromise product performance (Zemke and Woods, 2009). Indonesia is the largest palm oil producing country in the world followed by Malaysia in second place (MPOB, 2013).

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##### *E-mail addresses:*

resdiansyah.mansyur@upj.ac.id (Resdiansyah),

amidah@psa.edu.my (Amidah Mohd Ujang),

zzarinahkjk@gmail.com (Zarinah Zaini)

\*Corresponding Author

Empty fruit bunches (EFB), palm kernel shells (PKS) or oil palm shells (OPS), pericarp and palm oil mill effluent (POME) are palm oil by-products which can be used in the construction industry, such as to replace natural stone in asphalt concrete mixtures.

Ndoke (2006) investigated the suitability of palm kernel shells as a partial replacement for coarse aggregates in asphalt concrete, and found its suitability as a partial replacement for coarse aggregate up to 10% for heavily trafficked roads and 50% for light trafficked roads. Lee (2012) investigated the potential of raw oil palm shell (5mm) as an aggregate replacement in high volume road design, and concluded that palm kernel shells (5% of 5 mm) as the coarse replacement to be unsuitable for high volume road design. This study investigates the replacement of conventional coarse aggregates by palm kernel shells on stability, flow and the volumetric properties of pavement and low to medium traffic conditions.

## **MATERIALS AND METHODS**

### **Materials Used**

The raw material used for the study was sourced locally, and added to bitumen as a binder, fine aggregate, palm kernel shell (PKS) as coarse aggregates and ordinary Portland cement (OPC) as a mineral filler. The specific gravity of coarse aggregate, fine aggregate, palm kernel shell and OPS are 2.57, 2.26, 0.90 and 3.13 respectively. The bitumen used was 85.5 mm penetration grade and having softening point of 42.25°C.

### **Methodology**

Results from a trial and error method of blending aggregate revealed 53% of coarse-grained sizes, 35% of the fine-grained and mineral fine of 12% in the mixture. These material proportions were mixed with bitumen content at range 5%-7% with temperature between 175-190°C and compacted in the mould for the Marshall Stability tests. Two different number of compaction were applied, that is 50 blows and 35 blows. Palm kernel shells were added at 10%, 30% and 100% by weight of total coarse aggregate (5mm-14mm) still maintaining the percentages so that the palm kernel shell acts as a replacement for the coarse aggregate. Three samples were prepared and Marshall Stability tests were carried out on the samples as per shown below.



## RESULTS AND DISCUSSION

### Palm Kernel Shell Asphalt Mix Design Result

#### 50 Blows of Compaction (Medium Traffic Design)

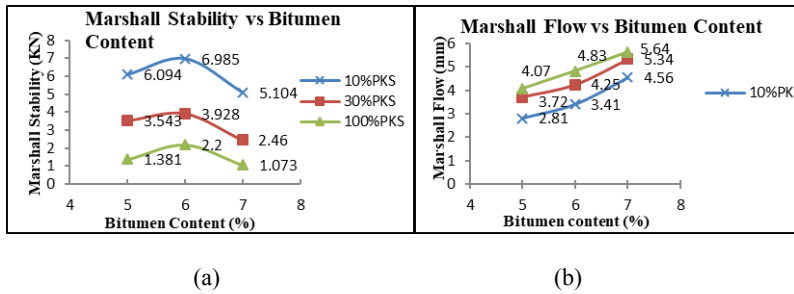


Figure 1. (a) Marshall Stability curves for modified mixes; and (b) Marshall flow curves for modified mixes

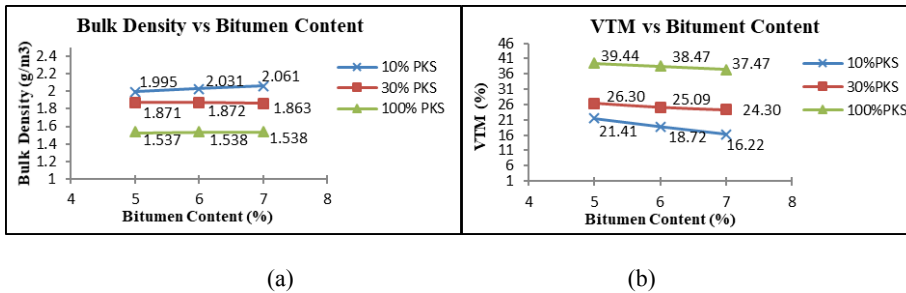


Figure 2. (a) Bulk density curves for modified mixes; and (b) Voids in Total Mix percent curves for modified mixes

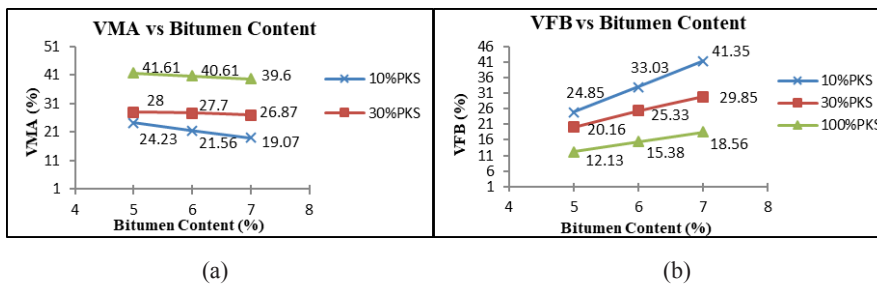


Figure 3. (a) Voids in Minerals Aggregates percent curves for modified; and (b) Voids Filled with Bitumen percent curves for modified mixes

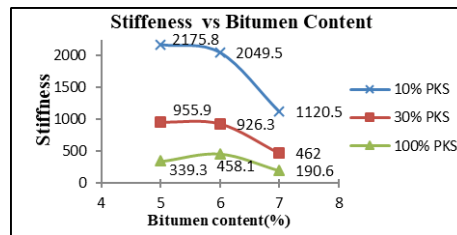


Figure 4. Stiffness curves for modified mixes

### Marshall Stability

The results shown in Figure 1(a) represent the stability of asphalt specimens at various percentages palm kernel shell (PKS) replacement. All of the line graphs had similar appearances as a smooth curve. Highest stability was reached 6.985 KN at 10% PKS replacement and lowest stability at 2.2 KN when replaced with 100% of PKS. This shows that a reduction in the percentage of up to almost 50%. When the course was reduced and palm kernel shells added, the Marshall stability was also reduced.

### Marshall Flow

Based on Figure 1(b), the highest flow values reached 100% PKS replacement is 4.07mm at 7% bitumen content while the second highest of flow was observed at 30% PKS replacement and almost similar value at 7% bitumen content with 100% PKS replacement with different of 0.03mm. The lowest flow was observed at 10% PKS replacement with 5% percentage of bitumen content, indicating the increased percentage of PKS in the mixture of the specimen tends to reduce the stability of the specimen. A reduction of flow implies better strength of the mixed specimen.

### Bulk Density

Figure 2(a) represents the computed test results obtained from bulk density of PKS asphalt specimens at various percentage of PKS replacement and mixed at specified bitumen content percentages. The specific gravity varies due to the aggregate composition and specific gravity of the PKS does not place it in the category of common rock groups whose gravities range from 2.62-3.00 (Nevile, 1995). Hence, the lowest bulk density is obtained when 100% of PKS replaced at the coarse aggregate compared to the 10% of PKS replacement which had the highest bulk density due to the normal coarse aggregate partially exist in the mix.

### Voids in Total Mix (VTM)

Based on the graph in Figure 2(b), 100% PKS mixtures achieved the highest VTM percent of 39.44% at 5% bitumen contents and decreased as the bitumen content was increased. The PKS replacement at the coarse aggregate will result in higher VTM which leads to the permeability

of water resulting premature hardening of the asphalt pavement. High percent VTM indicates the compacted mixture with PKS replacement has a high tendency not occupied by aggregate or asphalt. Besides due to the density and voids are directly related, the lower the bulk specific gravity or density, the higher the percentage of voids in the mix

**Voids in Mineral Aggregate (VMA)**

Figure 3(a) shows increasing bitumen content will reduce the percent of VMA as the aggregate tends to absorb more asphalt binder and reduced the volume of the asphalt not absorbed into the aggregate. The highest percent of VMA is 41.61% at 5% bitumen content for 100% PKS followed by 26.87% at 7% bitumen content for 30% PKS and lastly, the lowest VMA is 19.07% at 7% bitumen content for 10% PKS. This indicates the increasing PKS will result in a high percent of VMA due to PKS aggregate shape being is more angular.

**Voids Filled with Bitumen (VFB)**

Figure 3(b), shows 10% PKS has the highest percent of VFB compared to 30% PKS and 100% PKS. This indicates as more PKS is introduced to the specimen, the percent of VFB decreases, and where low percent VFB indicates the modified bitumen mix resulting thin film of binder due to PKS aggregate reveal higher in binder absorption compared to normal coarse aggregates.

**Stiffness**

Figure 4 shows the relationship between stiffness and bitumen content. The stiffness for 10% PKS replacement was greater than the 30% PKS replacement and 100% PKS replacement. The decrease in Marshall Stability value indicates the specimens are less stiff. The low value of stiffness is due to the lack of a proper degree of both internal friction and cohesion of the modified bitumen mix which can result in the aggregate particles being moved past each other by the forces exerted.

**35 Blows of Compaction (Low Traffic Design)**

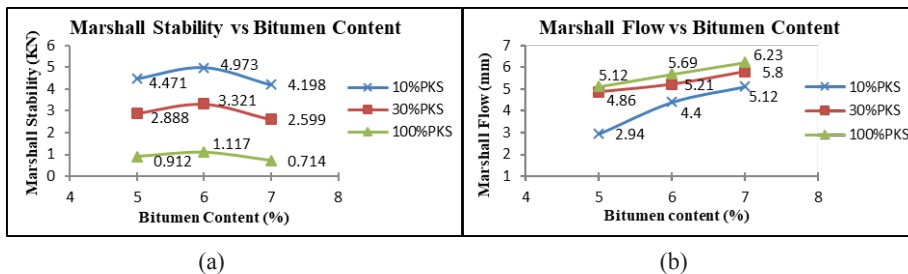


Figure 5. (a) Marshall stability curves for modified mixes; and (b) Marshall flow curves for modified mixes

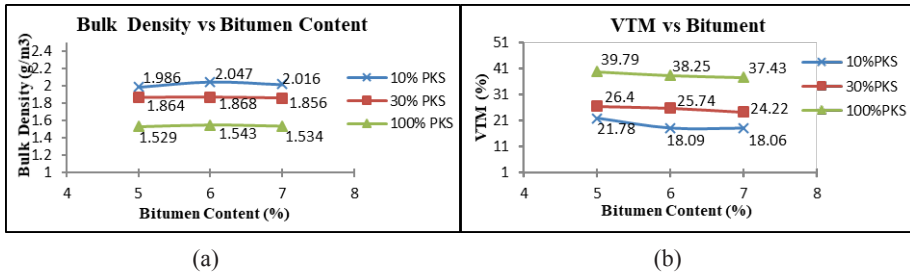


Figure 6. (a) Bulk Density curves for modified mixes; and (b) Voids in Total Mix percent curves for modified mixes

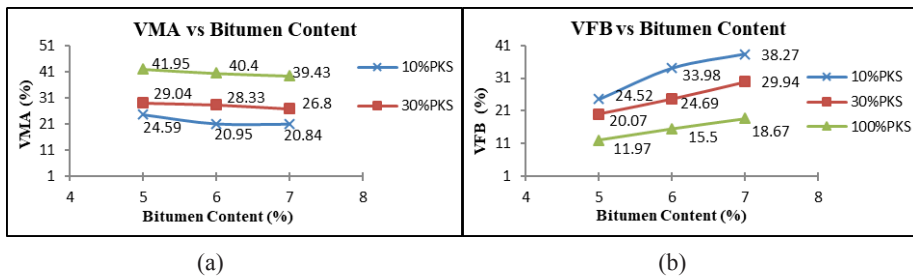


Figure 7. (a) Voids in Minerals Aggregates percent curves for modified; and (b) Voids Filled with Bitumen percent curves for modified mixes

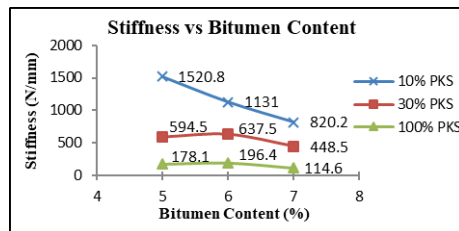


Figure 8. Stiffness curves for modified mixes

### Marshall Stability

Figure 5(a) shows the graph of Marshall Stability with 35 numbers of blows. The pattern of the graph is similar with Figure 1 and the reduction of Marshall Stability value is due to the low percentage of normal aggregate used. At 35 blows of compaction a low value of Marshall Stability was recorded since particles in the mixture are not interlocked as closely as when the specimens are subjected to 50 blows of compaction. Blades and Kearney (2004) mentioned that compaction provides adequate lubrication for aggregates to stick each other, and improves quality.

### **Marshall Flow**

Figure 5(b) presents Marshall Flow values based on bitumen content. It is clear that flow values of different percentage PKS replacement increases as the bitumen content increases, and similar to asphalt concrete mixture. The result indicates the replacement of PKS at coarse aggregate gives higher values of Marshall Flow due to the low interlocking and friction resistance of PKS aggregate.

### **Bulk Density**

Figure 6(a) shows the bulk density for various percentages of PKS as a function of bitumen content. It was noted bulk density curves for all percentage PKS replacement shows the same trend as that of hot mixes prepared with various bitumen contents. The graph also shows that for the same bitumen content, the bulk density for 10% PKS replacement is higher than that of 30% PKS replacement and 100% PKS replacement. This reduction in values of bulk density for PKS asphalt specimen results from the low specific gravity of PKS.

### **Voids in the Total Mix (VTM)**

Figure 6(b) shows the relationship between the percent of voids in the total mix and bitumen content for different percentage of PKS replacement. It can be noticed that the percentage of VTM decreases with an increase in the bitumen content. So too, the percentage of VTM for 100% PKS replacement is higher than that of 10% PKS replacement and 30% replacement for various bitumen content. The surface texture of PKS is rough and different from normal coarse aggregate. According to Chadbourn (2000), aggregates with rough surfaces have a high level of internal frictions, higher air voids and higher VMA. Hence, the greater the amount of PKS added to a specimen the higher the percentage of VTM.

### **Voids in Mineral Aggregate (VMA)**

Figure 7(a) shows the percentage of VMA for various quantities of PKS and bitumen content. It indicates that percentage of VMA for different proportions of PKS replacement decreased with increasing percent of bitumen content and rising when PKS added to the specimen is increased. This is due to the increased number of sharp edges and fractured faces as angularity of the PKS aggregate creates more void space during compaction.

### **Voids Filled with Bitumen (VFB)**

Figure 7(b) shows the percentage of VFB rises with an increase in bitumen content. The graph above indicates that for the same bitumen content, percentage of VFB for 10% PKS replacement is higher than that of 30% and 100% PKS replacement.

## Stiffness

Figure 8 shows the relationship between stiffness and bitumen content. The graph shows stiffness for 10% PKS replacement was greater than 30% and 100% PKS replacement. The reduction in the Marshall Stability value with the increase of Marshall Flow value will indicate lower stiffness of the specimens. Additionally, the stiffness of asphalt improved due to higher degree of compaction.

## Marshall Result and Specifications

Table 1 until Table 2 shows the Marshall result and specification based on JKR/SPJ/rev 2008 and Asphalt Institute standard, 1979. The results obtained are based on the optimum bitumen content of the mix.

Table 1  
50 blows of compaction

	Value at OBC			Specifications	
	10% Replacement	30% Replacement	100% Replacement	JKR/SPJ/rev 2008	Asphalt Institute, 1979
				Heavy Traffic Volume Design	Medium Traffic Design
Stability	5.57 KN	3.19 KN	1.35 KN	>8000 N	3336 N (minimum)
Flow	4.33 mm	4.80 mm	5.44 mm	2.0 mm - 4.0 mm	2.0 mm - 4.5 mm
Stiffness	1351 N/mm	692 N/mm	257 N/mm	>2000N/mm	-
Air Voids in Total Mix (VTM)	17%	25%	38%	3.0% - 5.0%	3.0% - 5.0%
Voids in Aggregate Filled with bitumen (VFB)	39%	28%	18%	70% - 80%	-
Voids in Mineral Aggregate (VMA)	38%	27%	40%	-	14.8%

Table 2  
35 blows of compaction

	Value at OBC			Specifications	
	10% Replacement	30% Replacement	100% Replacement	JKR/SPJ/rev 2008	Asphalt Institute, 1979
				Heavy Traffic Volume Design	Medium Traffic Design
Stability	4.59 KN	3.14 KN	0.92 KN	>8000 N	2224 N (minimum)
Flow	4.76 mm	5.35 mm	5.96 mm	2.0 mm - 4.0 mm	2.0 mm – 5.0 mm
Stiffness	974 N/mm	590 N/mm	155 N/mm	>2000N/mm	-
Air Voids in Total Mix (VTM)	18%	25%	38%	3.0% - 5.0%	3.0% - 5.0%
Voids in Aggregate Filled with bitumen (VFB)	36%	26%	17%	70% - 80%	-
Voids in Mineral Aggregate (VMA)	20.4%	28%	40.2%	-	14.8%

Generally, 10%, 30% and 100% replacement of PKS in ACW 14 does not satisfy the requirement needed by JKR standard. Data shown in Table 1 and table 2 is based on the standard requirement stated in Asphalt Institute, 1979. Replacement of 10% of PKS in ACW 14 has potential for medium traffic design and 10% and 30% for light traffic design. Percent of VTM and VMA does not meet the requirement.

## CONCLUSION

Data from this research found that palm kernel shell used as a coarse aggregate replacement has potential for use in both medium and light traffic design. Based on the optimum bitumen content, 10% PKS and 30% PKS can be used to replace coarse aggregate in HMA for light traffic design and only 10% PKS for medium traffic design. The performance on modified bitumen mix is not 100% perform well as several parameters did not satisfy the specification.

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## REFERENCES

- Blades, C., & Kearney, E. (2004). Asphalt paving principle. *Cornell Local Roads Program*.
- Chadbourn, B. A., Skok, E. L., Newcomb, D. E., Crow, B. L., & Spindle, S. (1999). The effect of voids in mineral aggregate (vma) on hot-mix asphalt pavements. *Minnesota Department of Transportation*.
- Lee, S. L., & Chan, R. A., (2012). Examining the potential used of raw oil palm shell as aggregate replacement for high volume road. *UNIMAS E-journal of Civil Engineering*, 1(1).
- MPOB (Malaysian Palm Oil Board). (2013). Malaysian oil palm statistics 2013 – oil palm planted area by states as at December 2012. Malaysia. Retrieved from: <http://bepi.mpob.gov.my/index.php/statistics/area/110-area/567-oil-palm-planted-area-dec-2012.html>. Accessed on 3 June 2013.
- Ndoke, P. N. (2006). The performance of palm kernel shells as a partial replacement for coarse aggregate in asphalt concrete. *Leonardo Electronic Journal of Practices and Technologie*, 5(6), 145-152
- Nevile A. M. (1995) *Properties of concrete*. Edinburg, Scotland: Pearson Education. 108-176.
- Sherwood, P. T., (1995). *Alternative Materials in Road Construction*. 1sted. Thomas Telford Publications, London.
- Zemke, N., & Woods, E. (2009). *Rice Husk Ash*. California Polytechnic State University.



## Honeydew Rind Activated Carbon as an Adsorbent for Zn(II) and Cr(III) Removal from Aqueous Solution: An Optimization Study

Zalilah Murni Yunus<sup>1\*</sup>, Norzila Othman<sup>2</sup>, Rafidah Hamdan<sup>2</sup> and Nurun Najwa Ruslan<sup>1</sup>

<sup>1</sup>Department of Science, Faculty of Science, Technology & Human Development, University Tun Hussein Onn, 86400 Parit Raja, Johor, Malaysia

<sup>2</sup>Department of Water Engineering, Faculty of Civil & Environmental; Engineering, University Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia

### ABSTRACT

A combination of phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) 20% v/v impregnation and carbonization method was employed to convert honeydew rind into activated carbons (ACPHDR) for Zn(II) and Cr(III) removal aqueous solution. The characterization of ACPDHR by N<sub>2</sub> sorption, iodine number and Boehm analysis result 1272 m<sup>2</sup>/g surface area, 1174 mg/g and 1.13 mmol/g total acidic functional groups respectively. Fourier transform infrared (FTIR) and Field emission scanning electron microscopy-electron dispersed microscopy (FESEM-EDX) analysis of unloaded and metal-loaded carbon showed shifted of significance peaks and the changes of surface morphology of the sorbent. The adsorption was optimized at pH, shaking duration, initial metal concentration and mass of adsorbent of 5.5, 40 min and 500 mg/L, 0.4 g for Zn(II) and 4, 40 min, 1000 mg/L, 0.1 g for Cr(III) removal. It is concluded that the metal removal was influenced by pH solution, contact time, initial metal concentration and mass of adsorbent. The highest removal of Zn(II) and Cr(III) was observed at 84.24% and 90.10% respectively. Waste from honeydew will be benefited from this research which offer a cheaper alternative precursor to coal based activated carbons.

*Keywords:* Heavy metals, honeydew rind, impregnated, low cost adsorbent, phosphoric acid

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*E-mail addresses:*

zalilah@uthm.edu.my (Zalilah Murni Yunus),

norzila@uthm.edu.my (Norzila Othman),

rafidahh@uthm.edu.my (Rafidah Hamdan),

nurunajwa@uthm.edu.my (Nurun Najwa Ruslan)

\*Corresponding Author

### INTRODUCTION

Heavy metals removal from polluted water has become one of the most imperative environmental issues due to their acute toxicity towards aquatic, human and other forms of life. Zn(II) is a harmful metal toxin and frequent contaminant found in industrial discharge. Types of industrial discharge

contains Zn(II) are chemicals, petroleum refinery, pulp and paper mills plants (Moreno-Barbosa et al., 2013). Cr(III) in effluents commonly originated from textile mills, batteries, fertilizers, air craft plating and finishing (Sharma et al., 2011). Unlike other toxins, heavy metals are non-biodegradable and remain serious potential hazard to human lives (Hegazi, 2013). Therefore, sufficient remediation of the industrial wastewater before it is discharged into public water bodies is of essential for human health and environmental nature.

Method of the industrial effluents remediation commonly used are precipitation, coagulation, ion exchange, adsorption and electroplating. Although these conventional methods have been in use over the years for the elimination of excess concentration of heavy metals from polluted water, they are usually expensive and sometimes resulted to incomplete removal of pollutant issue (Zhao et al., 2016). Adsorption is known as the most practical method of wastewater treatment. However the use of activated carbon (AC) such as economical-coal-based adsorbent and palm kernel activated charcoal spikes the operational cost (Abdullah et al., 2010). Therefore there is the need to develop more potent and economical method of treatment for the elimination of heavy metals from effluents specifically to new precursor of AC (Nowicki et al., 2015).

Rice husk (Suhas et al., 2016), soybean hulls, waste tea leaves (Wankhade & Ganvir, 2013), peanut shells, and langsat (Foo & Hameed, 2012) are among of fruit waste contain carboxyl and hydroxyl functional groups which can be involved in metal binding and have been studied as a potential AC precursors (Chen et al., 2013). To date, little research works have been done to investigate honeydew rind (HDR) for its potential as activated carbon. This work is therefore to contribute to the search and the possibility of utilizing HDR, which are found in abundance locally. The objectives are to produce activated carbon form honeydew rind by chemical activation, to study the optimization of Zn(II) and Cr(III) removal in batch adsorption using ACPHD and to study the isotherm and equilibrium adsorption.

## **MATERIALS AND METHODS**

### **Preparation of Impregnated HDR**

Honeydew rinds were collected from fruit juice stalls and restaurants in Batu Pahat, Johor. They were washed with tap water and soaked in nitric acid 5% for 6 h to remove earthy impurities. After the acid was drained the rinds was immersed in distilled water in order to discard excess acid. The rinds was next rinsed and oven-dried at 60°C, kept in dry storage for the use as precursor material in activated carbon production (Yunus et al., 2015).

### **Impregnation**

The purpose of impregnation step is to improve pores development on the surface of the rind. Phosphoric acid has been preferred in agricultural base-AC production in previous work (Birbas, 2011; Humpola et al., 2016). The superiority of H<sub>3</sub>PO<sub>4</sub> is its environmental character (Birbas, 2011). The dried HDR was soaked with H<sub>3</sub>PO<sub>4</sub> of 20% v/v for 6 h. The chemical was drained off and the impregnated HDR and oven dried at 110°C.

## Carbonization

All the impregnated HDR were carbonized in muffle furnace (Protherm PLF, Turkey). The sample was placed in crucible and the furnace was run at the following temperature program; the muffle was heated at 5°C/min up to 300°C. At this temperature, it was held for 15 min to release any volatile organic compounds from the sample. The heating was continued up to 490°C at 5°C/min and soaked for 30 min (Kalijadis et al., 2011). The carbon was allowed to cool down in desiccator. The low temperature-ramp rate was applied to lessen the internal temperature acclivity of the sample. Specific temperature range was subjected to the sample for to get desirable carbonization extent (Nurdin et al., 2015).

## Characterization

FTIR spectrometer (PE Spectrum 100 USA) was employed to determine the presence of surface functional groups in ACPHDR with the range of 4000–400 cm<sup>-1</sup>, FESEM-EDX (JEOL JSM-6335F, USA) for surface morphology observations, atomic absorption spectrometer (PE Analyst 800, USA) for metal ions concentration determination, Brunauer, Emmet and Teller (BET) for surface area determination (SA 3100 Surface Analyser (Beckman Coulter)) at 77 K, Iodine number test ASTM D4607-94 (ASTM 2006) and Boehm (Boehm, 2002).

## Adsorption Optimization Study

The optimization of metal adsorption parameter was investigated. The parameters were pH of solution, shaking duration and initial metal concentration. Table 1 shows the adsorption parameters for optimization study.

Table 1  
*The conditions used for the Zn(II) and Cr(III) adsorption onto ACPHDR optimization experiments*

Parameter	Range	
	Zn(II)	Cr(III)
pH	4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0	2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5
Shaking duration (min)	10, 20, 40, 60, 90, 110	10, 20, 40, 60, 90, 110
Initial metal concentration (mg/L)	200, 300, 400, 500, 600	700, 800, 900, 1000, 1100
Mass of adsorbent (g)	0.1, 0.2, 0.3, 0.5, 0.7, 1.0	0.1, 0.2, 0.3, 0.5, 0.7, 1.0

## RESULTS AND DISCUSSION

### FTIR Spectra and SEM Micrographs

The band assignments of native and metal-bounded carbons, the shifted peaks are presented in Table 2. The metal-loaded adsorbent performed shifted peak as the effect of metal bound. The bands at around 3200 cm<sup>-1</sup> representing bonded OH functional groups for all AC. The presence of C=C and C–O–C groups were marked by the bands at 1221.83 cm<sup>-1</sup> for native ACPHDR and shifted to 1219.83 cm<sup>-1</sup> for Zn(II) loaded AC and 1219.02 cm<sup>-1</sup> for Cr(III) loaded AC due to metal adsorption. These peaks were the acclaimed potential adsorption sites for the metal ions (Humpola et al., 2013).

Table 2  
*FTIR assignments for native ACPHDR and metal bound ACPHDR*

Unloaded ACPHDR	Wavenumber (cm <sup>-1</sup> )				Assignment
	Zn(II)-loaded ACPHDR	Difference	Cr(III)-loaded ACPHDR	Difference	
1033.97	1057.04	+23.07	1060.58	+26.61	hydrogen-bonded P=O to O-C
1221.84	1219.83	-2.01	1219.02	-2.82	C-O-C bond
1237.61	1242.38	+4.77	1243.53	+10.92	C-N amine group
1580.94	1581.75	+0.81	1587.03	+6.09	Secondary amine group
2910.58	2893.53	-17.05	2891.49	-19.09	C-H aliphatic group
3205.31	3224.79	+19.48	3231.04	+25.73	Bonded -OH groups

### Surface Textural and Surface Morphology Analysis

The observation from FESEM micrograph reveals that native ACPHDR of the group were highly porous with honeycomb-like or tunnel shaped surface structures (Figure 1a(i)). The surface morphology of metal bound ACPHDR (Figure 1(b)(i) and (c)(i)) appeared differently whereby the pores have been covered with Zn and Cr that appears as shiny particle due to adsorption process. EDX spectra of bounded sorbent indicates of metal adsorption has occurred on the sorbent surface (Figure 1(a)(ii) and (b)(ii)) which did not exist on native adsorbent (Figure 1(a)(ii)). The surface textural analysis, iodine number and Boehm analysis has resulted as follows; 1272 m<sup>2</sup>/g surface, 1174 mg/g and 1.13 mmol/g respectively. In comparison, the iodine number of commercial AC has in average of 800-1200 mg/g (Higazi, 2015). The analysis demonstrated ACPHDR has high porosity surface and acidic in nature. The acidic functional groups was complex with Zn(II) and Cr(III) and thus increased metal adsorption by the carbons (Ibrahim et al., 2016; Zhou et al., 2016).

### The Effect of pH

In aqueous system, solubility and polarity of sorbate influenced by pH solution thus impact the adsorption capacity of adsorbent (Sharma et al., 2011). It is observed an increase of Zn(II) removal with increasing of pH solution from the initial pH to the higher pH value (Figure 2(a)). The optimum pH solution was found at 5.5, which showed 87.23% removal before it decreased consistently at the higher pH until the maximum pH value was reached. The best Cr(III) removal percentage was obtained at pH 4; 90.14% meanwhile the adsorption capacity was 900.02 mg/g.

### The Effect of Shaking Time

The adsorption rate of both metals were observed as rapid in the initial shaking duration succeeded by a gradual ascending with time until equilibrium adsorption (Zn(II) 339.25 mg/g; Cr(III) 888.06 mg/g) was noticed at 40 min (Figure 2(b)). Additional increment in shaking time

did not demonstrate obvious change in equilibrium concentration. The behavior is common as a result of the surfeit of the available adsorption sites (Hegazi, 2013). The metals rapid adsorption at the early stage was probably as the effect of the initial concentration gradient as the removal value decreased to (Zn(II) 54.14%, Cr(III) 79.87%) at the final pH.

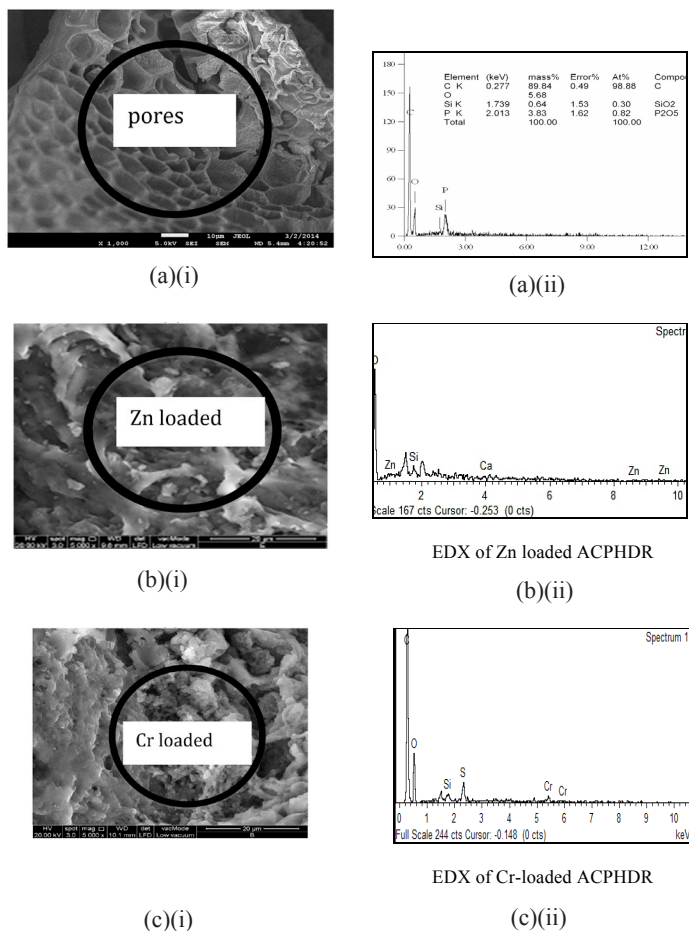


Figure 1. FESEM micrograph of adsorbent surface and EDX Diagram: (a) Native ACPHDR. (1000x magnification); (b) Zn-loaded ACP; and (c) Cr-loaded ACP (marked as in the circle) (5000x magnification)

### The Effect of Initial Metal Concentration

Both metals uptake and percentage removal lessen at higher solution concentrations (Figure 2(c)). Lower concentrations resulted low metal ions binding due to the small number of available sorption sites and consequently the initial concentration affect the constituent adsorption until it reached equilibrium pH. At higher concentrations, however, the binding sites of adsorption

become less available concluded the initial concentration is a significant factor in metals removal (Wahi et al., 2011).

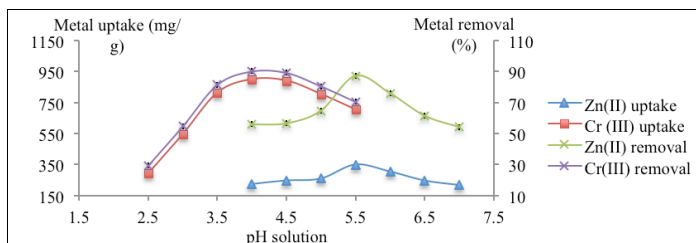


Figure 2. (a) The effect of pH solution Zn(II) and Cr(III) adsorption

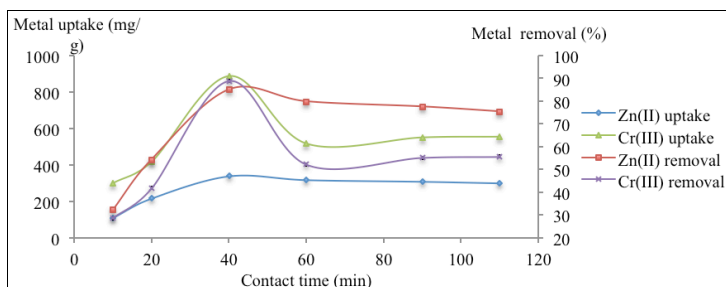


Figure 2. (b) The effect of contact time and on Zn(II) and Cr(III) adsorption

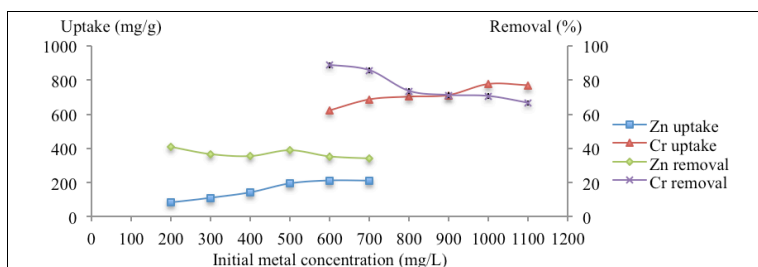


Figure 2. (c) The effect of initial metal concentration on Zn(II) and Cr(III) adsorption

### The Effect of Mass of Adsorbent

Result indicated that both metals uptake decrease with an increase in adsorbent mass (Figure 2(d)). Metal uptake of Zn(II) and Cr(III) showed a decrease from 305.93 mg/g to 64.31 mg/g and 859.36 mg/g to 281.57 mg/g respectively when the mass of adsorbent rose from 0.1 g to 1.0 g. The removal of Zn(II) increased from 74% to 82.90% at (0.1-0.5 g) of ACHDR and however decrease until the final mass of adsorbent. Cr(II) removal was observed continual decrease (85.94 - 50.13%) until the final mass of ACPHR. The optimum ACPDHR mass was found at 0.4 g and 0.1 g for Cr(III) and Zn(II) respectively.

## Honeydew Rind Activated Carbon as an Adsorbent

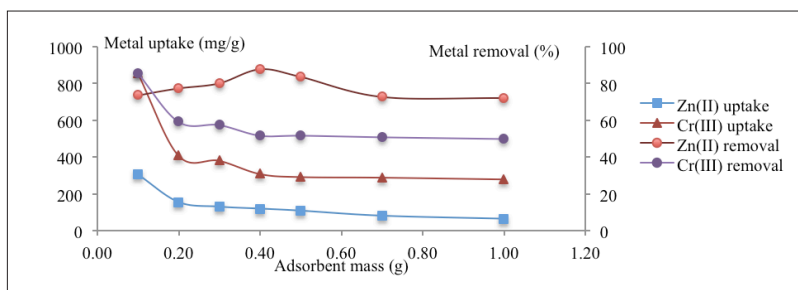


Figure 2. (d) The Effect of Mass Adsorbent on Zn(II) and Cr(III) adsorption

## CONCLUSION

According from the present work, activated carbon generated from honeydew rind demonstrates as being a good adsorbent for wastewater treatment. Adsorption study concluded that the metals removal was influenced by pH solution, contact time, initial metal concentration and mass of ACPHDR. The highest removal of Zn(II) and Cr(III) was investigated at 84.24% and 90.10% respectively at optimized adsorption condition. It is concluded that the waste from honeydew will be benefited from this research because offers a cheaper alternative precursor to coal based activated carbons. Thus, the study convinces that ACPHDR could be promising material as adsorbent for the removal of Zn(II) and Cr(III) from aqueous solution.

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## REFERENCES

- Abdullah, L. C., Muhammad, Shima, S. J., & Choong, T. S. Y. (2010). Modelling of single and binary adsorptions of heavy metals onto activated carbon - Equilibrium studies. *Pertanika Journal of Science and Technology*, 18(1), 83–93
- Birbas, D. (2011). Preparation of Activated Carbon : Forest residues activated with Phosphoric Acid and Zinc Sulfate. *P. Royal Institute of Technology, Sweden*, 12-14.
- Boehm, H. P. (2002). Surface oxides on carbon and their analysis : A critical assessment. *Carbon*, 40, 45–149.
- Carbon, S. T. M. for D. of I. N. of A. (2006). *ASTM Designation:D. 4607-94*.
- Foo, K. Y., & Hameed, B. H. (2012). Preparation of activated carbon by microwave heating of langsat (*Lansium domesticum*) empty fruit bunch waste. *Bioresour. Technol.*, 116, 522–525.
- Gundogdu, A., Duran, C., Senturk, H. B., Soylak, M., Imamoglu, M., & Onal, Y. (2013). Physicochemical characteristics of a novel activated carbon produced from tea industry waste. *J. Anal. Appl. Pyrolysis*, 104, 249–259.
- Hegazi, H. A. (2013). Removal of heavy metals from wastewater using agricultural and industrial wastes as adsorbents. *HBRC Journal*, 9(3), 276–282.



- Humpola, P. Odettie, J., Moreno-Pirajan, J.C., & Giraldo, L. (2016). Activated carbons obtained from agro-waste: textural analysis and adsorption environmental pollutants. *Adsorption*, 22, 23-31.
- Ibrahim, W. M., Hassan, A F., & Azab, Y A. (2016). Biosorption of toxic heavy metals from aqueous solution by *Ulva Lactuca* activated carbon. *Egyptioan Journal of Basic Applied Sciences*. doi: 10.1016/j.ejbas.2016.07.005
- Moreno-Barbosa, J., Lopez-Velandia, Maldonado, A., Giraldo, L., & Moreno-Pirajan, J. (2013). Removal of lead(II) and zinc(II) ions from aqueous solutions by adsorption onto activated carbon synthesized from watermelon shell and walnut shell. *Adsorption*, 19(2-4), 675–685.
- Nowicki, P., Kazmierczak, J., & Pietrzak, R. (2015). Comparison of physicochemical and sorption properties of activated carbons prepared by physical and chemical activation of cherry stones. *Powder Technol.*, 269, 312–319.
- Nuridin, S., Roslan, A., Seddiq A. Abbakar, M., A. Khairuddin, S., & Athirah M. Sukri, H. (2015). Rock melon activated carbon (rmac) for removal of Cd(II), Ni(II) and Cu(II) from Wastewater: Kinetics and Adsorption Equilibrium. *Intern. J. Chem. Eng. Appl.*, 6(2), 105–110.
- Sharma, P., Kaur, H., Sharma, M., & Sahore, V. (2011). A review on applicability of naturally available adsorbents for the removal of hazardous dyes from aqueous waste. *Environ. Monitor. Asses.*, 183(1-4), 151–195.
- Suhas, Gupta, V., Carrott, P.J.M., Singh, R., Chaudhary, M., & Kushwaha, S. (2016). Cellulose: A review as natural, modified and activated carbon adsorbent. *Bioresour. Technol.* 216, 1066-1076.
- Wahi, R., & Senghie, H. (2011). The use of microwave derived activated carbon for removal of heavy metal in aqueous solution. *J. Sci. Technol.*, 3(1), 97–108.
- Wankhade, A. A., & Ganvir, V. N. (2013). Preparation of low cost activated carbon from tea waste using sulphuric acid as activating agent. *Int. Res. J. Environment Sc*, 2(4), 53–55.
- Yunus, Z. M., Othman, N., Hamdan, R., & Ruslan, N. N. (2015). Characterization of phosphoric acid impregnated activated carbon produced from honeydew peel. *J. Teknol.*, 76(5), 15–19.
- Zhou, Y., Zhang, Z., & Zhang, J. (2016). New insight into adsorption characteristics and mechanisms of biosorbent from waste activated sludge for heavy metals. *J. Environ, Sci. (China)*, 45, 248-256.





## The Effects of POFA and SF as TBC Binder on the Heat of Hydration and Compressive Strength of Mortar

Nor Umairah Abd Rahim<sup>1\*</sup> and Mohd Fadzil bin Arshad<sup>2</sup>

<sup>1</sup>Linton University College, 71700 Mantin, Negeri Sembilan, Malaysia

<sup>2</sup>FKA UiTM Shah Alam, 40450 Shah Alam, Selangor, Malaysia

### ABSTRACT

Ordinary Portland Cement (OPC) is widely used by the construction industry. Research to find the precise proportion of cement replacement material which can be used to produce a product called Ternary Blended Cement (TBC) is not new. The objective of this study is to determine the effect of POFA and SF as TBC on the heat of hydration and compressive strength of mortar. Before producing TBC, specimens using BBC is required. Mix design proportion for POFA and SF are 5%, 10%, 15%, and 20%. Mix design proportion TBC are chose from the highest compressive strength value achieved at 7 days of curing. This research found the heat of hydration of TBC containing 20% POFA and 5% SF is high in the beginning to drop at the end of hydration process in addition to producing lower compressive strength.

*Keywords:* BBC, compressive strength, heat of hydration, OPC, POFA, SF, TBC

### INTRODUCTION

#### Background of Study

Excessive carbon dioxide (CO<sub>2</sub>) emissions need to be reduced in the interest of ensuring sustainability. The use of cement replacement material is to replace the excessive usage of Ordinary Portland cement (OPC) can reduce CO<sub>2</sub> emission. Among the cement replacement

materials examined in this study are Palm Oil Fuel Ash (POFA) and Silica Fume (SF). These two wastes have been selected to produce Ternary Blended Cement (TBC) binder.

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##### E-mail addresses:

umairah@ktgeducation.edu.my (Nor Umairah Abd Rahim),

fadiil2013@yahoo.com (Mohd Fadzil bin Arshad)

\*Corresponding Author

#### Scope of Study

This study examines the effect of POFA and SF as cement replacement material in TBC binder on the heat of hydration and

compressive strength of mortar. Presently pozzolans are used only in BBC binder and the optimum replacement of pozzolan to OPC to be not more than 20% (Fadzil, Azmi, Hisyam, & Azizi, 2008). The percentage of cement replacement chosen for this study are 5%, 10%, 15% and 20% respectively. The water cement ratio was set at 0.50, and the experiments conducted at the Faculty of Civil Engineering, UiTM, Shah Alam Concrete and Non-Destructive Test Laboratory. The main materials used are OPC collected from Tasek Cement Berhad, POFA from palm oil mill factory Jengka Pahang, SF from SIKA Berhad, river sand from a local supplier, tap water from Syarikat Bekalan Air Selangor (SYABAS) Sdn Bhd, and distilled water. The SF used in this study is unclassified. 72 hours was needed for the cement hydration test equipment to complete the heat of hydration test. Total specimen for the test was 10. The specimen containing mortar weighed 10 g of control mortar with different percentage of POFA and also SF. Data from this experiment was collected and graph showing degree of hydration versus time was obtained. Reference and standard documents used for the test are ASTM C1679-14. For the compressive strength test, 120 mortar mould sized 50 mm x 50 mm x 50 mm was prepared. All TBC binder specimens can be tested for 1, 3, 7 and 28 days of curing, following which they were placed inside the curing tank and tested using compressive strength machine. British Standard BS EN196-1: 2005 served as the reference and standard document.

### **Significant of Study**

There is still some gap in knowledge on the effect of POFA and SF as TBC binder on the heat of hydration and compressive strength of mortar. The findings should be useful in encouraging the usage of TBC binder and reduce the usage of OPC for construction and contribute to greater sustainability.

## **MATERIALS AND METHODS**

### **Materials**

The cement is OPC and complies with ASTM Type 1 and Malaysian Standard MS522. Tasek Cement Berhad is the company supplier of this OPC. The sand that had been used is river sand and came from a local supplier. During the mixing of mortar specimen for Compressive Strength Test tap water from Syarikat Bekalan Air Selangor (SYABAS) Sdn Bhd is added gradually. The water cement ratio used in this study is 0.50. POFA was collected from palm oil mill factory Jengka Pahang, while unclassified silica fume (SF) came in the form of a 20 kg bag from SIKA Berhad. Distilled water was used when preparing mortar paste specimen for heat of hydration test. The water cement ratio of distilled water is same as water cement ratio used in mortar specimen in compressive strength test that is 0.50.

### **Methods**

The ratio that had been used in this study is 1:3 and aimed at achieving Grade 60 mortar. For the BBC binder test specimen, the design mix proportion used was 5%, 10%, 15% and also 20%. For TBC binder test specimen, design mix proportion was s OPC 75%, POFA 20% and SF 5%

and based on the highest compressive strength value achieved at 7 days of curing in BBC test specimen. A summary of the design mix proportion of mortar specimen is presented in Table 1.

Table 1  
*Design mix proportion of mortar specimen*

Control (%)	POFA (%)	SF (%)	Water Cement Ratio
100	-	-	0.5
95	5	-	0.5
90	10	-	0.5
85	15	-	0.5
80	20	-	0.5
95	-	5	0.5
90	-	10	0.5
85	-	15	0.5
80	-	20	0.5
75	20	5	0.5

The first step is the weighting of the material according to the chosen proportion, and mixed using a standard BS EN 196-1:2005 mechanical mixer. Sand is added into the bowl mixer following which OPC, POFA and SF was added together with water. In this study, the mould size 50mm x 50mm x 50mm was used and the poured in 3 layers. Each specimen is labelled according to date of casting and type of pozzolonic material used. After 24 hours, the mould were removed and cured by submerging them in a curing water tank for 1, 3, 7, 28 days before they are dried and weighed and recorded before being subjected to compressive test. For heat of hydration test the selected material is poured onto paper on the weighting machine. The mortars need to be exactly 10 g and are mixed and poured into a test tube and compacted. A syringe is used to take distilled water based on the ratio described in BS EN 196-1:2005. Figure 1 shows the mortar specimen casting process.

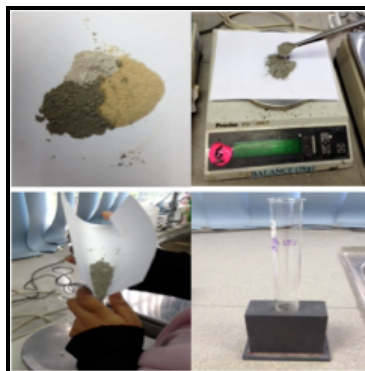


Figure 1. Casting process of mortar specimen

## Heat of Hydration and Compressive Strength Test for TBC Binder

For heat of hydration test, 3 tests cube specimens were tested and called Cell 1, Cell 2, and Cell 3. Before turning the cover of each cell holders clockwise, it is important to ensure that the display monitor is at zero. The compressive strength testing is conducted at 1, 3, 7 and 28 days following the curing process. The mortar specimen is tested to evaluate its performance according to BS 1881-16:1983. Before the compressive strength test is begun, the mortar specimen is dried and weighted. The machine is operated at pace rate of 0.9 kN/sec.

## RESULTS AND DISCUSSION

### Heat of Hydration of Tbc Binder

Figure 2 shows the heat of hydration of TBC binder and the controlled specimen. It shows the control specimen achieves the highest degree of hydration value compared to TBC binder. When mixing cement with water, a rapid heat evolution of a few minutes from 0 to 0.03 hours occurs. The graph shows that the heat of the aluminium and sulphates solution of TBC binder is higher than the control specimen.

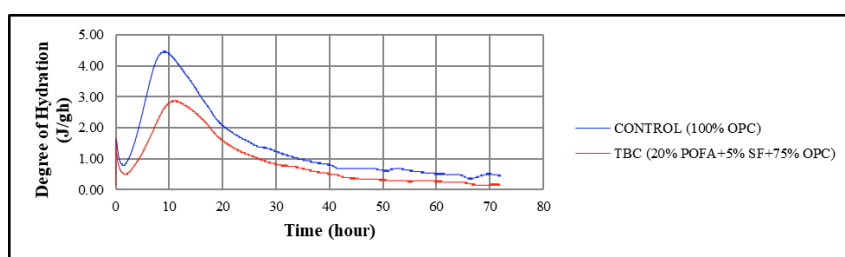


Figure 2. Heat of hydration of TBC binder (OPC+POFA+SF)

The graph shows hydration peak takes place at 8 to 11 hours. The highest value for hydration is 4.49 J/gh which is at 8.83 hour for the control specimen and 2.87 J/gh in 10.68 hour when TBC binder is used. Percentage difference between control specimens and TBC binder is more than 20%, which is 36.08% and considered significant. These difference in values of hydration maybe due to the different of pozzolanic reaction between TBC binder and the control specimen. The high degree of hydration for the control specimen might due to reactivity of 100% OPC caused the energy released at this point is higher as compared to TBC binder. At 0 to 10 hours, there is a huge difference in the projection of degree of hydration value for TBC binder and the control specimen, and be caused by initial thermal power by dissolution of cement and initial cement hydration occurs is differing between TBC binder and control specimen. From 20 to 72 hours the hydration value for both TBC binder and control specimen continues to decrease. From the discussion, it can be concluded that the degree of hydration

value for TBC binder is higher than the control specimen in the early stage of the hydration process. TBC binder is finer than OPC and therefore affect the rate of heat development for concrete or mortar mixture. Based on the finding obtained from this experiment, the hydration value of TBC binder containing 75% OPC, 20% POFA and 5% SF is high in the early stage; that is at 0.03 hours and continues to decline compared to the control specimen.

### Compressive Strength for Tbc Binder

Compressive strength test was successfully done on 120 samples. The compressive strength result for control specimen, different percentages of BBC binder and TBC binder contains POFA and SF at 1, 3, 7, and 28 days of curing as shown in Table 2. The purpose of preparing BBC binder specimen at different percentages of POFA or SF is to obtain the highest compressive strength value at 7 days of curing in order to choose the design mix proportion for the following TBC binder specimen.

Table 2  
*Design mix proportion of mortar specimen*

Control %	POFA %	SF %	Compressive Strength (N/mm <sup>2</sup> )			
			1 day	3 day	7 day	28 day
100	-	-	17.24	29.14	40.60	58.62
95	5	-	7.67	14.03	19.63	26.98
09	10	-	5.88	9.81	13.00	21.30
85	15	-	8.17	14.53	19.02	38.74
80	20	-	9.94	15.81	21.71	39.03
95	-	5	11.30	18.83	26.82	38.45
90	-	10	10.08	16.41	22.22	32.83
85	-	15	11.38	19.83	26.18	36.88
80	-	20	9.58	15.84	22.31	32.17
75	20	5	8.99	17.30	22.84	33.43

Based on Figure 3, the compressive strength value between TBC binders containing 20% POFA, 5%SF and 75% OPC and the control specimen is shown. From the figure, the control specimen still achieves the highest compressive strength value compared to TBC binder, which is 17.24 N/mm<sup>2</sup>, 29.14 N/mm<sup>2</sup>, 40.60 N/mm<sup>2</sup> and 58.62 N/mm<sup>2</sup> at 1, 3, 7 and 28 days of curing. TBC binder only achieved compressive strengths of 8.99 N/mm<sup>2</sup>, 17.30 N/mm<sup>2</sup>, 22.84 N/mm<sup>2</sup> and 33.43 N/mm<sup>2</sup> at 1, 3, 7 and 28 days of curing. The percentage difference between the control specimens and TBC binder at 28 days of curing was more than 20%, or 42.97% and is considered significant.

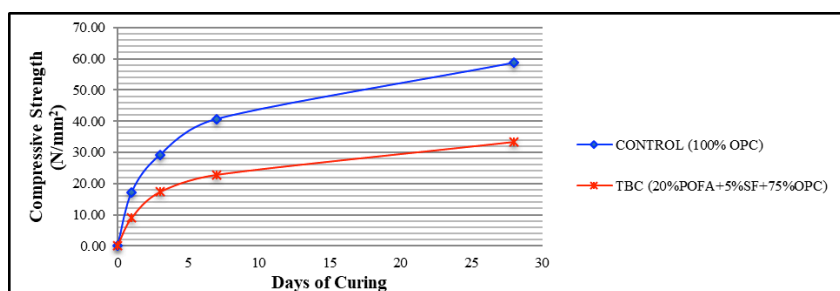


Figure 3. Graph compressive strength versus days of curing for control and TBC Binder (OPC+POFA+SF)

As seen from the graph, the compressive strength of the control specimen is increased drastically when cured from 1 to 7 days. For the TBC binder, strength is moderately increased until curing of 3 days. The high compressive strength of the control specimen compared to the TBC binder may be due to the high rate of hydration of OPC particles. Due to the effect of hydration process, the porosity of OPC decreases daily. The compressive strength of TBC binder at 3 days of curing is 17.30 N/mm<sup>2</sup> similar to that of 7 day of BBC binder containing 10% POFA. It can be concluded that TBC binder containing POFA and SF as cement replacement material improves the strength development of mortar. The result also shows that by using both cement replacement material like POFA and SF to create a new TBC binder can further strengthen the product. Research done by Rukzon and Chindaprasit (2009), stated that the blend of fine pozzolans is responsible for improving the strength of concrete due to the synergic effect. These findings are also supported by Bleszynski et al. (2002) which showed TBC binder has better overall durability compared to BBC binder.

## CONCLUSION

The heat of hydration of TBC binder containing 75% OPC, 20% POFA and 5% SF produces a high value of degree of hydration only in the early period and decreases towards the end of hydration process. The compressive strength of TBC binder with 75% OPC, 20% POFA and 5% SF produces a lower compressive strength value compared to the control specimen.

## REFERENCES

- Awal, A. S. M., & Hussin, M. W. (1997). The effectiveness of palm oil fuel ash in preventing expansion due to alkali-silica reaction. *Cement and Concrete Composites*, 19(4), 367-372.
- Bleszynski, R., Hooton, R. D., Thomas, M. D., & Rogers, C. A. (2002). Durability of ternary blend concrete with silica fume and blast-furnace slag: laboratory and outdoor exposure site studies. *ACI Materials Journal*, 99(5).
- Fadzil, A. M., Azmi, M. M., Hisyam, A. B., & Azizi, M. K. (2008). Engineering Properties of Ternary Blended Cement Containing Rice Husk Ash and Fly Ash as Partial Cement Replacement Materials. *ICCBT, A (10)*, 125-134.
- Rukzon, S., & Chindaprasit, P. (2009). Strength and chloride resistance of blended Portland Cement mortar containing POFA and Fly Ash. *International Journal of Minerals, Metallurgy and Materials*, 16(4), 475-481.

## Characterisation of Lateral and Vertical Subsurface Heterogeneity in the Ground using Sustainable Seismic Surface Wave Methodology

Madun, A.\*, Wijeyesekera, D. C., Ahmad Tajuddin, S. A., Zainalabidin, M. H., Yunus, R. and Tajul Baharudin, M. F.

*Faculty of Civil and Environmental Engineering & Research Centre for Soft Soil, University of Tun Hussein Onn, 84600 Parit Raja, Johor, Malaysia*

### ABSTRACT

Seismic surface waves are a non-destructive technique used to obtain the dynamic properties of soil by measuring the shear wave velocity and calculating the shear modulus of soil. The shear modulus is one of the parameters to measure the stiffness of materials. This study evaluates soil profiles and the position of the sensor while conducting measurements of two soil profiles, i.e. lateral and vertical non-homogeneities, using a continuous surface wave analysis (CSW) and multi-channel analysis of surface waves (MASW). Results showed the dispersive curve demonstrated an increased shear wave velocity with increasing depth for the sensor pair measurements on the clay (between columns), and decreased shear wave velocity with increasing depth for the sensor pair measurements on the column. In both instances the surface wave velocity results influenced by the depth and size of the wavelength, indicating that depth and wavelength controlled the volume of measurement in an elliptical shape. Therefore, the shear wave velocities and thus stiffness measured from the surface wave velocity techniques are represented the volume of soil measured across the sensor length.

*Keywords:* Continuous surface wave analysis, multi-channel analysis of surface wave, seismic surface wave testing, site investigation

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*E-mail addresses:*

aziman@uthm.edu.my (Madun, A.),

devapriya@uthm.edu.my (Wijeyesekera, D. C.),

saifulaz@uthm.edu.my (Ahmad Tajuddin, S. A.),

hazreek@uthm.edu.my (Zainalabidin, M. H.),

riduan@uthm.edu.my (Yunus, R.),

mdfaizal@uthm.edu.my (Tajul Baharudin, M. F.)

\*Corresponding Author

### INTRODUCTION

One of the main parameters used for predicting ground movement is its stiffness profile (Abbiss, 1981; Matthews et al., 1996). Stiffness can be defined as the resistance of the body to deformation under applied force (Clayton, 2011). The seismic-based techniques shake the ground and produces



very small strains and soil velocities measured to derive the geotechnical properties related to strain, maximum shear modulus, bulk modulus (B), Young's modulus (E), and Poisson's ratio ( $\nu$ ) (Badee et al., 2016; McDowell et al., 2002; Crice, 2005). Stiffness can be measured using seismic surface wave techniques such as continuous surface wave analysis (CSW) and multi-channel analysis of surface waves (MASW). Many studies had been conducted to obtain an empirical correlation between seismic data and geotechnical parameters. However, due to the heterogeneities of the ground the empirical correlation between seismic and geotechnical parameter is unique (Madun et al., 2010a; Madun et al., 2016c; Madun et al., 2016d). As experience by Ahmed et al. (2012) were made mistake in its interpretation of the shallow bedrock instead of a very soft sediment due to subsurface condition when using the multi-channel analysis of surface wave (MASW) technique. In contrast Matthews et al. (1995) concluded seismic wave technique can deliver results of significant quality and avoid the disadvantages associated with either laboratory or physical field tests. Therefore to ascertain seismic profile the nature of the ground has to be studied. In this paper soil profiles and the position of the sensor is evaluated when conducting seismic wave measurement. Two soil profiles, i.e. lateral and vertical non-homogeneities were evaluated using a continuous surface wave analysis (CSW) and multi-channel analysis of surface waves (MASW), respectively. The continuous surface wave analysis (CSW) used a pair of sensor while multi-channel analysis of surface waves (MASW) used 24 sensors. The aim of this paper was to evaluate the seismic surface wave test for characterizing the lateral and vertical non-homogeneities. Results of lateral non-homogeneities measurements are based on previous published papers (Madun et al., 2012b). Meanwhile, vertical heterogeneity was evaluated on soft marine clay deposits at the university campus. The site profile was confirmed via borehole records (Azhar et al., 2016; Madun et al., 2012e; Noor et al., 2016).

## MATERIALS AND METHODS

Two cases soil profiles, i.e. lateral and vertical non-homogeneities were evaluated using a continuous surface wave analysis (CSW) and multi-channel analysis of surface waves (MASW), respectively. Lateral non-homogeneities measurements conducted in laboratory-scale stone column model using continuous surface wave analysis (CSW) method was explained in Madun et al. (2012a). The array of receivers consisted of up to four piezoelectric accelerometers. The shaker as a seismic source was located at the middle of sensor-pairs. This technique is called the continuous surface wave analysis (CSW). The distance between the source and the first receiver,  $d$ , was set at 7 cm and receiver spacing,  $\Delta x$ , was 3 cm. The equipment was set up on the soft clay that contained the gravelly sand columns. The measurements made were: sensor-pair on column and sensor-pair between columns.

Vertical non-homogeneities measurements were conducted at a test site in the campus of Universiti Tun Hussein Onn Malaysia using the multi-channel analysis of surface waves (MASW) method. The borehole was located at the centre of the multi-channel analysis of surface waves (MASW) array. The MASW method uses an active seismic source which means the seismic wave energy generated at specified location along linear direction with spread length. This method requires three components, i.e. seismic source, sensor and data logger. A 7



kg of sledgehammer was used as source that impacted to the metal plate. The distance between source to the first sensor at set up at 15 m and sensor spacing of 5 m. The 24 sensors of 4.5 Hz vertical geophones were used to connect with 24 channel cables and ABEM Terraloc MK-8 seismograph was used as data logger. The record data at least 1 second length with sampling interval and number of samples at 250  $\mu$ s and 4096 respectively. Any filtering of noise must be turned off, in order to capture any seismic wave data. Array line cable at a length of 115 m long and should be in linear. The MASW data was processed using SeisImager software by Geometric.

## RESULTS AND DISCUSSION

### Seismic Surface Wave Test Results

**Lateral Heterogeneities Laboratory Experimental.** Figure 1 shows the dispersion curves that was measured using sensors located on the clay region between columns and with sensors located on the 4-cm column. The shear wave velocities for sensors on clay was 62 m/s and then increased with larger wavelengths to 69 m/s. Meanwhile, the shear wave velocities measured on the column was 110 m/s decreased with increasing wavelengths to 67 m/s. Both dispersive curves demonstrate the influence of the lateral heterogenous introduced by the column within the soft clay.

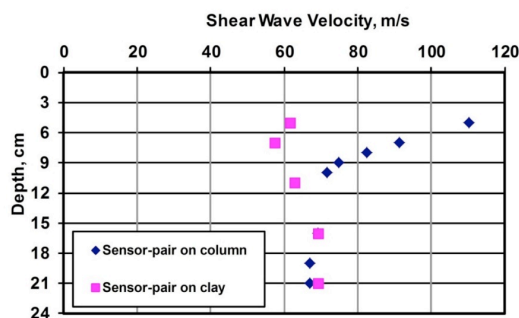


Figure 1. The shear wave velocities sharply decreased between depths 3.5 cm and 10 cm for sensor-pair on column

**Vertical Heterogeneities Field Experimental.** The MASW test result was performed with 24 sensors located on the soft clay region as shown in Figure 2. Figure 2(a) shows the dispersive curve of phase velocity versus frequency, and Figure 2(b) shows the shear wave velocity soil profile from MASW test and relate with the SPT-N value from borehole data. The shear wave velocities in clay were increased with increasing of the depth. For very soft clay shear wave velocity less than 103 m/s, soft clay velocity between 103 m/s and 210 m/s and firm clay velocity higher than 210 m/s. The shear wave velocities demonstrate the influence of the vertical heterogeneous which the SPT-N value increased by depth.

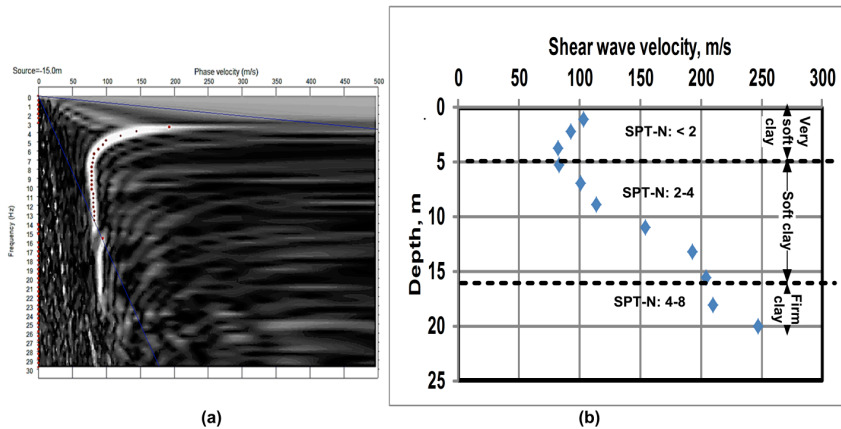


Figure 2. (a) Dispersion curve of MASW data; and (b) shear wave velocity profile after inversion from dispersive curve

## DISCUSSION

The first case of lateral heterogeneity tested in the laboratory shows the characteristics of the dispersive curves of soft clay between 2 columns and another sensor pair on top of the 4 cm diameter column. The elliptical particle motion illustrated in Figure 3 explaining the downward trend in shear wave velocities for sensors on top of the column and upward trend for sensors on clay corresponding to depths and wavelengths. The growth of this effective region of measurement was presented the largest change in the averaged shear wave velocity. The illustrated elliptical region of measurement begins to encroach into the surrounding clay or column, but as it grows further, the change in ratio of column-to-clay. This illustration can explain the upward and downward trend in shear wave velocities for a sensor on clay and column with further increase in depth.

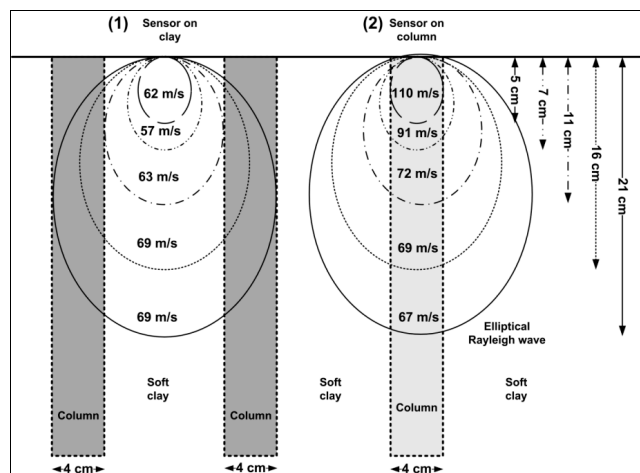


Figure 3. The shear wave velocities affected by the vertical and horizontal span of elliptical which encroach into the clay and column

In case of vertical heterogeneous, the relationship between the shear wave velocity and the effective region and wavelength is important for analysing and interpreting the measured result. As shown in Figure 4, almost 100 % of the elliptical effective regions sit within the first layer of very soft clay at a depth of 5 m. The wavelength will increase and the effective region will present the largest change in averaged shear wave velocity at the point where the elliptical begins to encroach into the second and third layer of soft and firm clay. This can explain the relationship between the upward trend in shear wave velocities and depth.

The test conducted in the laboratory and in the field, demonstrates that there is a relationship between shear wave velocity and the lateral, vertical, span of the effective measurement region. The shape and size of the effective region of measurement in the medium in the lateral and vertical dimensions can be used to identify the sampling volume of the wavelength. To date, this observation has received little attention in the literature on surface waves. The measured shear wave velocities via surface wave technique was shown to be influenced by the volume of measurement of Rayleigh wave with an elliptical particle movement, which in turn is a function of its wavelength. As a result, the measured shear wave velocities are directly influenced by the material as a medium for the energy transferred in the elliptical particle motion. This is important as it suggests that the wavelength not only relates to an effective depth, but may also have a lateral and vertical span and, therefore, is associated with an effective volume.

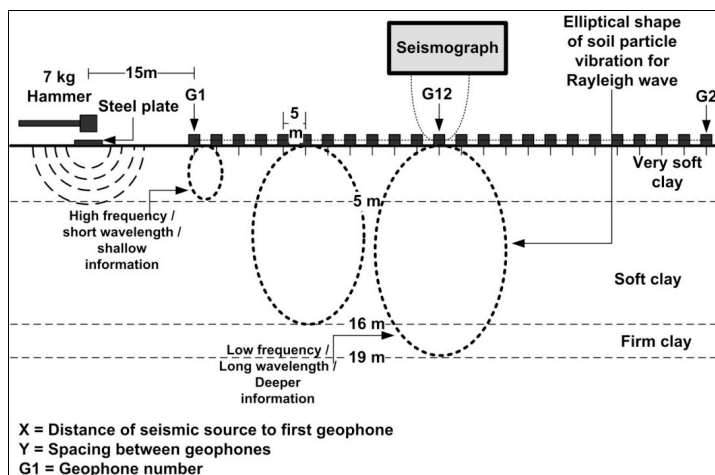


Figure 4. Sketch of the elliptical shape of phase velocities encroaching the surrounding clay

This laboratory and field study indicates phase velocity is influenced by both the vertical and horizontal spans of the material. Figure 3 and 4 shows the volume of each material in the effective region can be assessed by fitting the elliptical volume as a function of wavelengths. In real-world the relationship between the wavelength and the effective region of measurement (the sampling volume) is important when plotting a graphical representation of the dispersion curve and explain the variation and description of the soil boundaries. Consequently, the seismic

surface wave potentially can deliver a great device to evaluate the shear wave velocity in a non-destructive and non-invasive. It is important to understand that the MASW underestimates actual velocity for deeper layer if velocity increases with depth due to the effect of soil properties on the upper layer.

The velocity very soft clay is in the range of 57 m/s to 63 m/s and 83 m/s to 103 m/s when measured in the laboratory and field respectively. In the field, the effective stress controlled by the depth and groundwater level as well as confining pressure affects the pore water pressure, and can influence the shear wave velocity. The laboratory derived measurements served as a bench scale model, which does not involve any confining pressure and groundwater flow.

## CONCLUSION

The surface wave testing to evaluate the factor of soil profiles and the position of the sensor were demonstrated in this study. Two soil profiles, i.e. lateral and vertical non-homogeneities, were evaluated using the continuous surface wave analysis (CSW) and multi-channel analysis of surface waves (MASW). Remoulded clay and gravelly sand columns from a typical stone column site create the lateral heterogeneous condition. The field test on soft clay was conducted at a test site which had the necessary soil profile. The study shows the shear wave velocity acquired from surface wave technique is dependent on the depth and the horizontal spans of the soil properties. Thus, the depth and horizontal spans could be adopted to identify the effective sampling volume. This allowed the dispersive curve to be projected and to evaluate the correlation between seismic velocity and soil index properties or soil strength.

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## REFERENCES

- Abbiss, C. P. (1981). Shear wave measurements of the elasticity of the ground. *Géotechnique*, 31(1), 91-104.
- Azhar, A. T. S., Hazreek, Z. A. M., Aziman, M., Haimi, D. S., & Hafiz, Z. M. (2016). Acidic barren slope profiling using electrical resistivity imaging (ERI) at Ayer Hitam area Johor. *Journal of Physics: Conference Series*, 710 (1) 012008, IOP Publishing.
- Badee, A., Ismail, B., Aziman, M, Lokmane, A., & Haimi, D. S. (2016). Effect of coarse materials percentage in the shear strength. *IOP Conference Series: Materials Science and Engineering*, 136 (1), 012017, IOP Publishing.
- Ahmed, I., Edward, S., Andrew, P., & Andrew, S. (2012). Pitfalls in interpretation of shallow seismic data. *Applied Geophysics*, 9(1), 87-94.
- Clayton, C. R. I. (2011). Stiffness at small strain: research and practice. *Géotechnique*, 61(1), 5-37.

- Crice, D. (2005). MASW: the wave of the future. *Journal of Environmental and Engineering Geophysics*, 10(2) 77–79.
- Luna, R., & Jadi, H. (2000). Determination of dynamic soil properties using geophysical methods. *Proc. of the First International Conference on the Application of Geophysical and NDT Methodologies to Transportation Facilities and Infrastructure, St. Louis*.
- Madun, A., Jefferson, I., Chapman, D. N., Culshaw, M. G., Foo K. Y., & Atkins, P. R. (2010a). Evaluation of the multi-channel surface wave analysis approach for the monitoring of multiple soil-stiffening columns. *Near Surface Geophysics*, 8(6), 611-621.
- Madun, A., Jefferson, I., Foo K. Y., Chapman, D. N., Culshaw, M., G. & Atkins, P. R. (2012b). Characterization and quality control of stone columns using surface waves testing. *Canadian Geotechnical Journal*, 49(12), 1357-1368.
- Madun, A., Zainalabidin, M. H., Tajudin, S. A. A., & Haimi, D. S. (2016c). Compressive and shear wave velocity profiles using seismic refraction technique. *Journal of Physics: Conference Series*, 710, 012011, IOP Publishing.
- Madun, A, Supa'at, M. E. A., Tajudin, S. A. A., Zainalabidin, M. H., Sani, S., & Yusof, M. F. (2016d). Soil investigation using multichannel analysis of surface wave (MASW) and borehole. *ARPN Journal of Engineering and Applied Sciences*, 11(6).
- Madun, A, Tajudin, S. A. A., Abdullah, M. E., Zainalabidin, M. H., Sani, S., & Alvin, S. (2016e). Conversion shear wave velocity to standard penetration resistance. *IOP Conference Series: Materials Science and Engineering*, 136(1), 012009, IOP Publishing.
- McDowell, P. W., Barker, R. D., Butcher, A. P., Culshaw, M. G., Jackson, P. D., McCann, D. M., Skipp, B. O., Matthews, S. L., & Arthur, J. C. R. (2002). *Geophysics in engineering investigations*. London: Construction Industry Research and Information Association, CIRIA, 562.
- Matthews M. C., Hope V. S., & Clayton C. R. I. (1995). The geotechnical value of ground stiffness determined using seismic methods. *Geological Society, London, Engineering Geology Special Publication*, 12, 113-123.
- Matthews, M. C., Hope, Y. S., & Clayton, C. R. I. (1996). The use of surface waves in the determination of ground stiffness profiles. *Proceedings of the Institution of Civil Engineers Geotechnical Engineering*, 119: 84-95.
- Moxhay, A. L., Tinsley, R. D., & Sutton, J. A. (January, 2001). Monitoring of soil stiffness during ground improvement using seismic surface waves. *Ground Engineering Magazine*, 34-37.
- Noor, M. A. M., Madun, A., Kamarudin, A. F., & Daud, M. E. (2016). A study of geological formation on different sites in Batu Pahat, Malaysia Based on HVSR method using Microtremor measurement. *IOP Conference Series: Materials Science and Engineering 136(1), 012038*, IOP Publishing.
- Pan, J. G., Wang, H. B., Li, C., & Zhao, J. G. (2015). Effect of pore structure on seismic rock-physics characteristics of dense carbonate. *Applied Geophysics*, 12(1), 1-10.



## **Cost Implication Analysis of Concrete and Masonry Waste in Construction Project**

**Kasvar, K. K., Nagapan, S.\*, Abdullah, A. H., Ullah, K., Deraman, R., Yunus, R. and Sohu, S.**

*Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia*

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### **ABSTRACT**

Concrete and masonry waste are the main types of waste typically generated at a construction project. There is a lack of studies in the country regarding the cost implication of managing these types of construction waste. To address this need in Malaysia, the study is carried out to measure the disposal cost of concrete and masonry waste. The study was carried out by a site visit method using an indirect measurement approach to quantify the quantity of waste generated at the project. Based on the recorded number of trips for waste collection, the total expenditure to dispose the waste were derived in three construction stages. Data was collected four times a week for the period July 2014 to July 2015. The total waste generated at the study site was 762.51 m<sup>3</sup> and the cost incurred for the 187 truck trips required to dispose the waste generated from the project site to the nearby landfill was RM22,440.00. The findings will be useful to both researchers and policy makers concerned with construction waste.

*Keywords:* Construction project, cost analysis, concrete and masonry waste, indirect measurement, sustainable

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*E-mail addresses:*

kaizens.kanesh@gmail.com (Kasvar, K. K.),

sasi81@hotmail.com (Nagapan, S.),

abdhalid@uthm.edu.my (Abdullah, A. H.),

gf150051@siswa.uthm.edu.my (Ullah, K.),

riduan@uthm.edu.my (Yunus, R.),

rafikullah@uthm.edu.my (Deraman, R.),

sohoosamiullah@gmail.com (Sohu, S.)

\*Corresponding Author

### **INTRODUCTION**

The construction sector plays a vital part in Malaysia's economic development. Rapid urban development, such as the construction of buildings and infrastructure projects have however led to the large construction waste generation and the increasing problem of illegal disposal (Begum et al., 2007). According to Mei and Fujiwara (2016), construction waste in Central and Southern Malaysia accounts for 28.34%. Furthermore,

a study in Johor indicated 42% of 46 illegal dumping sites are construction waste material (Rahmat & Ibrahim, 2007). A study by Liu et al. (2012), highlighted the urgency of estimating construction waste using scientific and other rational methods or more efficient management of the government.

Concrete and masonry waste needs to be managed and handled carefully (Nagapan et al., 2013; Faridah et al., 2004). This study has been conducted to measure the quantity of concrete and masonry waste generated at the site to ascertain the cost related to its management.

### **Previous Research Works**

There are many studies on waste generation rates. Table 1 delineates a summary of previous studies that investigated waste generation rates. In general, there are two approaches for measuring waste generation: by classifying waste into different categories or treating them as a whole. It can be seen from Table 1 that different practices were applied to measure waste either by weight (kg or ton) or by volume (m<sup>3</sup>). Bossink and Brouwers (1996), investigated waste by differentiating materials such as steel, cement, concrete, mortar, timber, and packaging waste. A study by Formoso et al. (2014) has summarized there are four typical measurements of waste generation rate such as a percentage of material purchased, percentage of material required by the design, kg/m<sup>2</sup> of Gross Floor Area (GFA), and m<sup>3</sup>/m<sup>2</sup> of GFA. Meanwhile, professional standard and the classification system for waste generation rate was used by Liu et al. (2012) in China. In this study, the estimation methods using Apparent Constructed Volume and Apparent Wreckage Waste Volume were used. It contrasts with other studies which have used direct measurement method of stockpiled waste volume (m<sup>3</sup>) on site using rectangular or pyramid based assumptions studies by Lau et al. (2008) and Nagapan et al. (2013). Poon et al. (2004) conducted research through direct observation, tape measurement, and truck load records. It can be seen that research of this kind normally adopts hard methods of measuring waste, such as on-site sorting and weighing and truck load records. This method requires precise information and easy access to accurate data on the amount of waste that are disposed from the site using trucks. The aim of this study is to quantify the cost implication analysis for the concrete and masonry waste. Indirect measurement by weighing truck load records has been adopted for this study.



Table 1  
 Summary of waste generation rate study from past researchers.

Author	Country	Measurement of Generated Construction Waste	Methodology	Conclusions
Bossink and Brouwers (1996)	Netherlands	Percentage by weight (purchased material)	Sorted and weighed the waste materials	1-10% weight of the amount purchased for seven materials, with an average 9% end up as waste.
Formoso et al. (2002)	Brazil	Waste (%) = $[(M_{\text{purchased}} - \text{Inv}) - M_{\text{designed}}] / M_{\text{designed}}$ where Inv indicates the final inventory of materials	Direct observation and contractors' records	19.1-91.2% by weight according to the amount purchased for eight materials
Poon et al. (2004)	Hong Kong	The volume (m3) of waste generated per m2 of gross floor area	Visual inspection, tape measurement, truck load records	The total waste generation rate: 0.176m3/m2 (Construction) and 0.4-0.65m3/m2 (Demolition)
Lau et al. (2008)	Malaysia	Measure the stockpiled waste volume(m3) on site using rectangular or pyramid based assumptions	Direct measurement using measuring tape and interviews	Wood is highest construction waste material in Site A and B, Concrete is highest waste generator in Site C.
Liu et al. (2012)	China	The classification of waste item has referenced a relevant professional standard and the classification system is hierarchic, in which the list of construction wastes is divided into different levels, such as chapters and sub- chapters	Estimation Method using Apparent Constructed Volume and Apparent Wreckage Waste Volume	Waste generation of 0.34 m3/m2 (Soil is considered) for the new construction projects and generate the biggest volume are soil, concrete and bricks.
Nagapan et al. (2013)	Malaysia	Method adopted from Lau (2008), measure the stockpiled waste using pyramid or rectangular based assumptions.	Direct measurement using measurement tapes	Six types of construction wastes found at the sites were timber, metal, bricks, concrete, packaging waste and mortar.  Timber waste was the dominant waste at all of the sites.

## MATERIALS AND METHODS

### Demography of the Project Site A

To maintain its anonymity, this project is labelled as Site A, which is located in Johor, Malaysia. It is a mixed development with shop office, boutique outlet and service residences. The project started in May 2014 and was estimated to be completed in August 2016, and worth more than RM250 million.

### Concrete and Masonry Waste

Concrete and bricks are important construction materials used in construction. (Shen et al., 2010). Mana Reixach et al. (2000), stated that masonry works mixture of concrete, bricks, tiles and ceramic materials generated high construction and demolition waste in Spain. The waste consists of bricks, stone, concrete block, plaster debris and block tile (Ong, 2009). Figure 1 shows Concrete and Masonry Waste that were collected and mixed up at Project Site A. In this project, waste collectors provide special waste bin for concrete and masonry waste due to the heavy waste load.



Figure 1. Concrete and masonry waste

### Quantifying and Costing Methods

The study used a site visit method and an indirect measurement approach that weighed truck load records adopted from Poon et al. (2004). The number of trucks for waste collection is recorded 4 times weekly over a 12-month period. The truck's bin size is Length (L) = 3.6576 m (12'), Width (W) = 1.8288 m (6') and Height (H) = 0.6096 m (2') as shown in Figure 2.

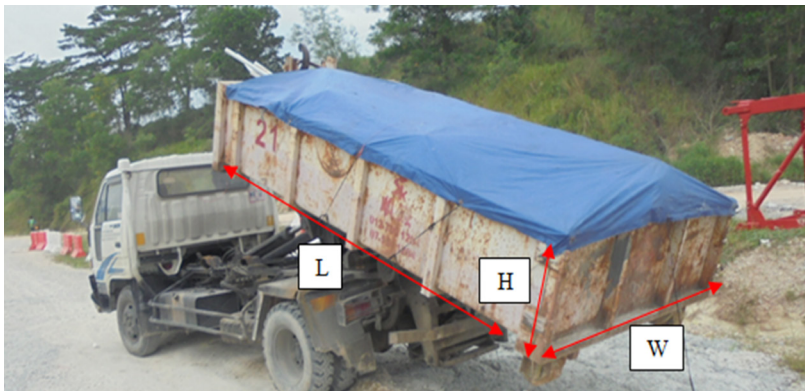


Figure 2. Measurement (L x B x H)

The volume of the bin is calculated in cubic meter (m<sup>3</sup>) to quantify the waste which had been disposed. Meanwhile, the amount of cost for managing concrete and masonry waste is rated per trip. Based on the project’s contract agreement, each trip is charged RM120.00 by the roll off the truck to transport out the concrete and masonry waste. The amount for transporting the waste out is calculated by the Total Number of Truck Trips times the Charge per Truck Trip (Total Truck Trips × RM120.00).

**RESULTS AND DISCUSSION**

Table 2 presents the total volume of concrete and masonry waste generated for 12-month period and total cost that had been expensed to remove this waste from project site to the landfill.

Table 2  
*Summary of waste generated in cubic meter and total amount expenditures for waste collection*

No	Construction Stages	Size of Bin Month	(12' x 6' x 2') Trip Per Month	Volume (cubic meter)	Rate (RM)	Amount (RM)
1	Pre-Construction	Jul-14	1	4.08		
2	Stages and Phase 1&	Aug-14	2	8.16		
3	2 RC Works	Sep-14	2	8.16	120.00	240.00
4		Oct-14	7	28.54	120.00	840.00
5	Podium Carpark	Nov-14	8	32.62	120.00	960.00
6	RC Works and	Dec-14	13	53.01	120.00	1,560.00
7	Architecture Works	Jan-15	18	73.40	120.00	2,160.00
8	For Phase 1	Feb-15	10	40.78	120.00	1,200.00
9	Phase 2 Service	Mar-15	33	134.56	120.00	3,960.00
10	Residence RC	Apr-15	40	163.10	120.00	4,800.00
11	Works and	May-15	27	110.10	120.00	3,240.00
12	Architecture Works	Jun-15	26	106.02	120.00	3,120.00
Total			<b>187</b>	<b>762.51479</b>		<b>22,440.00</b>

**Pre-Construction Stages and Phase 1 & 2 RC Works**

In the preliminary stages of construction site clearing, site office set up, site mobilization and basement reinforced concrete works began. The site was handed over to the contractor on June 2014. It can be seen from Table 2 that the number of concrete and masonry waste slowly increased at this stage. By October 2014, the number of waste generated was high (28.54 m<sup>3</sup>) as sub-contractors started to complete the Basement and Phase 1 (Shop Office and Boutique Outlets) RC Works.

**Podium Carpark RC Works and Architecture Works for Phase 1**

This is the intermediate stage where RC works began for Phase 2 Podium Carpark. The area of the Podium Car Park is approximately 4300 m<sup>2</sup> with 5 levels. Architectural works commenced for Phase 1 with brick wall and plastering works. The concrete and masonry waste generated was

significantly higher at this stage due to slab and beam structure works, ramp construction, lift shaft works, brickworks, ceiling plastering, skim coat plastering and external plastering works.

### **Phase 2 Service Residence RC Works and Architecture Works**

Based on the site visit method, this is the crucial stage in the project site. At this stage, the structural works for service residences commenced utilising the IBS system formwork as the main construction method. This project achieved project cycle of 5 floors per month, hence generating high concrete waste. Besides that, masonry waste generation was also high due to the fact that the contractor had to catch up with the progress of architectural works for Phase 1 completion works. The results showed the highest concrete and masonry waste produced was 163.10 m<sup>3</sup> and the amount spent on waste collection for the month was RM4,800.00.

### **CONCLUSION**

Through this study, a database for concrete and masonry waste at Project Site A is determined. There are two major findings from this study, which include: (i) concrete and masonry waste generated for the 12 month period at Project Site A is 762 m<sup>3</sup>; and (ii) the total expenses to dispose this waste is RM22,440.00 based on 187 trips, or RM29.45 per m<sup>3</sup>. Thus indicating proper concrete and masonry waste management practices at the site can be cost saving, beneficial and sustainable.

### **ACKNOWLEDGMENTS**

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### **REFERENCES**

- Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2007). Implementation of waste management and minimization in the construction industry of Malaysia. *Resources, Conservation and Recycling*, 51(1),190–202. Retrieved from: <http://doi.org/10.1016/j.resconrec.2006.09.004>
- Bossink, B.A.G., & Brouwers, H. J. H. (1996). Construction waste: quantification and source evaluation. *Journal of Construction Engineering and Management*, 122(1), 55-60
- Faridah, A. H., Hasmanie, A. H., & Hasnain, M. I. (2004). A study on construction and demolition waste from buildings in Seberang Perai, *Proceeding of 3<sup>rd</sup> National Conference in Civil Engineering*, Tanjung Bungah, Malaysia: Cophorne Orchid.
- Formoso, T.C., Soibelman, M. L., Cesare, C. D., & Isatto, E. L. (2002). Material waste in building industry: main causes and prevention. *Journal of Construction Engineering and Management*, 128 (4), 316–325.

- Lau, H. H., Whyte, A. A., & Law, P. L. (2008). Composition and characteristics of construction waste generated by residential housing project. *International Journal of Environmental Research*, 2(3), 261–268.
- Liu, J., Wang, Y., Yang, B., & Lin, Y. (2014). A model for quantification of construction waste in new residential buildings. *Proceedings of the 17<sup>th</sup> International Symposium on Advancement of Construction Management and Real Estate*, 1079–1088. Retrieved from [http://doi.org/10.1007/978-3-642-35548-6\\_110](http://doi.org/10.1007/978-3-642-35548-6_110).
- Mana Reixach, F., Gonzalez and Barroso, J., Sagrera and Cusco, A. (2000). Plan to run waste in construction and demolition. *Technological Institute of Construction Catalonia Barcelona, Spain*.
- Mei, M. H., & Fujiwara, T. (2016). A survey of Construction and Demolition Waste in Malaysia, Mixed-Use Development. *Journal of Faculty of Environmental Science and Technology, Okayama University*, 21, 1-2.
- Nagapan, S., Rahman, I. A., Asmi, A., & Adnan, N. F. (2013). Study of site's construction waste in Batu Pahat, Johor. *Procedia Engineering*, 53, 99–103. <http://doi.org/10.1016/j.proeng.2013.02.015>.
- Ong, E. G. (2014). Universiti Teknologi Malaysia Declaration of Thesis / Undergraduate Project Paper and Copyright Approach for Improving Code Reusability and, 16(April).
- Poon, C. S., Yu, A. T. W., See, S.C., & Cheung, E. (2004). Minimizing demolition wastes in Hong Kong public housing projects. *Construction Management Economic*, 22(8), 799–805.
- Rahmat, N. S., & Ibrahim, A. H. (2007). Illegal Dumping Site: Case Study in the District of Johor Bahru Tengah, Penang, Malaysia.
- Shen, L. Y., Tam, V. W. Y., Tam, C. M., & Ho, S. (2010). Material Wastage in Construction Activities - A Hong Kong Survey. *CIB W107: Creating a Sustainable Construction Industry in Developing Countries*, 7, 1–7.





## **Risk Factors for Design and Build Projects in Malaysia – Project Manager’s Perception**

**Sabihah Saaidin<sup>1\*</sup>, Intan Rohani Endut<sup>1</sup>, Siti Akmar Abu Samah<sup>2</sup> and Ahmad Ruslan Mohd Ridzuan<sup>1,3</sup>**

<sup>1</sup>*Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

<sup>2</sup>*Academy of Language Studies, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

<sup>3</sup>*Institute for Infrastructure Engineering and Sustainable Management, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

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### **ABSTRACT**

The design and build concept has become a popular contract system. It requires the owner and contractor to identify, analyse and manage risks and search for the best solutions to improve performance. The objective of this paper is to identify the project manager’s perception of risk factors associated with the design and build project in Malaysia. A total of 100 usable questionnaires were received and analysed using mean ranking and factor analysis. The results show that three most risky factors are: “client financial capability”, “inadequate cash flow by contractor”, and “lack of payment (delayed progress payment by owner to the contractor)”. Risk can be grouped into 12 categories, namely: (1) lack of management competency; (2) lack of contractor experience; (3) political issues; (4) lack of standardized system; (5) unpredictable issues; (6) lack of client experience; (7) safety issues; (8) lack of teamwork; (9) poor supervision by client; (10) lack of client information; (11) material availability; and (12) design error.

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*E-mail addresses:*

sabihah@ymail.com (Sabihah Saaidin),

intan@salam.uitm.edu.my (Intan Rohani Endut),

sitiakmar.uitm@gmail.com (Siti Akmar Abu Samah),

ahmad299@salam.uitm.edu.my (Ahmad Ruslan Mohd Ridzuan)

\*Corresponding Author

### **INTRODUCTION**

Design and build is a method of project delivery where the contractor is responsible for carrying out the design and construction of the project for a client (Modupe et al., 2012). This method of project delivery has increased market share because of the speed of project completion, and cost reduction (Ogunsanmi et al., 2011). However, design and build projects are prone to risks, some of these risks are borne by the design and build



contractor, client, and in some cases shared by both parties. In addition, this type of contract transfers more risks to the contractors than other construction contracts (Seng & Yusuf, 2006). According to Dada et al. (2003), contractors in developing countries have insufficient experience and knowledge to manage risk effectively. This study aims to identify perceptions of risk factors related to the design and build project in Malaysia. It hopes its findings will help project managers manage risk effectively.

### **Potential Risk in Design and Build Project**

The construction sector is evolving towards a stage whereby cost, time and quality are being stressed. Although the use of design and build contract has been around for some time it has overtime found to be not effective.

According to Azizan and Ibrahim (2015), a design and build project is classified as the riskiest project, because of a combination of design activities, on site supervision and participation in the actual construction project. The contractors exposed to a high degree of control over the entire project. In addition, contractors and owners have insufficient experience and knowledge to manage and control risks involved in design and build projects (Akintoye & Fitzgerald, 1995).

The profit margin has become thinner and thinner due to high inflation rates, rise in labour costs, and more stringent environmental and safety control, affecting quality of work and completion dates (Oztas & Okmen, 2004). A total of 64 risk factors were identified and used in a questionnaire survey to obtain the perception of project manager towards this construction sector.

## **MATERIALS AND METHODS**

This study used a quantitative approach to analyse risk factors and literature review to identify risk factors associated with Design and Build projects. A comprehensive list of 64 risks was identified and used in a questionnaire that was designed to get the perception of the construction professional experts (project manager) in design and build projects. The project manager was chosen for the study because he has acquired the relevant knowledge and skill, to perform effectively in their professional roles. The first section of the questionnaire solicited demographic information related to the respondents. The second section consists of three parts of 64 risk factors, two of which were related to the probability and impact of each risk factor for a design and build project on a five-point Likert scale. The scale for risk probability ranged from 1 (low) to 5 (high). Meanwhile, the scale for risk impact ranged from 1 (insignificant) to 5 (catastrophic). A total of one hundred questionnaires were obtained and by statistical analysis (mean ranking) and factor analysis.

## **RESULTS AND DISCUSSION**

In order to identify the risk factors related to a design and build project on the part of a project manager several statistical analysis techniques were adopted for data analyses.



### Risk Ranking in Design and Build Project

The aim of this section is to identify high significance risk factors related to design and build projects as perceived by project managers. It can be seen from the analysis 10 of risk factors among of 64 risk factors the mean value greater than 15.620 was recorded. Table 1 shows, “client financial capability”, “inadequate cash flow by contractor” and “lack of payment (delayed progress payment by owner to the contractor)” are high risk factors, each of which has a mean value 17.469 and 16.717. Kartam and Kartam (2001) agreed that financial failure has high significance ranking in surveys done in Kuwait. “Lack of design/build knowledge/experience/competency” and “contractor’s lack of staff knowledge/experience” rank fourth and fifth high risk factors (mean value: 16.661 and 16.157). “Lack of teamwork” was ranked sixth highest risk factor (mean value: 16.016) related to design and build project. “Scope of work is uncertainty” was ranked as the seventh (mean value: 16.016). In order to meet the objective of the project success, time management can play an important role for project managers (Wang & Yuan, 2011). Thus “Insufficient time for completion date” was ranked as the eighth higher risk factors (mean value: 16.006). “Lack of project manager competency and authority” was ranked ninth (mean value: 15.806). Finally, “lack of payment (delayed progress payment by contractor to sub-contractor)” was ranked last with mean value 15.620.

Table 1  
*Top ten of risk ranking in design and build project as perceived by the project managers*

Item	Description	Mean Probability	Mean Impact	Mean Risk	Risk Ranking
PI1	Client financial capability	4.045	4.318	17.469	1
PI2	Inadequate cash flow by contractor	4.045	4.318	17.469	2
PI3	Lack of payment (delayed progress payment by owner to the contractor)	3.955	4.227	16.717	3
PI4	Lack of design/build knowledge / experience / competency	3.818	4.364	16.661	4
PI5	Contractors lack of staff’s knowledge/ experience	3.864	4.182	16.157	5
PI6	Lack of teamwork	3.955	4.050	16.016	6
PI7	Scope of work is uncertainty	3.955	4.050	16.016	7
PI8	Insufficient time for completion date	3.820	4.190	16.006	8
PI9	Lack of project manager competency and authority	3.864	4.091	15.806	9
PI10	Lack of payment (delayed progress payment by contractor to the sub-contractor)	3.818	4.091	15.620	10

## Factor Analysis on Project Manager Perception

Factor analysis, a data reduction technique, is used to discover patterns among the variation in values of several variables in studying risk in design and build projects. Factor analysis assumes that the underlying dimensions or factors can explain complex phenomena (Oyewobi et al., 2012). There are 12 factors of Principal Factors Extraction.

The “lack of management competency” Factor 1 consists of 12 risk factors and includes ‘*insufficient time for completion date, delay in commencing work because under-estimated time needed to obtain statutory, client financial capability, complexity of the project, lack of design/build knowledge/experience/competency, lack of teamwork, lack of project manager competency and authority, inadequate cash flow by contractor, insufficient communication between team member to meet project success, lack in quality control and assurance, Lack of communication of design/builder with end users to meet their requirements, and contractors lack of staff knowledge and experience*’. This factor accounts for 40.924% of the total variance explained among all risk factors related design and build project. ‘Insufficient time for completion date’ and ‘delay in commencing work because under-estimated time needed to obtain statutory’ were highest loading with (Sig = 0.942 and 0.903, respectively). This indicates that ‘insufficient time for completion date’ is the most critical risk factors.

“Lack of contractor experience” Factor 2 consists of 10 risk factor included ‘*incompetent sub-contractors, mistake during construction, lack in availability of skilled labour, lack in availability of equipment, lack on supervision of labour and works, team members are not participating in technical discussions with owners, lack of coordination with sub-contractor, lack in effectiveness of communication in design, delay in design approval from client and change of original design from client*’. This factor accounts for 12.128% of the total variance explained among all risk factors. Zou et al. (2007) warned that to keep the project success, experienced contractors need to be highlighted at the early project execution. Wang and Yuan (2011), further interpreted contractor with rich experience will increase their possibilities for better handling risk-based on decisions in construction projects.

“Political issues” Factor 3 consists of eight risk factors ‘*slow approval permit by BOMBA department, slow approval permit by local authorities, slow approval permit by town planning department, slow approval permit by public work department, exchange rate fluctuation/devaluation, tax rate exchange, owner lack of knowledge and experience and change in government regulation and law*’. This factor accounts for 8.248% of the total variance explained among all risk factors.

The “lack of standardized system” Factor 4 consists of five risk factors ‘*insufficient time during request for proposal to sub-contractor, insufficient time in preparing tender documents to sub-contractor, insufficient time to evaluate tenders from sub-contractor, lack of standardized systems during tender evaluation and bureaucracy in government agencies*’. This factor accounts for 5.292% of the total variance explained among all risk factors.

The “unpredictable issues” Factor 5 comprises five risk factors ‘*unidentified utilities, lack of payment (delayed progress payment by owner to the contractor), unforeseen site condition, scope of work is uncertainty and lack of payment (delayed progress payment by contractor to*

*the sub-contractor*'. This factor accounts for 4.802% of the total variance explained among all risk factors.

"Lack of client experience" Factor 6 consists of two risk factors '*redesign because of over budgeted and insufficient information of site access/right of way*'. This factor accounts for 4.434% of the total variance explained among all risk factors. Gary et al. (1994) stated that many owners lack of experience in design and build project. To ensure that public sector would investigate this situation to prevent it from happening will impact on the project success.

"Safety issues" Factor 7 consists of three risk factors '*lack of training on safety at site, lack of information on safety at site and catastrophes (Act of God)*'. This factor accounts for 3.577% of the total variance explained among all risk factors. Safety issues also play an important role in the success of the project. All parties should be aware of the safety issues during construction project.

The "lack of teamwork" Factor 8 consists of two risk factors '*insufficient of original design and lack of suitable organizational structure*'. This factor accounts for 3.093% of the total variance explained among all risk factors.

"Poor supervision by client" Factor 9 consists of two risk factors '*poor supervision by the client and inflation*'. This factor accounts for 2.757% of the total variance explained among all risk factors.

The "lack of client information" Factor 10 consists of three risk factors '*contractor's detailed design does not meet owner's expectation, insufficient information in contract document and inadequate specification in contract document*'. This factor accounts for 2.688% of the total variance explained among all risk factors. Incomplete design and specification in the design phase of a project result in inaccurate cost estimating and increase the risk in design and build project. The incompleteness of the data and information at the time of project commencement should be considered in the contract document and the risk of inaccurate information assigned to the owners (Moazzami et al., 2011).

The "material availability" or Factor 11 consists of two risk factors '*difficulties in availability of materials and rigid specification in contract document*'. This factor accounts for 2.407% of the total variance of all risk factors.

"Design error" Factor 12 consists of '*errors of original design*'. This factor accounts for 1.924% of the total variance explained among all risk factors. The contractor's design consultants should understand the construction process and develop a cost-effective design on time.

## CONCLUSION

This paper examined the perception among project managers of the risk factors in design and build project in Malaysia. The research concludes the most common risk factors are: "client financial capability, inadequate cash flow by contractor and lack of payment (delayed progress payment by the owner to the contractor)". In this study, 12 principal factors: "lack of management competency, lack of contractor experience, political issues, lack of standardized in system, unpredictable issues, lack of client experience, safety issues, lack of teamwork,

poor supervision by client, lack of client information, material availability and design error”, are considered as the most critical risk factors by project managers. Lu et al. (2008) suggest identification of risk factors can help project manager to be more focused, manage resources and maximise effort in the interest of design and build projects.

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## REFERENCES

- Akintoye, A. & Fitzgerald, E. (1995). Design and Build: A survey of Architects' views. *Engineering, Construction and Architectural Management*, 2(1), 27-44.
- Azizan, M. A., & Ibrahim, F. A. (2015). Implementation of risk management in Malaysia design and build projects. *Advances in Environmental Biology*, 9(3), 108-111.
- Dada, J. O. et al. (2003). An assessment of risk factors in the procurement of building project in Nigeria. *Conference Proceedings of Globalization, Culture and the Nigeria Built Environment*, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.
- Fowler, F. J. (1993). Survey research methods. 2<sup>nd</sup> ed. U.K. International Educational and Professional Publisher.
- Gay, L. R. (1996). Educational research competencies for analysis and application. USA: Prentice Hall.
- Kartam, A. N., & Kartam, A. S. (2001). Risk and its management in the Kuwaiti construction industry: A contractors' perspective. *International Journal of Project Management*, 19, 325-335.
- Luu, V. T. et al. (2008). Improving project management performance of large contractors using benchmarking approach. *International Journal of Project Management*. 26, 758-769.
- Modupe, A. O. et al. (2012). Impact of risk on performance of design and build projects in Lagos State, Nigeria. *Journal of Civil Engineering and Architecture*, (6)9, (58), 1210-1217.
- Ogunsanmi, O. E. et al. (2011). Risk classification model for design and build projects. *Journal of Engineering, Project, and Production Management*. 1(1), 46-60.
- Oyewobi, L. O. et al. (2012). Evaluating the impact of risk on contractor's tender figure in public buildings projects in Northern Nigeria. *Journal of Engineering, Project and Production Management*. 2(1), 2-13.
- Oztas, A., & Okmen, O. (2004). Risk analysis in fixed price design build construction projects. *Building and Environment*. 39, 229-237.
- Seng, N. W., & Md. Yusof, A. (2006). The success factors of design and build procurement method: A literature visit. *Proceedings of the 6<sup>th</sup> Asia Pacific Structural Engineering and Construction Conference. APSEC. Kuala Lumpur, Malaysia*.
- Wang, J., & Yuan, H. (2011). Factors affecting contractors' risk attitudes in construction projects: Case study from China. *International Journal of Project Management*, 29, 209-219.
- Zou, P. X. W. et al. (2007). Understanding the key risks in construction projects in China. *International Journal of Project Management*. 25, 601-614.



## A Case Study of Green Building in Malaysia: Cost Saving Analysis

Soon, C. K.<sup>1</sup>, Zaini, Z.<sup>2</sup>, Mohd Ujang, A.<sup>2</sup>, Nagapan, S.<sup>1\*</sup>, Abdullah, A. H.<sup>1</sup>, Hasmori, M. F.<sup>1</sup> and Rassiah, K.<sup>3</sup>

<sup>1</sup>Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 84600 Parit Raja, Johor, Malaysia

<sup>2</sup>Department of Civil Engineering, Politeknik Sultan Salahuddin Abdul Aziz Shah, 40150 Shah Alam, Selangor, Malaysia

<sup>3</sup>Department of Mechanical Engineering, Politeknik Port Dickson, 71050 Si Rusa, Negeri Sembilan, Malaysia

### ABSTRACT

The building sector consumes about forty percent of world energy, making energy efficiency in existing buildings an important issue. This study has been undertaken to investigate energy consumption of a building that has been redesigned to incorporate energy efficient features. It was found that the introduction of energy efficient features has helped to achieve savings up to 46% of the total spent on energy particularly based on electricity bills.

*Keywords:* Cost saving, energy efficiency, green building, greenhouse gases, Malaysia

### INTRODUCTION

In developed countries across Europe, America and Asia, green building has been widely adopted and integrated into the building and construction sector (Ding, 2008; Gray, 2015).

Particularly, countries like Canada, Germany and United States have successfully implanted the concept of green building deep into their building foundation, to become the leaders in sustainability (Kats, 2003; Wang et al., 2005; Kibert, 2016). In Malaysia, the awareness level of sustainable construction is still nascent. With the launch of Green Building Index (GBI), Malaysia has taken a huge step forward to rate the performance of green buildings in the country (Chua and Oh, 2011). The evaluation of Green Building Index (GBI)

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##### E-mail addresses:

chikang1234@gmail.com (Soon, C. K.),  
amidah@psa.edu.my (Mohd Ujang, A.),  
zzarinahkja@gmail.com (Zaini, Z.),  
sasi81@hotmail.com (Nagapan, S.),  
abdhalid@uthm.edu.my (Abdullah, A. H.),  
mfikri@uthm.edu.my (Hasmori, M. F.),  
kannan780915@gmail.com (Rassiah, K.)

\*Corresponding Author

is based on six important criteria: Energy Efficiency, Indoor Environmental Quality, Sustainable Site Planning and Management, Material and Resources, Water Efficiency and Innovation (Yusoff & Wen, 2014; GBI, 2016).

In order to reduce energy usage and greenhouse gas emission, existing buildings need to be redesigned to meet green building standards. To this end, a rating category known as Green Building Index for Non-Residential Existing Building (GBI-NREB) was established to ensure greater environmental consciousness. Thus, by selecting a building as a case study, its energy efficiency features can be studied and energy efficient design concepts introduced.

### Green Building

Green building is defined as a structure that is environmentally responsible and resource efficient for the duration of its lifetime (EPA, 2014; Kibert, 2016). Green Building Index (GBI) is Malaysia’s industry recognised green rating tool for buildings to promote sustainability in the built environment and raise awareness among construction practitioners on environmental issues (Papargyropoulou et al., 2012; Sin et al., 2011). The GBI rating tool provides an opportunity for developers and building owners to design and construct green, sustainable buildings that can provide energy savings, water savings, a healthier indoor environment, better connectivity to public transport and the adoption of recycling and greenery (GBI, 2016).

**Study Area: Case Study of Building X.** For confidentiality purposes, the study subject is labelled as Building X. It is a federal administrative office building that is 12 years old. Building X is integrated with an efficient building design concept and achieved Silver rating of GBI after obtaining a score of 68 out of 100 maximum points. The breakdown of the score according to criteria is given in Table 1.

Table 1  
*Summary of GBI scores obtained from Building X*

Part	Item	Maximum points	Score
1	Energy Efficiency	38	32
2.	Indoor Environmental Quality	21	16
3.	Sustainable Site Planning and Management	10	4
4.	Materials and Resources	9	6
5.	Water Efficiency	12	1
6.	Innovation	10	9
Total Score		100	68

The design features of the Building X can be divided into: passive and active design. Passive design can be further broken down into building orientation, daylighting, space and layout planning and natural ventilation. Active design, on the hand consists of air conditioning and mechanical ventilation, an innovative lighting system, energy efficient office appliances and comprehensive Energy Management System (EMS).

**MATERIALS AND METHODS**

The necessary data was gathered for a period of 6 months using site visit approach. During the site visit, the data for the study is obtained from the building manager. The provided data, including building history, the redesign cost, energy efficiency features and energy usage of the building from 2005 until 2012.

**RESULTS AND DISCUSSION**

The energy that is consumed is in the form of electricity from Tenaga National Berhad and chilled water from the district cooling plant. The chilled water consumption is shown in ton/day and electricity in kWh/day. It can be seen from Figure 1 that the average chilled water consumption is 2014 ton/h/ day and the average electricity consumption is 4532 kWh/day. This means that the energy used for electric is higher than chilled water. The percentage of the total energy consumption for equipment, lighting and cooling usage is shown in Figure 2.

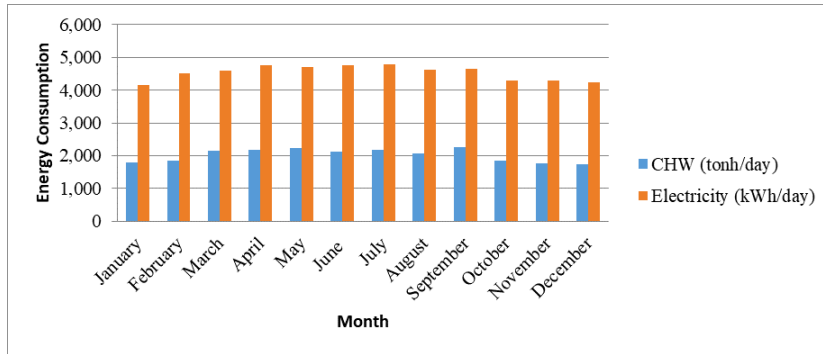


Figure 1. Monthly energy consumption of the Building X

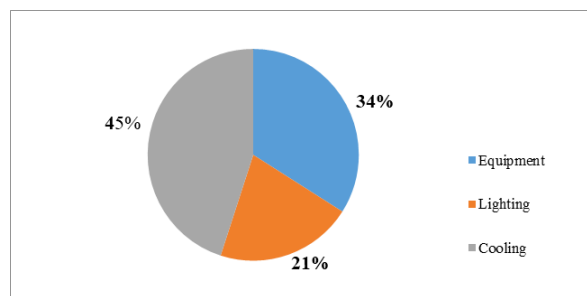


Figure 2. Percentage of energy consumption

It was also found from Figure 2 that the energy consumption allocated for cooling purpose is 45% of the total building energy usage. The energy demand for equipment is 34% and it includes energy demand for small power and fan energy; while lighting constitutes 21% of the total energy consumed. The cost saving on energy consumption with and without energy



efficiency features is as shown in Table 2. Actual total savings from 2005 till 2012 successfully recouped the investment of RM5 million in 8 years. It can be seen clearly from Table 2 that the total amount of saving is of RM5,863,369.00.

Table 2  
*Cost saving analysis of the Building X with energy efficiency features*

Year	Conventional Building (Cost in RM)	Building X with Energy Efficiency Features (Cost in RM)	Total Saving (RM)	Percentage of saving (%)
2005	1,098,000	492,700	605,300	44.5
2006	1,166,889	480,471	686,418	41.2
2007	1,166,889	558,832	608,057	47.9
2008	1,449,933	628,363	821,570	43.3
2009	1,449,933	738,197	711,736	50.9
2010	1,426,087	740,430	685,657	51.9
2011	1,547,417	697,253	850,164	45.1
2012	1,547,417	652,950	894,467	42.2
TOTAL	10,852,565	4,989,196	5,863,369	46.0

## CONCLUSION

The performance of Building X depends on how effective its energy efficient features functioning. Given that almost half of the energy in Building X is used for cooling purposes, it was found that savings in energy expenditure can be achieved through redesigning. It is proven that within 8 years it was possible to recoup the additional investment of RM5 million spent on redesigning.

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## REFERENCES

- Chua, S. C., & Oh, T. H. (2011). Green progress and prospect in Malaysia. *Renewable and Sustainable Energy Reviews*, 15(6), 2850-2861.
- Ding, G. K. (2008). Sustainable construction - The role of environmental assessment tools. *Journal of Environmental Management*, 86(3), 451-464.
- Environmental Protection Agency (EPA). (2014). United States Environmental Protection Agency.
- Green Building Index (GBI). (2016). Retrieved on: <http://new.greenbuildingindex.org/whatandwhy>
- Gray, C. (2015). Top 10 countries for LEED in 2015. United States: Green Building Council.



- Kats, G. (2003). Green building costs and financial benefits. Boston, MA: Massachusetts Technology Collaborative. United State of America.
- Kibert, C. J. (2016). Sustainable construction: green building design and delivery (4th Edition), John Wiley & Sons. United State of America.
- Papargyropoulou, E., Padfield, R., Harrison, O., & Preece, C. (2012). The rise of sustainability services for the built environment in Malaysia. *Sustainable Cities and Society*, 5, 44-51.
- Sin, T. C., Sood, S. B. M., & Peng, L. Y. (2011). Sustainability development through energy efficiency initiatives in Malaysia. *Paper of Green and Energy Management*.
- Wang, W., Zmeureanu, R., & Rivard, H. (2005). Applying multi-objective genetic algorithms in green building design optimization. *Building and Environment*, 40(11), 1512-1525.
- Yusoff, W. Z. W., & Wen, W. R. (2014). Analysis of the international sustainable building rating systems (SBRSS) for sustainable development with special focused on green building index (GBI) Malaysia. *Journal of Environmental Conservation Research*, 11, 11-26.



## Engaging Game Design in Learning Historical Patriotic Heroes: Students' Perceptions

N. H. Mat Zain<sup>1\*</sup>, H. Zaini<sup>1</sup>, M. N. Zulhemay<sup>1</sup>, A. Baharum<sup>2</sup>, W. F. Bustamam<sup>1</sup>  
and F. H. Abdul Razak<sup>1</sup>

<sup>1</sup>Faculty of Computer and Mathematical Sciences (FSKM), Universiti Teknologi MARA (UiTM), Melaka, Kampus Jasin, 77300 Merlimau, Melaka, Malaysia

<sup>2</sup>Faculty of Computing and Informatics, Universiti Malaysia Sabah (UMS), 88400 Kota Kinabalu, Sabah, Malaysia

### ABSTRACT

Computer games are often considered a teaching and learning tool as it is generally appealing to students. In this preliminary study, we investigate students' perceptions of engaging game design in Learning of Historical Patriotic Heroes. In total, 33 students were involved in this study. The data was examined using standard descriptive statistical approaches. The results of the study indicated that the majority of the respondents are interested in the idea of Learning of Historical Patriotic Heroes through game approach. Hopefully, the outcome of this preliminary study will underline the need for developing a rigorous engaging game design for education.

*Keywords:* Engagement, game design, historical patriotic heroes, students' perceptions

### INTRODUCTION

Computer games as a medium for learning is not a new. Computer games promote active learning, critical thinking, knowledge creation, collaboration, and effective use of electronic forms of information (Boyle, Connolly, Hailey, & Boyle, 2012). From an educational perspective, games are engaging and adaptable to almost any subject. Enhancing engagement in learning activities is widely considered as an important goal to be reached (Watson, Mong, & Harris, 2011). The purpose of this preliminary study is to investigate students' perceptions of engaging game design in Learning about Historical Patriotic Heroes. The study sample consisted of students who

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##### *E-mail addresses:*

nurulmz@tmsk.uitm.edu.my (N. H. Mat Zain),  
hazrati\_zaini@salam.uitm.edu.my (H. Zaini),  
nabilz@melaka.uitm.edu.my (M. N. Zulhemay),  
aslinabaharum@gmail.com (A. Baharum),  
riduan@uthm.edu.my (W. F. Bustamam),  
fariza@tmsk.uitm.edu.my (F. H. Abdul Razak)

\*Corresponding Author

wanted to learn about patriotic heroes in Malaysia. We took students as a sample study because the previous research findings showed that playing computer games was a popular activity among students (Bourgonjon, Valcke, Soetaert, & Schellens, 2010; Ott & Tavella, 2009). The outcome of this study can be used as guideline for game designers throughout the design process.

## **Theoretical Background**

**Engaging Game Design.** Engagement has been proposed as an essential tool behind the success of educational games (Garris, Ahlers, & Driskell, 2002; Kiili, 2005). Moreover, engagement seems to provide a way to address the important issue of active learning (Admiraal, Huizenga, Akkerman, & Dam, 2011). In the literature, the term engagement is used in different ways. It is used in expressions such as learner engagement (Whitton, 2011), engaging by design (Dickey, 2005), and engagement level (Filsecker & Hickey, 2014). Some researchers examine how educational games can enhance individuals' engagement (Filsecker & Kerres, 2014). Others study the role of engagement on achievement (Fredricks, Blumenfeld, & Paris, 2004) and how classroom activities can produce high levels of engagement (Engle & Conant, 2002).

In this study, engagement is defined as the simultaneous elements of concentration, interest, and enjoyment encapsulating the experience of flow. All three elements are inherently related to learning (Shernoff, 2013). Concentration is central to flow and related to meaningful learning including depth of cognitive processing as well as academic performance (Corno & Mandinach, 1983). Interest leads to attention, reproduces intrinsic motivation, stimulates the desire to continue engagement in an activity, and is related to school achievement (Schiefele, Krapp, & Winteler, 1992). Engagement has been divided into three types of engagement: behavioural, cognitive, and emotional (Fredricks et al., 2004). The three dimensions of engagement were correlated in game-based learning environment (Pellas, 2014).

A study by Byun and Loh (2015) also found that voiceovers in a game can also contribute to positive effect on engagement in game-based learning environment. Moreover, Sabourin and Lester (2014) found that game-based learning was able to support learning and promote engagement. Admiraal, Huizenga, Akkerman, and Dam (2011) also found that flow had a positive effect on students' performance in the game but did not have an effect on learning outcomes; yet, if the students were engaged in a group competition, the more the students learned.

**Learning Historical Patriotic Heroes through Computer Games.** An increasing number of researchers are recognizing the impact of computer games and exploring the potential for gaming technology to engage learners (Zain, Jaafar, & Razak, 2012) such as in learning of historical patriotic heroes. In this study, we define a historical patriotic hero as a person who makes significant contributions to the development of civilization and is admired for any of a number of qualities, including courage and outstanding achievements. Besides, historical

patriotic heroes are individuals who are encountered when studying the history of Tanah Melayu (Malaysia). Some of the renowned national heroes Tun Perak, Tok Gajah, Mat Kilau, Hang Tuah, Dato' Maharaja Lela Pandak Lam, Haji Abdul Rahman Limbong, Tok Janggut, Yamtuan Antah, and Rentap.

The learning of historical patriotic heroes involves memorizing the events, characters, and dates occurred in the sequence. One of the approaches to learn historical context is by referring to history textbooks. However, many students have a hard time recalling historical information due to oral semantic memory storage limitation. Moreover, the abstract context of the period of the places of events is not present (Foreman, Korallo, Newson, & Sarantos, 2008). Hence, we proposed learning of historical patriotic heroes through engaging game design.

According to Radetich and Jakubowicz (2015), computer games can be used in teaching when learning and playing takes place at the same time. In addition, as stated by Thillainathan, Hoffmann, Hirdes, and Leimeister (2013), computer games are the medium that combines gameplay experience with educational context by conveying learning objectives into a game, thereby sustaining the player's enthusiasm. In other words, computer games can provide an effective learning medium in the fields of higher declarative knowledge, procedural knowledge, and higher retention (Fang, Tan, Subramaniam, & Loi, 2013).

## **MATERIALS AND METHODS**

### **The Participants**

The participants were required to indicate their agreement with the items related to perceptions of engaging game design in learning historical patriotic heroes. Participants were required to respond to 10 items, with each item having five options for the response on a scale from 1 = strongly disagree, 2 = disagree, 3 = moderately agree, 4 = agree, and 5 = strongly agree. It was expected that the survey would take approximately 5-10 minutes to complete. Confidentiality and anonymity was protected at all times, and participants were informed that the data would only be disclosed with their consent. The participants were also informed that the data obtained from the questionnaire would be assigned a subject number that would not be paired with other personal details.

### **Instrument and Procedure**

The instrument adapted from the literature review contained 10 items. The instrument concerns students' perception of engaging game design in Learning Historical Patriotic Heroes. Table 1 shows the list of items that were adapted from previous studies. On the day of the assessment, consent forms and detailed guidelines were given to the participants prior to distribution of the questionnaires. The researcher was present to clarify any enquiries, and participants were informed that the assessment would involve responding to questions related to perception of engaging game design in learning historical patriotic heroes.

Table 1  
*The items that were adapted from literature review*

No	Items	Ref.
1.	I am interested in learning historical context through computer games.	(Watson, Mong, & Harris, 2011)
2.	Learning historical context through computer games will enhance students' engagement.	(Watson et al., 2011)
3.	Learning process will enhance through engaging game design.	(Ke, 2014)
4.	I will enjoy learning historical context through engaging game design.	(Boyle, Connolly, Hailey, & Boyle, 2012)
5.	I will be excited to learn historical context through engaging game design.	(Garris, Ahlers, & Driskell, 2002)
6.	I will enjoy the engaging historical gameplay.	(Federoff, 2002)
7.	I feel informative with the engaging historical storyline.	(Sylaiou, Mania, Karoulis, & White, 2010)
8.	I feel easier to remember historical facts through engaging game design.	(Sampayo-Vargas, Cope, He, & Byrne, 2013)
9.	I understand historical context with the engaging game interaction.	(Ke, 2014)
10.	I prefer to learn historical context through computer games rather than traditional methods.	(Rondon, Sassi, & Furquim de Andrade, 2013)

## RESULTS AND DISCUSSION

The data was analysed using the SPSS software to estimate the frequency (%), standard descriptive statistical methods were used for the variables. In total, 33 students participated (9 male and 24 female) involved in this study and all of them were computer game users. The participants were distributed in the age groups of 13-19 and > 20 years. The findings of the descriptive analysis for each item are based on a Likert Scale. Figure 1 (a) shows the findings of the statement - *I am interested in learning historical context through computer games*. The findings show that most students agreed (N = 22, 66.67%) and strongly agreed (N = 5, 15.15%) to learn through computer games. Based on the results, the maximum score on the scale is agree, followed by strongly agree and moderately agree. Only one respondent (3.03%) disagreed and strongly disagreed with less than 10% disagreeing. Figure 1(b) presents the percentage results of item 2. One respondent strongly disagreed and another disagreed with statement of item 2. There are 10 respondents (30.30%) who moderately agreed and more than half of the respondents strongly agreed (N = 19, 57.58%) that learning historical context through computer games can enhance engagement among students for the subject.

As shown in Figure 2(a), more than half the respondents agreed that engaging game design will enhance learning process (N = 18, 54.5%). Only one respondent (3.03%) disagreed and one strongly disagreed with this statement. Figure 2(b) presents the results of item 4. The results revealed that most of respondents agreed (N = 11, 33.3%) that they enjoy learning historical

context through engaging game design. Meanwhile, eight respondents disagreed and eight strongly disagreed, which is less than 10% of disagreeing.

As shown in Figure 3(a), approximately half of the respondents (N = 13, 39.4%) agreed that they were enthusiastic to learn historical context through engaging game design. Based on the result, the answers of the respondents tended towards broadly agreeing. Figure 3(b) shows the results of the statement - *I feel fun with the engaging historical gameplay*. Half of the respondents agreed (N = 17, 51.52%) and strongly agreed (N = 4, 12.12%) that it will be fun when the game has an engaging gameplay. Results indicate the highest proportion fell in the category of agree, strongly agree and moderately agree, respectively. Only one respondent (3.0%) strongly disagreed with item 6.

Figure 4(a) presents the results of item 7. The results revealed that more than half of the respondents agreed (N = 21, 63.64%) that they felt informed with the historical storyline. Meanwhile, five respondents disagreed and strongly disagreed, which is less than 10% of disagreeing. Figure 4(b) presents the results of item 8. The results revealed that respondents agreed (N = 18, 54.55%) that they felt it was easier to remember historical facts through an engaging game design. Meanwhile, there are 24.24% (8 respondents) who moderately agree with this statement.

The participants responded to the questions on the understanding of historical context with the engaging game interaction. As shown in Figure 5(a), 11 respondents (33.33%) moderately agreed with the statement, followed by 16 respondents (48.48%) who were in full agreement. There were two respondents (6.06%) who disagreed and one respondent (3.03%) who strongly disagreed of, the almost 10% who disagreed. Figure 5 (b) presents the results of item 10. The results revealed that more than 50% of respondents expressed agreement in terms of preference to learn historical context through computer games rather than traditional methods. Meanwhile, there are 6.06% (2 respondents) who disagreed with this item.

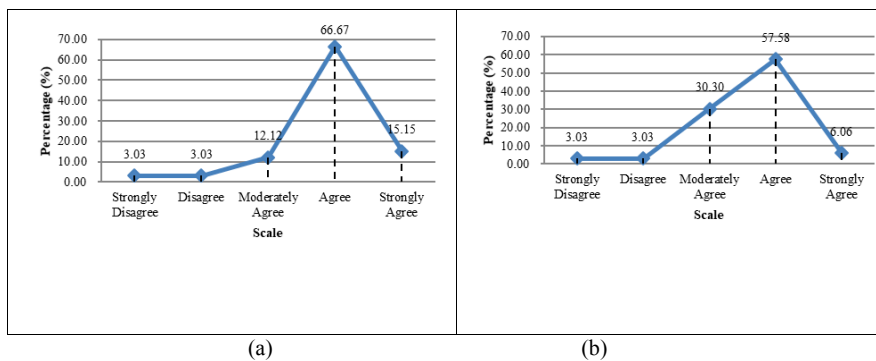


Figure 1. (a) Percentage result item 1; and (b) Percentage result item 2

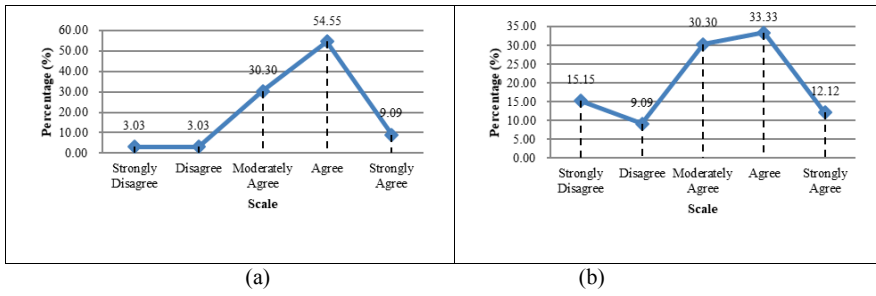


Figure 2. (a) Percentage result item 3; and (b) Percentage result item 4

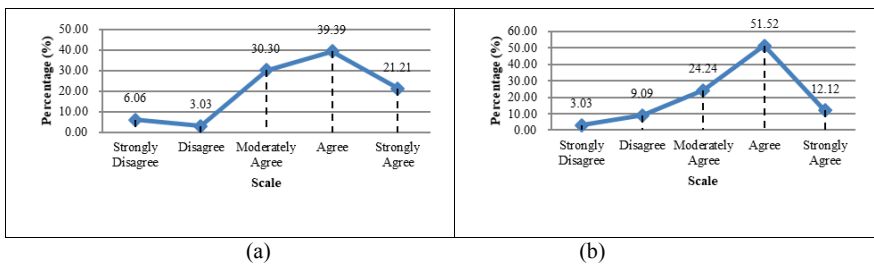


Figure 3. (a) Percentage result item 5; (b) Percentage result item 6

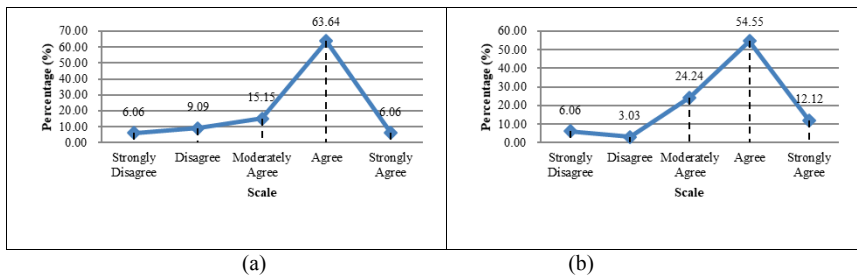


Figure 4. (a) Percentage result item 7; (b) Percentage result item 8

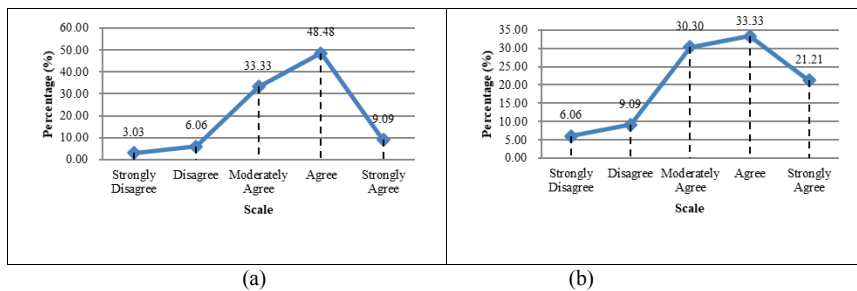


Figure 5. (a) Percentage result item 9; (b) Percentage result item 10



## CONCLUSION

The objective of this preliminary study was to examine students' perceptions of engaging game design in Learning Historical Patriotic Heroes. Descriptive analysis were presented using SPSS. It was found the majority of the respondents are interested in the idea of Learning Historical Patriotic Heroes through game approach finding it a boost to their motivation and engagement to learn. The results also highlight the need to develop a rigorous and engaging game design to learn historical context easier in an interactive way.

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## REFERENCES

- Baharum, A., & Jaafar, A. (2013). Users' expectation of web objects location: Case study of ASEAN countries. In *International Visual Informatics Conference*, pp. 383–395. CONF, Springer.
- Boyle, E. A., Connolly, T. M., Hainey, T., & Boyle, J. M. (2012). Engagement in digital entertainment games: A systematic review. *Computers in Human Behavior*, 28(3), 771–780. Retrieved from <http://doi.org/10.1016/j.chb.2011.11.020>
- Fang, L., Tan, J., Subramaniam, S., & Loi, M. M. L. (2013). Learning Singapore history in a virtual world. In *Educational Media (ICEM), 2013 IEEE 63<sup>rd</sup> Annual Conference International Council for IEEE*, pp. 1–10.
- Federoff, M. A. (2002). Heuristics and usability guidelines for the creation and evaluation of fun in video games. *FUN in Video Games Thesis University Graduate School of Indiana University*, 52. Retrieved from <http://doi.org/10.1.1.89.8294>
- Foreman, N., Korallo, L., Newson, D., & Sarantos, N. (2008). The incorporation of challenge enhances the learning of chronology from a virtual display. *Virtual Reality*, 12(2), 107–113.
- Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation and Gaming*, 33(4), 441–467.
- Ke, F. (2014). An implementation of design-based learning through creating educational computer games: A case study on mathematics learning during design and computing. *Computers and Education*, 73, 26–39. Retrieved from <http://doi.org/10.1016/j.compedu.2013.12.010>
- Mat Zain, N. H., Jaafar, A., & Abdul Razak, F. H. (2016). Enjoyable game design: Validation of Motor-Impaired User GameFlow Model. *International Journal of Computer Theory and Engineering (IJCTE)*, 8(2), 116–121. Retrieved from <http://doi.org/10.7763/IJCTE.2016.V8.1029>
- Radetich, B. L., & Jakubowicz, E. (2015). Using Video games for teaching history. Experiences and Challenges. *Athens Journal of History*, 1(January), 9–22. Retrieved from <http://www.atiner.gr/journals/history/2015-1-1-1-Radetich.pdf>

- Rondon, S., Sassi, F. C., & Furquim de Andrade, C. R. (2013). Computer game-based and traditional learning method: a comparison regarding students' knowledge retention. *BMC Medical Education*, 13(1), 30. Retrieved from <http://doi.org/10.1186/1472-6920-13-30>
- Sampayo-Vargas, S., Cope, C. J., He, Z., & Byrne, G. J. (2013). The effectiveness of adaptive difficulty adjustments on students' motivation and learning in an educational computer game. *Computers and Education*, 69, 452–462. Retrieved from <http://doi.org/10.1016/j.compedu.2013.07.004>
- Sylaiou, S., Mania, K., Karoulis, A., & White, M. (2010). Exploring the relationship between presence and enjoyment in a virtual museum. *International Journal of Human Computer Studies*, 68(5), 243–253. <http://doi.org/10.1016/j.ijhcs.2009.11.002>
- Thillainathan, N., Hoffmann, H., Hirdes, E. M., & Leimeister, J. M. (2013). Enabling educators to Design serious games—A serious game logic and structure modeling language. In *Scaling up Learning for Sustained Impact*, 643–644. Springer.
- Watson, W. R., Mong, C. J., & Harris, C. A. (2011). A case study of the in-class use of a video game for teaching high school history. *Computers and Education*, 56(2), 466–474. Retrieved from <http://doi.org/10.1016/j.compedu.2010.09.007>
- Zain, N. H. M., Jaafar, A., & Razak, F. H. A. (2012). SGameFlow framework: How to experience enjoyment in Serious Game (SG) for Motor Impaired Users (MIU). In *2012 International Conference on Computer and Information Science, ICCIS 2012 - A Conference of World Engineering, Science and Technology Congress, ESTCON 2012 - Conference Proceedings*, 2, pp. 1020–1024.

## Use of Sawdust as Admixture in Cement-Sand Brick

**Rosnani Ahmad\*, Rohaidah Md Nor and Siti Azliya Ismail**

*Department of Civil Engineering, Politeknik Sultan Salahuddin Abdul Aziz Shah, 40150 Shah Alam, Malaysia*

### ABSTRACT

Sawdust is considered a waste material and a number of innovative ways are being taken to mitigate its effects on the environment. The use of sawdust as additional admixture in cement-sand brick production is an alternative option to mitigate the problem. In this study, three different types of cement-sand brick mixture in proportion of 1%, 2% and 3% of sawdust added to the normal mixture are prepared. Compression test was conducted on the brick mixture and results indicated 1% sawdust satisfy the Class 1 loadbearing brick whilst the 2% sawdust is slightly above the minimum required strength of 5.2 MN/m<sup>2</sup> for an ordinary quality brick set by the Standards MS 76:1972. Thus, the use of sawdust as admixture in cement-sand brick should not exceed 3%.

*Keywords:* Cement-sand brick, compressive strength, sawdust brick

### INTRODUCTION

Sawdust is a by-product of wood-based processing mills or workshops. It is of little use and usually dumped with detriment to the environment. Recycling unmanaged industrial wastes is one way this problem can be overcome (Turgut & Algin, 2007).

Many researches have considered sawdust in building materials such as in concrete and bricks. Sawdust up to 25% can be used as replacement for sand in concrete (Joseph et al., 2014). Raheem (2012) reported that sawdust ash in concrete reduces the slump and compacting factor

thus indicating reduction of workability. For optimum strength the percentage of sawdust ash should be at 5% replacement (Raheem et al., 2012). Saeed (2013) studied the use of pre-treated sawdust in sawdust concrete and found its compressive and flexural strength improved while at the same time maintaining basic advantages such as lightness of weight, saw-ability and nail-ability. It was also found that with the increase in the amount of

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##### *E-mail addresses:*

nani\_psa@yahoo.com (Rosnani Ahmad),

zurida5267@gmail.com (Rohaidah Md Nor),

adamono2006@gmail.com (Siti Azliya Ismail)

\*Corresponding Author

sawdust, the workability and density of concrete decreased; however, the water absorption capacity of concrete increased with the volume whilst its strength and the modulus of elasticity decreased (Hossain, 2016). In the case of bricks, Turgut and Algin (2007) reported that limestone dust in combination with wood sawdust in high quantities resulted in less unit weight, smooth surface and ductile fracture. Chemani (2013) studied the effect of adding sawdust to ceramic clay brick by drying and firing shrinkage, water absorption, porosity, bulk density and compressive strength. They concluded that up to 9% sawdust of particle size 1.6 mm can be used in the mixture for better results. (Chemani & Chemani, 2013). Mageed (2012) reported that the combination of limestone dust and cement can be used in the production of masonry building bricks with acceptable mechanical properties. Studies of sawdust in sand blocks showed that not more than 10% replacement will maintain the compressive strength but will reduce the weight and cost of the sandcrete blocks (Adebakin & Adeyemi, 2012). The objective of this study is to determine the compressive strength of cement-sand brick mixed with different proportion of sawdust to the normal mixture.

## MATERIALS AND METHODS

Methodology of the study is prepared based on the chart shown below:

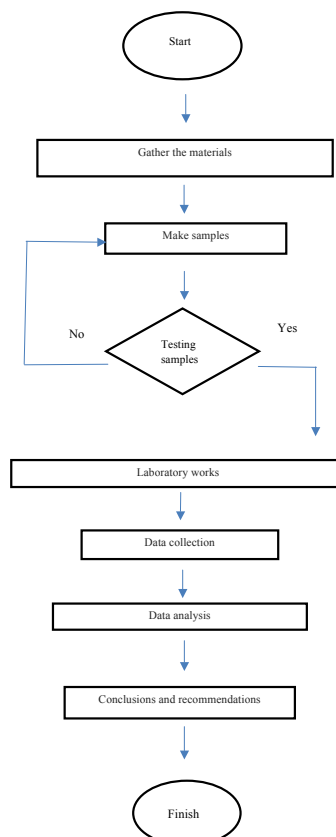


Figure 1. Methodology flow chart for sawdust bricks

Laboratory experiments was done to determine the compressive strength different quantities of sawdust in the 1%, 2% and 3% range respectively. Malaysian Standard, MS 76:1972 states that the compressive strength of ordinary brick must pass 5.2 MN/m<sup>2</sup>. Bricks with a compressive strength of 5.2 MN/m<sup>2</sup> can be used for the construction of single and two-storey buildings.

**Process of cement sand bricks from sawdust.**

The sawdust used was filtered and surpassed 600 micrometer in size, the percentage of sawdust used is 1%, 2% and 3% of the total weight of sawdust bricks that were made.

Table 1  
Proportion of sawdust for cement bricks

The Average Weight of a Brick	2700g
Weight 1% sawdust in a brick	27g
Weight 2% sawdust in a brick	54g
Weight 3% sawdust in a brick	81g

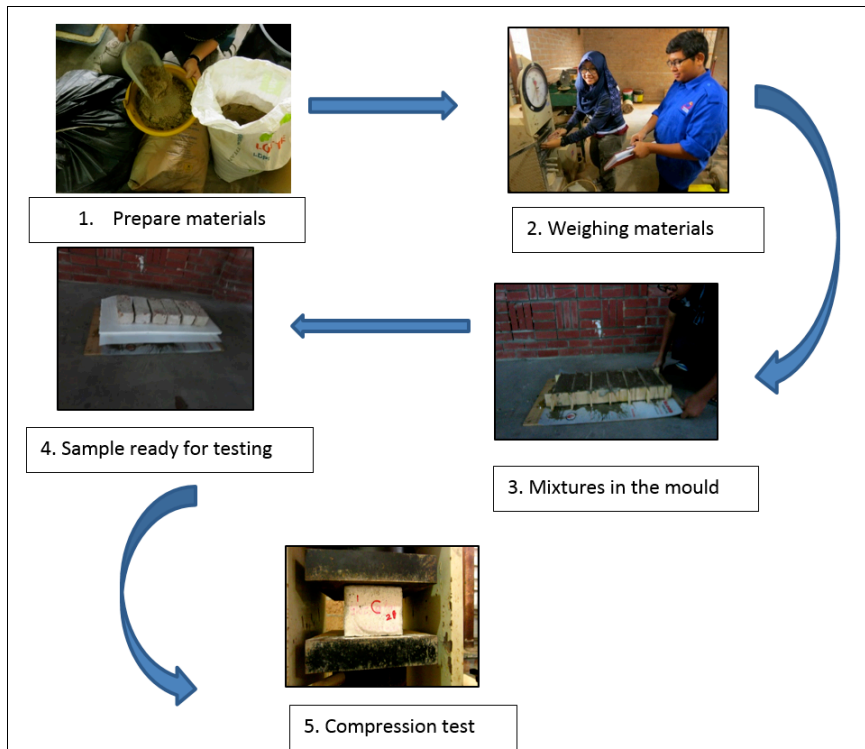


Figure 2. Selecting materials until testing of compression strength

## RESULTS AND DISCUSSION

The compressive strength test for sawdust bricks was carried out at intervals of i.e. 7, 14 and 28 days. The results of the compressive strength is tabulated below:

Table 2  
*Compressive strength of sawdust bricks at different ages*

Sample mixture	7 days	14days	28 days	Average	Difference
Sawdust bricks (1%)	7.32 MN/m <sup>2</sup>	8.54 MN/m <sup>2</sup>	8.67 MN/m <sup>2</sup>	8.18 MN/m <sup>2</sup>	2.98 MN/m <sup>2</sup>
Sawdust bricks (2%)	6.08 MN/m <sup>2</sup>	7.18 MN/m <sup>2</sup>	7.29 MN/m <sup>2</sup>	6.85 MN/m <sup>2</sup>	1.65 MN/m <sup>2</sup>
Sawdust bricks (3%)	3.87 MN/m <sup>2</sup>	4.68 MN/m <sup>2</sup>	5.25 MN/m <sup>2</sup>	4.60 MN/m <sup>2</sup>	-0.6 MN/m <sup>2</sup>

Table 2 shows that, the average compressive strength for sawdust bricks with 1% addition saw dust is 8.18 MN/m<sup>2</sup>, 2% sawdust is 6.85 MN/m<sup>2</sup> whilst 3% sawdust is 4.60 MN/m<sup>2</sup>. It means, the when the proportion of sawdust is increased the compressive strength of the bricks decreases. This leads to an average difference of 2.98MN/m<sup>2</sup>, 1.65MN/m<sup>2</sup> and (-0.6 MN/m<sup>2</sup>) for 1%, 2% and 3% respectively as compared to standard bricks.

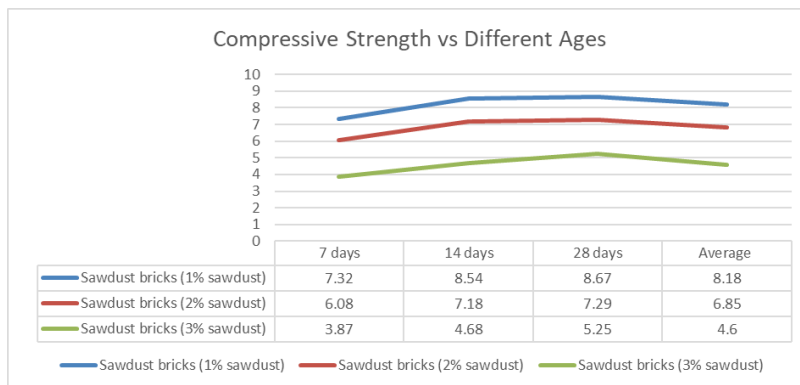


Figure 3. Compressive strength vs different ages

The data shown in Figure 3 shows that the compressive strength of 1% sawdust bricks is 8.18 MN/m<sup>2</sup> meets the requirement of Class 1 for load bearing bricks. While the compressive strength of 2 % sawdust bricks is 6.85 MN/m<sup>2</sup> fulfils the criteria stated in Clauses 12, 17 & 22 as stated in MS 76: 1972 as a load bearing brick. Therefore, it can be deduced that sawdust has the potential to be an additive in the manufacture of cement bricks although the amount used as additive it should not exceed 2%.

## CONCLUSION

This study was carried out to determine the potential of waste sawdust from work based workshop as an additive in cement bricks. The tests prove that sawdust can be used in the manufacture of cement bricks. However, the percentage of sawdust that has to be added in cement bricks cannot exceed 2%.

## ACKNOWLEDGEMENT

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## REFERENCE

- Adebakin, I., & Adeyemi, A. (2012). Uses of sawdust as admixture in production of lowcost and light-weight hollow sandcrete blocks. *American Journal of Scientific and Industrial Research*, 3(6), 458–463. <http://doi.org/10.5251/ajsir.2012.3.6.458.463>
- Chemani, H., & Chemani, B. (2013). Valorization of wood sawdust in making porous clay brick, 8(15), 609–614. Retrieved from <http://doi.org/10.5897/SRE12.608>
- Hossain, M. Z. (2016). Some aspects of physical and mechanical properties, 10(21), 1918–1923.
- Joseph, O., Seun, O., Oluwajana, D., & Peter, S. (2014). Investigation of properties of concrete using sawdust as partial replacement for sand, 6(2), 35–42.
- Kumar, D., Singh, S., Kumar, N., & Gupta, A. (2014). Low cost construction material for concrete as sawdust, 4(5), 3428–3430.
- Mageed, A. A., & AbdelHafez, S. (2012). Utilization of limestone dust in brick making. *Journal of Engineering Sciences*, 40(3), 913–922.
- Malaysian Standard : MS 76 : 1972 Specification for bricks and blocks for fired bricksearth, clay or shale part 2: Metric units
- Raheem, A. A., Olasunkanmi, B. S., & Folorunso, C. S. (2012). Saw dust ash as partial replacement for cement in concrete. *Organization, Technology and Management in Construction: An International Journal*, 4(2), 474–480. Retrieved from <http://doi.org/10.5592/otmcj.2012.2.3>
- Saeed, H. H. (2013). Pretreatment of sawdust for producing sawdust concrete. 31(3), 541–549.
- Turgut, P., & Algin, H. M. (2007). Limestone dust and wood sawdust as brick material. *Building and Environment*, 42(9), 3399–3403. Retrieved from <http://doi.org/10.1016/j.buildenv.2006.08.012>







## Development of E-ACTIVETRANS for Young Professional Planners/Engineers

Bibie Sara Salleh<sup>1\*</sup>, Jasni Md Noor<sup>1</sup>, Riza Atiq O.K Rahmat<sup>2</sup> and Amiruddin Ismail<sup>2</sup>

<sup>1</sup>Politeknik Sultan Salahuddin Abdul Aziz Shah, 40150 Shah Alam, Selangor, Malaysia

<sup>2</sup>Fakulti of Engineering and Built Environment, UKM Bangi, 43600 Bangi, Selangor, Malaysia

### ABSTRACT

This paper presents a development of an expert system to be used as an advisory in finding the solution to problems which are normally solved by human experts. The E-ACTIVETRANS is developed to help young engineers/planners in designing a new cycle lane in urban areas and also to help in reallocation of an existing roadway space for cycle lanes. This system has three sub-systems: Planning on Strategies to Shift from Passive Transportation to Active Transportation, Design on Bicycle Facilities and Examples of Successful Implementation. This paper focuses on the design of bicycle facilities whereby the prototype was developed based on data acquired from the domain experts who are involved in bicycle facility module design, as well as the initial text analysis obtained during the domain familiarisation stage. The validation of the system was performed through a comparison of knowledge content in E-ACTIVETRANS based on expert opinion. The average level of acceptance is 91 percent which validates the system and knowledge of the experts.

*Keywords:* Bicycle facilities, E-ACTIVETRANS, expert system, human experts

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*E-mail addresses:*

[bibiesalleh@gmail.com](mailto:bibiesalleh@gmail.com) (Bibie Sara Salleh),

[jasjka@yahoo.com](mailto:jasjka@yahoo.com) (Jasni Md Noor),

[rizaatiq@ukm.my](mailto:rizaatiq@ukm.my) (Riza Atiq O.K Rahmat),

[aismail@ukm.edu.my](mailto:aismail@ukm.edu.my) (Amiruddin Ismail)

\*Corresponding Author

### INTRODUCTION

E-ACTIVETRANS is developed as an advisory system to provide guidance to users on solutions to problems which are normally solved by experts (Forslund, 1995). Both expert and advisory systems play the role of problem-solving packages that mimic experts (Mansyur, 2011). E-ACTIVETRANS was developed using knowledge from experts in the transportation field, and information obtained from guidelines, encyclopaedia and research publications.

## DEVELOPMENT OF E-ACTIVETRANS

The E-ACTIVETRANS is developed using Visual Basic.NET and MY SQL. VB is an event language designed to interact with the user on a running system. The most widely used type of representation consists of collection of facts, while rules are used to represent IF-THEN reasoning. These rules have the form of “IF ‘condition’ THEN ‘action’.” According to Pauziah et al. (2009), if the condition part is true within the scope of the knowledge base, then the condition would store the facts portion of the system knowledge engine. Therefore, the condition part is performed.

The E-ACTIVETRANS begins by outlining some key guiding principles to help in the selection and identification of available types of bicycle facilities. This guide classifies bicycle facilities into four (4) types. There are no fast and hard rules in determining the most appropriate type of bicycle facility for a certain location (Mansyur, 2011b).

The knowledge extracted during the acquisition process is grouped together in 5 segments in this design module. For the development of knowledge modules, each module solves a specific aspect of the problem within the domain even though some inter-dependency exists between the component tasks. Figures 1, 2 and 3 show the flowchart for the development of E-ACTIVETRANS advisory system, beginning from the first step. This paper focuses on the design of bicycle facilities; it outlines TWO (2) suggestions based on the new design of cycle lane and reallocation of roadway space.

### New Design for Cycle Lane

There are several types of cycle lane in E-ACTIVETRANS. Choice is influenced by the vision of the route itself and the surrounding area in the context of delivering travel patterns. In this module, the user needs to know how to select the density area, type of user and other factors influencing the selection of bicycle facilities (VTPI, 2012). The E-ACTIVETRANS will advise the user on how to design the cycle lane according to the flowchart shown Figure 1.

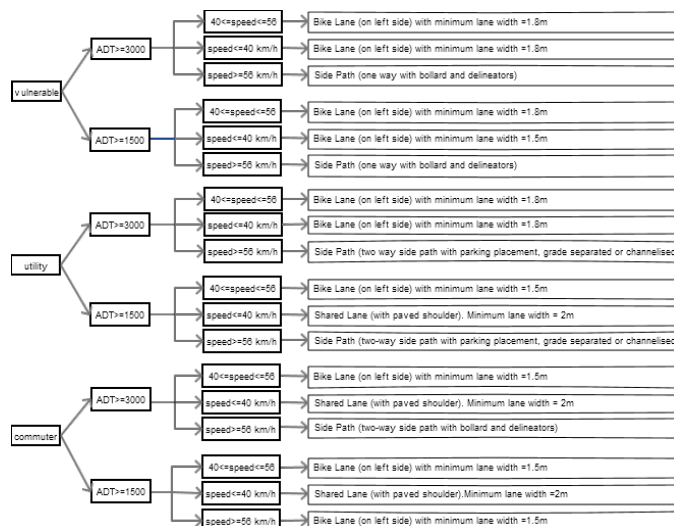


Figure 1. Advisory expert system for new design for cycle lane

### Reallocation of Road Way Space

This section describes how roadway design practices can encourage development of more efficient transportation system through reallocation of road space, such as shifting the road space from automobile traffic to other active transport modes such as bike lanes and sidewalks. Reallocation of roadway is particularly appropriate on congested streets (VTPI, 2014). The knowledge extracted during the knowledge acquisition process is grouped together into specific modules based on the objective of the users. Figure 2 and Figure 3 show the flowchart for the development of the reallocation of the existing roadway space for cycle lane’s diagnostic from the first step.

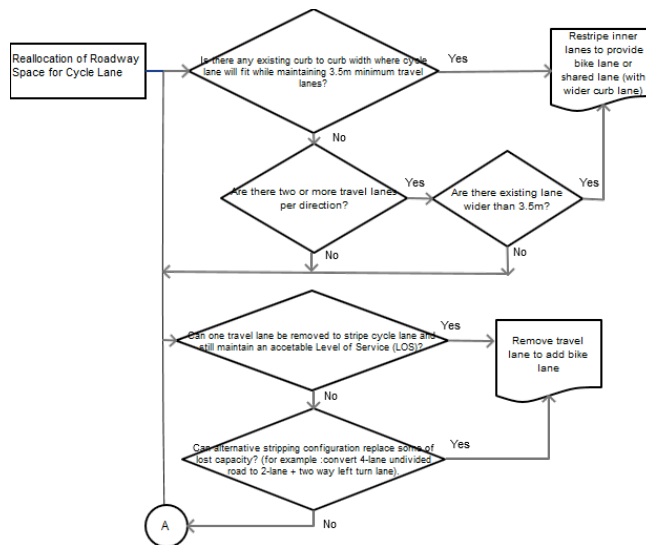


Figure 2. Advisory expert system for the reallocation of roadway space for cycle lane

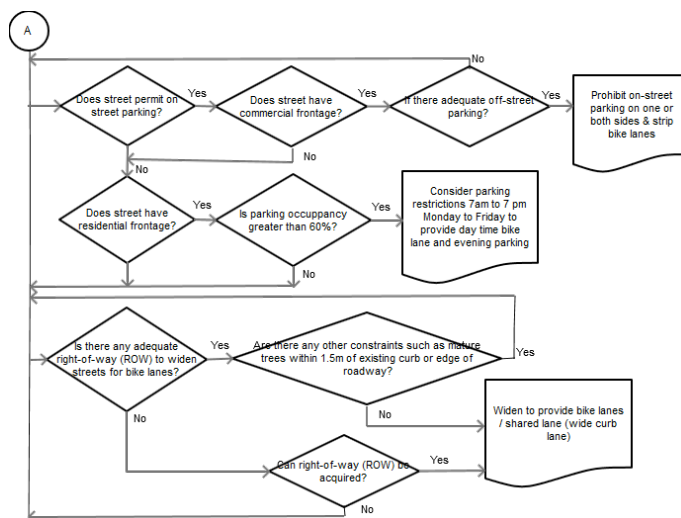


Figure 3. Advisory expert system for the reallocation of roadway space for cycle lane (continued)

### E-ACTIVETRANS REASONING VALIDATION

The reasoning rules of E-ACTIVETRANS were verified during system testing to ensure the validity of the system. A number of rules including the logical errors is summarized in Table 1.

Table 1  
Number of rules used in the E-ACTIVETRANS

Single Rules		Conclusion (THEN-Part)	
N	Condition (IF-Part)	Sub-Rule	Conclusion (THEN-Part)
1	If there is any existing curb to curb width where cycle lane will fit while maintaining 3.5m minimum travel lanes		Restripe inner lanes to provide a bike lane or a shared lane (with a wider curb lane)
2	If one travel lane can be removed to stripe cycle lane and still maintain the acceptable Level of Service (LOS)		Remove the travel lane to add a bike lane
Two Combined Rules			
N	Condition (IF-Part)	Operator	Sub-Rule
3	If there is no one travel lane can be removed to stripe the cycle lane and cannot maintain an acceptable Level of Service (LOS)	AND	If an alternative stripping configuration replaces some of the lost capacity (for example: convert a 4-lane undivided road to 2-lane + two way left, turn lane).
4	If there is an adequate right-of-way (ROW) to widen streets for bike lanes	AND	If there are no other constraints such as mature trees within 1.5m of the existing curb or edge of roadway
5	If there is no adequate right-of-way (ROW) to widen streets for bike lanes	AND	If right-of-way (ROW) is shared lane (wide curb lane) is Widen to provide bike lanes/ shared lane (wide curb lane)
Three Combine Rules			
N	Condition (IF-Part)	Operator	Sub-Rule
6	If there is no existing curb to curb width where cycle lane will fit while maintaining 3.5m minimum travel lanes	AND	If there are two or more travel lanes per direction
7	If there is a permit on street parking		If street have commercial frontage
8	If there is no permit on street parking		If street have residential frontage
		AND	If there is an existing lane wider than 3.5m
		AND	If there is an adequate off-street parking
		AND	Restripe the inner lanes to provide a bike lane/shared lane (with wider curb lane)
		AND	Prohibit on-street parking on one or both sides & strip a bike lane
		AND	Consider parking restrictions from 7am to 7 pm (Monday to Friday) to provide day time bike lane and evening parking
		AND	Consider parking restrictions from 7am to 7 pm (Monday to Friday) to provide day time bike lane and evening parking

## E-ACTIVETRANS INTERFACE WINDOW

The prototype of E-ACTIVETRANS was developed according to the knowledge acquisition derived from the expert domains. The example of data output is shown in Figure 4.

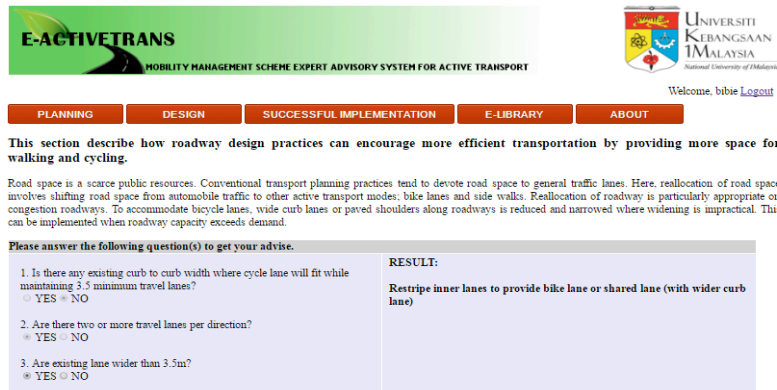


Figure 4. User interface for the decision of reallocation of roadway space

## COMPARISON OF E-ACTIVETRANS RESULTS AND DOMAIN EXPERTS

The system validation was performed through a comparison of knowledge contained in E-ACTIVETRANS with the opinion of FOUR (4) domain experts as shown in Table 2 .

Table 1

*Evaluation of domain experts for knowledge contained in E-ACTIVETRANS*

Module	EXP 1	EXP 2	EXP 3	EXP 4
Module 1	88	100	93	98
Module 2	96	93	92	95
Module 3	93	90	96	87
Module 4	92	88	90	91
Module 5	82	84	90	88
Overall	90	91	92	92

The overall acceptance levels of experts was 90%, 91%, 92% and 92%. Since an E-ACTIVETRANS is an abstraction of reality, perfect performance cannot be expected (O'Keefe, 1987).

## CONCLUSION

This paper presented the development of how knowledge acquisition obtained from expert individuals in the transportation field as the expert domain which has been arranged accordingly with references obtained from guidelines, encyclopaedia and research publications to form

the expert system. The level of acceptance was 90%, 91%, 92% and 92% shows that the system is validated and represents the knowledge of experts. Hence, the overall comments, the validation and evaluation results indicated that E-ACTIVETRANS system has a degree of user-friendliness acceptable for most intended users.

## REFERENCES

- Forslund, F. (1995). Toward cooperative advice-giving systems. *IEEE Expert: Intelligent Systems and Their Applications*, 10(4), 56-62.
- Gregg, G. D., & Walczak, S. (2006). Auction advisor: An agent-based online-auction decision support system. *Decision Support Systems*, 41, 449– 471. Elsevier. *IntelliCorp, Inc. Kappa-PC Ver. 2.4*
- Mansyur, R. (2011). Development of an expert advisory system for strategy implementation in transport demand management (E-ASSIST). PhD Thesis, Department of Civil and Structure Engineering, Universiti Kebangsaan Malaysia (UKM).
- Mansyur, R. (2011b). Decision support system for transport demand Management: Object oriented approach Using KAPPA PC 2.4 Expert System Shell, ARPN, *Journal of Engineering & Applied Science*, 6(2).
- O’Keefe & Smith, E. P. (1987). Validation of expert system performance. *IEEE Expert*, 2(4): 81-90
- Pauziah H. G., Mohd, K. Y., Latifah, M., & Mohamed, D. (2009). Knowledge based system for river water quality management. *European Journal of Scientific Research*, 33(1), 153-162.
- VTPI. (2012). Transport Demand Management (TDM) Encyclopedia, Non-Motorized Transportation Planning, Victoria Transport Policy Institute.
- VTPI. (2014). Transport Demand Management (TDM) Encyclopedia, Walking and cycling encouragement, Victoria Transport Policy Institute.

## Drying Shrinkage and Porosity of Polymer Modified Concrete Containing Vinyl Acetate Effluents

Ainul Haezah Noruzman<sup>1\*</sup>, Mohammad Ismail<sup>2</sup>, Taliat Ola Yusuf<sup>3</sup> and Parham Forouzani<sup>4</sup>

<sup>1</sup>Politeknik Sultan Salahuddin Abdul Aziz Shah, 40150 Shah Alam, Selangor, Malaysia

<sup>2</sup>Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

<sup>3</sup>School of Environmental Studies, Federal Polytechnic, Ede. P.M.B. 231.Ede, Osun State, Nigeria

<sup>4</sup>Department of Structures and Material, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

### ABSTRACT

The volume of waste generated from surface coating industries is of global concern. The disposal of this waste in the form of effluent has put enormous pressure on land and also poses as a health hazard when it leaches into soil and underground water. The study aims to examine the utilization of vinyl acetate effluents from water based paint factories as an admixture in concrete. Concrete specimens containing 0%, 2.5%, 5% and 10% of vinyl acetate effluents by weight of cement were prepared. The specimens were tested for drying shrinkage for 28 days and porosity was tested using mercury intrusion porosimetry. Findings show that concrete containing various proportions of vinyl acetate effluents manifests higher shrinkage behaviour compared to the control item. An investigation of pore size distribution reveals that polymer effluents have particles size larger than 50 nm which are categorized as macroporous in accordance to IUPAC classification. It can be concluded that adding polymer vinyl acetate effluents affects concrete deformation due to the condition of its pore structures. The utilization of this material may provide beneficial effect in terms of the durability performance of concrete and minimize environmental pollution.

*Keywords:* Drying shrinkage, polymer, pore size distribution, porosity, vinyl acetate effluents

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#### E-mail addresses:

ladyahn75@gmail.com (Ainul Haezah Noruzman),

mohammad@utm.my (Mohammad Ismail),

taliatyusuf@yahoo.com (Taliat Ola Yusuf)

\*Corresponding Author

### INTRODUCTION

There is a rapid growth in surface coating industries due to population growth and urbanization. The production of water based surface coating especially water based paint is likely to increase due to strict regulation aimed at lessening the effect of volatile substances in the environment. Excessive

waste disposal from these industries are sent to landfills where it is further segregated (Dursun & Sengul, 2006). Most of the wastes are in the form of solids and liquids as well as volatile organic compound (VOC) emission and must be taken into consideration before it is released into the environment. Research has shown that the use of low-solvent and solvent-free paints can minimize health risks (Harrington et al., 1994). Therefore, switching to water based paint has become pertinent. Apart from being a harmful waste generated by paint industries, there exists the potential of recycling the waste especially as waste polymer in concrete. Manufacturing of water based paint from vinyl acetate resin consumes a large amount of water, ammonia, dispersant, pigments, extenders, resins, preservatives, antifoaming agents and polyvinyl acetate emulsions. (Randall, 1992). The ensuing cleaning operations produces wastes (Lorton, 1988; Dey et al., 2004). Thus using these wastes in concrete production can be an effective recycling method.

Concrete made by combinations of cements and organics material is not new. The first patent of this modification was issued by Cresson 90 years back. Concrete and mortar made by mixing water with polymer is called polymer modified concrete (PMC) and polymer modified mortar (PMM) respectively. In general, PMC depends significantly on the polymer content rather than water content when assessing the normal concrete or mortar (Ohama, 1998). Recent research incorporating waste polymer in concrete and mortar showed promising results in terms of strength and durability. This utilization as an indirect way of its disposal, will furthermore reduce the potential environmental pollution of this waste. Additionally, it will reduce the cost encountered by its management. Previous researchers (Nehdi & Sumner, 2003; Mohammed et al., 2008) studied the potential use of waste latex paint as a partial replacement for virgin latex in latex modified concrete and as partial replacement of mixing water in municipal side walk. Other work (Ismail & Al-Hashmi, 2011) accomplished the study of assessing the recycle of polyvinyl acetate resin wastewater to replace fresh water in the concrete. Besides of these isolate remarks from the previous study, there is not much research effort utilizing of vinyl acetate effluents in concrete especially from strength and deformations aspect. This research aims to study the possible use of vinyl acetate effluents in concrete production as well as to minimize or to reduce the menace of the problem associated with the disposal of vinyl acetate effluents. More important the combinations of waste polymers with concrete could be useful in improving some of properties of concrete and constitute a sustainable construction material.

## **MATERIALS AND METHODS**

### **Materials**

Ordinary Portland cement (OPC) complying with BS EN 197-1(2000) was used. Table 1 presents the chemical compositions and physical properties of the cement Aggregates used are crushed granite gravel and natural-river washed quartz sand with minimum nominal sizes 10 mm and 2.75 mm respectively. The sand has a fineness modulus of 2.57.



Table 1  
*Chemical and physical properties of cement composition*

Composition	%
Silicon dioxide (SiO <sub>2</sub> )	20.1
Aluminium oxide (AlO <sub>3</sub> )	4.9
Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> )	2.4
Calcium oxide (CaO)	65.0
Sulphur oxide (SO <sub>3</sub> )	2.3
Magnesium oxide (MgO)	3.1
Insoluble residue	1.9
Loss on ignition	2.0
Lime saturated factor	0.85

Vinyl acetate effluents used in this study, i.e. the waste latex was generated from production of polymer dispersion factory in southern of Malaysia. The effluents were collected from washing or cleaning tank before production of another batch of paint. The effluents are milky white in colour and have a viscosity of 12.5 cp with the total solids of the effluent at 42%. The physical and chemical properties of vinyl acetate effluents are shown in Table 2.

Table 2  
*Physico-chemical characteristics of the vinyl acetate effluents (All values in mg/L except for pH, turbidity and temperature value)*

Parameter	Units	Parameter	Units
pH	7.12	Zinc (Zn)	1.0488
BOD	13363.00	Iron (Fe)	1.771
COD	77800.00	Calcium (Ca)	72.75
TSS	8200.00	Magnesium (Mg)	9.7165
TDS	5460.00	Sodium (Na)	1199.00
DO	2.72	Copper (Cu)	2.6921
Temperature, °C	19.91	Manganese (Mn)	0.9147
Turbidity, NTU	23.64	Nickel (ni)	0.0873
Tri-Chromium (Cr <sup>3</sup> )	23.64	Mercury (Hg)	3.4998
Sulfate (SO <sub>4</sub> <sup>2</sup> )	0.1376	Cadmium (Cd)	0.0004
Chloride (Cl <sup>-</sup> )	4514.00	Lead (Pb)	0.1302
Nitrate (NO <sub>3</sub> <sup>2</sup> )	27.53	Phosphates (P <sub>2</sub> O <sub>5</sub> )	222.00
Sulphide (S <sup>2-</sup> )	<0.002		

### Mixture proportion and curing condition

Table 3 shows the design mix studied. The samples were prepared by varying the polymer cement ratio of 0%, 2.5%, 5% and 10% by weight of cement. The control samples are cured in accordance to BS 12390-2: 2009 while the vinyl acetate effluents samples are cured following JIS A1171: 2000.

Table 3  
*Mix proportion*

Specimens	Vinyl acetate effluents (kg/m <sup>3</sup> )	Cement (kg/m <sup>3</sup> )	Fine aggregate (kg/m <sup>3</sup> )	Coarse aggregate (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )
PMCVAW 0%	-	380	824	1009	209
PMCVAW 2.5%	9.5	380	824	1009	204
PMCVAW 5%	19	380	824	1009	198
PMCVAW 10%	38	380	824	1009	187

### Drying Shrinkage

The drying shrinkage was measured in accordance to ASTM 596-09. The samples were casted in mortar specimen 25 mm x 25 mm x 250 mm. Each of the specimens were cured in 3 days and allowed to ambient curing for 28 days. Drying shrinkage is measured by using dial strain gauge between Demec points fixed at 100 mm from the central point on the top surface to the edge of specimens. The data is recorded every 24 hours until 28 days.

### Porosity

This test was performed on Autopore IV 9500V1.09 Micrometrics Instrument high pressure mercury intrusion porosimeter with a pressure range for sub ambient to 33,000 Psi. The contact angle and the surface tension of mercury were 130° and 0.485 N/m respectively for oven dried samples (Laskar et al., 1997). Based on the assumption that pores are cylindrical and entirely and equally accessible to mercury, the applied pressure can be converted into the pore diameter by using the Washburn equation (Cook & Hover, 1993) where  $P$  is the applied pressure,  $\gamma$  is the mercury surface tension and  $D$  is the equivalent pore diameter.

$$D = \frac{-4\gamma \cos\theta}{P}$$

Samples obtained after drying are weighed and placed into a chamber. The chamber was subsequently evacuated to remove air from the sample after which mercury was released to fill up the chamber under high pressure. While applying pressure, mercury is forced to intrude into the samples gradually and the applied pressure was recorded. The resulting average pore size distribution curve is determined.

## RESULTS AND DISCUSSION

### Drying Shrinkages of Polymer Modified Mortar

The measured values of shrinkage over a period of 28 days are plotted in Figure 1. It shows that the shrinkage strain of mortar containing vinyl acetate effluents was higher than control mortar. The greater the amount of the polymer in mortar tends to lead to increases in drying shrinkage created by the possible evaporation of water due to the lower water resistant of polymer vinyl acetate and concrete composite (Ramakrishnan, 1992). According to Lenart (2015), shrinkage values are mainly affected by temperature, environmental humidity and the wind speed as well as pore structure. Moisture easily evaporates from large capillary pores and the volume depends on the water-cement ratio. The greater the ratio, the greater the drying shrinkage (Aitcin, 2003). In the study however, higher shrinkages with increases in vinyl acetate effluents was observed may be due to the microstructure and pore size distribution created by the polymer film formation observed by Capener and Tang (2007). Shrinkage under practical conditions depends on loss of water from the mesopores and also the size of the macropores (Collins & Sanjayan, 2000).

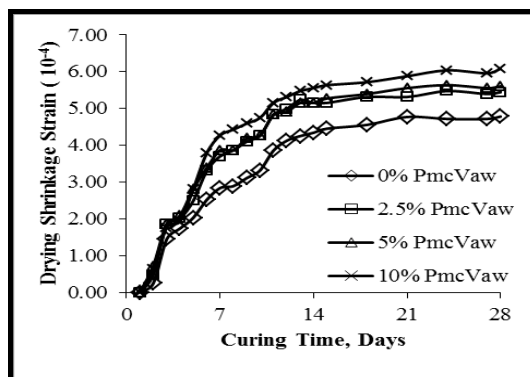


Figure 1. Drying shrinkage at 28 days

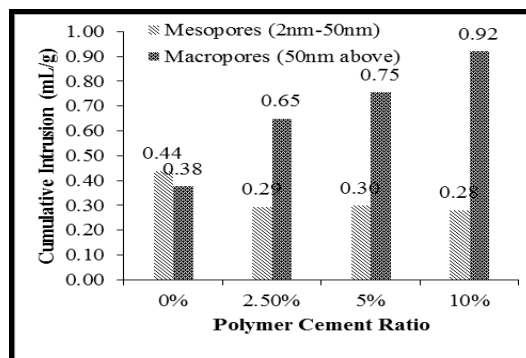


Figure 2. Characterization of pore size distribution among the samples

## Pore Structure Condition of Vinyl Acetate Effluents in Mortar

Results from MIP are used to characterize pore size distribution. Pore sizes can be classified according to the International Union of Pure and Applied Chemistry system (IUPAC, 1972). The capillary pores are made up of both the mesopores and macropores, and are the water filled spaces existing within the original cement grains, while the micropores are part of the calcium silicate hydrate gel component (Collins & Sanjayan, 2000). As shown in Figure 2, samples containing vinyl acetate effluents have higher macropores compared to the control specimen. This is probably due to the presence of surfactants that is present in the effluents. These indicate that the vinyl acetate effluent samples are porous material.

## CONCLUSION

Based on experimental findings, it can be concluded that drying shrinkage increased with vinyl acetate effluents in mortar due to moisture being absorbed by the polymer mortar matrix as a result of its lower resistance. The loss of water from the matrix is the reason for the increased shrinkage. Since the capillary pores of vinyl acetate effluents are made of mesopores and macropores they have the effect of increasing macropores making mortar made from the waste porous.

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## REFERENCES

- Aitcin J. P. (2003). Portland cement hydration seen by a civil engineer. *Cement Lime Concrete*, 70, 115–130.
- Capener, J. C.-M., & Tang, L. (2007). Early Age properties of modern rendering systems based on mineral binders modified by admixtures. *12<sup>th</sup> International Congress on the Chemistry of Cement.*, 863–870.
- Collins, F., & Sanjayan, J. G. (2000). Effect of pore size distribution on drying shrinkage of alkali-activated slag concrete. *Cement and Concrete Research*, 30(9), 1401–1406. doi:10.1016/S0008-8846(00)00327-6
- Cook, R. A., & Hover, K. C. (1993). Mercury porosimetry of cement-based materials and associated correction factors. *Construction and Building Materials*, 7(4), 231-240.
- Dey, B., Hashim, M., Hasan, S., & Sen Gupta, B. (2004). Microfiltration of water-based paint effluents. *Advances in Environmental Research*, 8(3-4), 455–466. doi:10.1016/S1093-0191(02)00122-3
- Dursun, D., & Sengul, F. (2006). Waste minimization study in a solvent-based paint manufacturing plant. *Resources, Conservation and Recycling*, 47(4), 316–331. doi:10.1016/j.resconrec.2005.12.004
- Harrington, J. M., Rose, F. G., & Koh, D. (1994). Paint -- Health and environmental risk management: Report of an international symposium held in Singapore: June 1-4, 1992. *Asia-Pacific Journal of Public Health*, 7(2), 115–118. doi:10.1177/101053959400700207

- International Union of Pure and Applied Chemistry (IUPAC). (1972). Manual of symbols and terminology, appendix 2, part 1, colloid and surface chemistry. *J Pure Appl Chem*, 31, 578.
- Ismail, Z. Z., & Al-Hashmi, E. A. (2011). Assessing the recycling potential of industrial wastewater to replace fresh water in concrete mixes: application of polyvinyl acetate resin wastewater. *Journal of Cleaner Production*, 19(2-3), 197–203. doi:10.1016/j.jclepro.2010.09.011
- Kardon, J. B. (1997). Polymer modified concrete: Review. *Journals of Materials in Civil Engineering*, 9(2), 85–92.
- Kim, J., Robertson, R. E., & Naaman, A. E. (1999). Structure and properties of poly (vinyl alcohol)-modified mortar and concrete 1, 29, 407–415.
- Laskar, M. A. I., Kumar, R., & Bhattacharjee, B. (1997). Some aspects of evaluation of concrete through mercury intrusion porosimetry. *Cement and Concrete Research*, 27(1), 93–105. doi:10.1016/S0008-8846(96)00192-5
- Lenart, M. (2015). Assessment of mortar shrinkage in aspect of organic and inorganic modifiers use. *Procedia Engineering*, 108, 309–315. doi:10.1016/j.proeng.2015.06.152
- Lewis, W. J., & Lewis, G. (1990). The influence of polymer latex modifiers on the properties of concrete. *Composites*, 21(6), 487–494. doi:10.1016/0010-4361(90)90421-R
- Lorton, G. A. (1988). Hazardous Waste minimization: Part III Waste minimization in the paint and allied products Industry. *Japca*, 38(4), 422–427. doi:10.1080/08940630.1988.10466394
- Mehta, P. K., & Monteiro, P. J. M. (2006). *Concrete Microstructure, properties, and materials* (Third Edi.). McGraw-Hill.
- Mohammed, A., Nehdi, M., & Adawi, A. (2008). Recycling Waste latex paint in concrete with added value. *ACI Materials Journal*, 105(4), 367–374.
- Nehdi, M., & Sumner, J. (2003). Recycling waste latex paint in concrete. *Cement and Concrete Research*, 33(6), 857–863. doi:10.1016/S0008-8846(02)01084-0
- Ohama, Y. (1998). Polymer-based admixtures. *Cement and Concrete Composites*, 20(2-3), 189–212. doi:10.1016/S0958-9465(97)00065-6
- Ramakrishnan, V. (1992). *Latex Modified concretes and mortars. A Synthesis of highway practice. NCHRP Synthesis 179*. Transportation Research Board, National Research council, Washington D.C.
- Randall, P. M. (1992). Pollution prevention methods in the surface coating industry. *Journal of Hazardous Materials*, 29(2), 275–295. doi:10.1016/0304-3894(92)85073-A



## Design of Optimum Wait Time for Random Arrival of Passengers at Bus Stop: A Case Study from Putrajaya, Malaysia

Ruslawati Abdul Wahab<sup>1,2,3\*</sup>, Muhamad Nazri Borhan<sup>1,2</sup> and Riza Atiq Abdullah O. K. Rahmat<sup>1,2</sup>

<sup>1</sup>Department of Civil and Structural Engineering, Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor, Malaysia

<sup>2</sup>Sustainable Urban Transport Research Centre (SUTRA), Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor, Malaysia

<sup>3</sup>Department of Polytechnic Education, Ministry of Higher Education, Persiaran Perdana, Presint 4, 62100 Putrajaya, Malaysia

### ABSTRACT

The waiting time can be reduced by providing information on bus arrival time. The absence of this information leads to long waiting time and affects passengers' planning travel time. Although the waiting period that is longer or shorter is subjective to each passenger, without information on bus arrival times, the uncertain passenger arrival time may cause difficulties to determine realistic waiting time. This study concentrates on the optimal design of the waiting time from the passengers' arrival time at random. The survey data were observed from one bus stop encoded as ALMD stop in Putrajaya. This stop has no mechanism for real bus arrival information, which raises issue of inconsistent bus arrival times to bus passengers. To analyze the problems, the combination of mathematics and response surface methodology-central composite design applications is used to design optimum waiting time. The design of arrival time was set up into two interval minutes: between 0–29 and 30–59 minutes, which was considered as the random arrival time of passengers. The modification on intervals for waiting time was designed between 0 and 15 minutes to meet the criteria of headway, one bus within 30 minutes. The design outputs resulted in a mathematical model for waiting time and optimization value. The results generated an optimum waiting time of 8.7 minutes for the first passenger and 13.81 minutes for the next passenger, which were the best times with respect to the bus operation headway.

*Keywords:* Bus passengers, design wait time, random arrival time, response surface methodology-central composite design (rsm-ccd), stop

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#### E-mail addresses:

[ruslawati@siswa.ukm.edu.my](mailto:ruslawati@siswa.ukm.edu.my)/[rusrazee@gmail.com](mailto:rusrazee@gmail.com)

(Ruslawati Abdul Wahab),

[mnazri\\_borhan@ukm.edu.my](mailto:mnazri_borhan@ukm.edu.my) (Muhamad Nazri Borhan),

[rizaatiq@ukm.my](mailto:rizaatiq@ukm.my) (Riza Atiq Abdullah O. K. Rahmat)

\*Corresponding Author

## INTRODUCTION

Problems in waiting time arise when lack of information on scheduled bus arrival times and does not match accurately with the actual arrival times of buses. Furthermore, some stops have no information on real arrival times of the bus, which would cause waiting time become more longer. Real-time bus arrival information is very important to the passengers because they can arrange to use their waiting time more fruitfully to choose or to select an alternative mode of transportation. The passenger is more satisfied if the unpredictable waiting time is reduced; therefore, bus ridership also increases (Mishalani et al., 2006). It has conclusively been shown that the major factor in behavioral purpose of users to use public transport is related to service quality (Borhan et al., 2014). Ben-Akiva and Morikawa (2002) trace without information of the availability for the bus, waiting time for the next bus is highly uncertain. Without information on expected arrival times, it could cause anxiety (Yu et al., 2012) and lead to a negative perception among passengers assuming that there was no bus.

The duration of the waiting time is related to the delay in the departure of a bus from its origin based on a headway, the delay at bus stops during alighting and boarding of passengers, the process of acceleration and deceleration of a bus, queuing for a turn at stops, dwell time at stops, traffic lights and intersections, and being caught in the traffic or changing of bus speeds until it reaches its destination. The delay process involves three main stops: deceleration of bus, delay while opening doors, and alighting and boarding of passengers and the acceleration of the bus after departing from stop (Chen et al., 2013). Bus delay at a stop resulted from waiting for entry; departure of the front bus and green light is the average waiting time (Huo et al., 2015). Waiting time or delays play a critical role in the bus services. It is very precious and valuable. The value of waiting time is estimated to be half of a provided headway (Chang & Schonfeld, 1991; Chien & Qin, 2004; Furth & Muller, 2006; Wardman, 2001). According to Mohring et al. (1987), passenger waiting time is two to three times more than the transit time. According to the previous investigation, the value of waiting time is US\$10/h/passenger (Chang & Schonfeld, 1991; Chien et al., 2003 - study case three cities in United States), RMB 2.7/h/passenger (Yu & Yang, 2009), 26 yen/min (Shimamoto & Schmöcker, 2012), and €51.29/bus (Ibeas et al., 2010 - study area in Santander, Spain). The actual arrival times from a bus information system have reduced waiting time to 0.7 minutes or 13% (Watkins et al., 2011).

There are many previous researches to reduce waiting time and is a significant model with a headway or bus frequency (Berrebi et al., 2015; Furth & Muller, 2006), household income (Mohring et al., 1987), total in-vehicle travel time and total operating cost (Liu et al., 2013), passenger crowding and effect on waiting time (Tirachini et al., 2013), partway deadheading operation optimization (Yu et al., 2012), overall delay a bus experiences at a stop (Huo et al., 2015), and social costs (Wagale et al., 2013). A relationship between a real-time information studied by Cats and Loutos (2016) yield that a predict waiting time is more closer to the actual waiting time compared with the timetable. Meanwhile, Wu et al. (2015) considered timetabling problem with stochastic travel times to minimize waiting time. Although while some researches have been carried out on waiting time, unfortunately very few studies have been carried out on design of the waiting time. This article will focus on the design of the waiting time for the random arrival time of passengers and buses at stops in Putrajaya. This issue was raised as a



result of claims by passengers regarding the inconsistent bus arrival times at bus stops. The waiting time at the stops will be examined to find out whether the standards meet the limits and will be analyzed based on observations of actual data. This study also determined the length of waiting time caused, no information on actual arrival time, and vulnerabilities in the operating system or even the perception of bus passengers alone.

## MATERIALS AND METHODS

### Concept and Framework Design

The study was investigated in a bus stop, coded as ALMD in Putrajaya, which has an average of 77 passengers per hour. It is the most popular stop for various routes because it is a transit or major stop to the business area. This stop had no facility of support vector machines for information on bus arrivals. Observations and collecting data conducted on-site using the scheduled time series were carried out randomly at off-peak time bus operation for 28 hours. Bus arrival times were observed and compared with the scheduled bus arrival times to elicit the waiting time. An interval of 30 minutes was set up on the first round and the second bus round, which was differentiated by the intervals, from 0 to 29<sup>th</sup> minute and the next 30<sup>th</sup> to 59<sup>th</sup> minute.

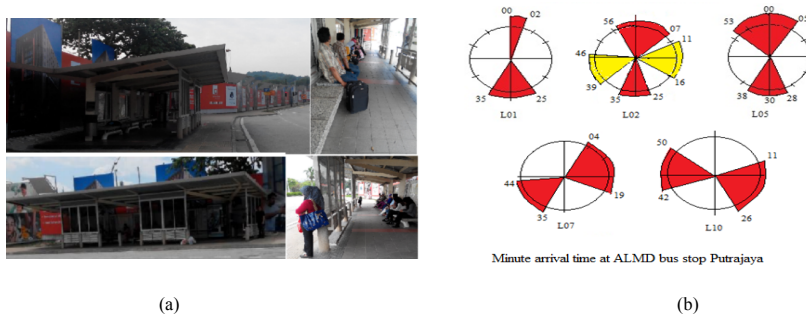


Figure 1. (a) The ALMD Stop in Putrajaya; and (b) A Sketch on up-to-the-minute arrival information

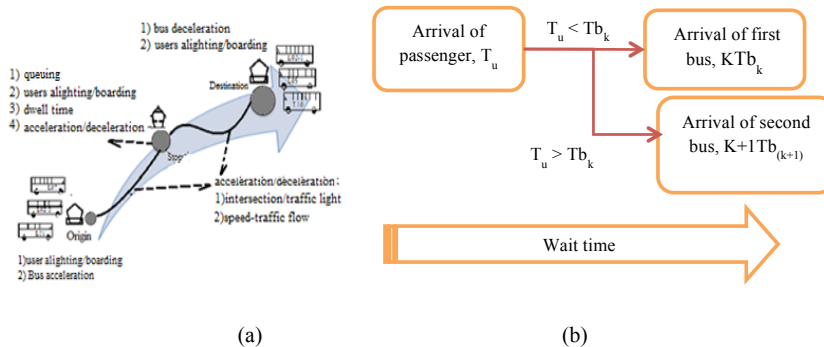


Figure 2. (a) Location of bus delays; and (b) Flowchart of passenger arrival time at random  
 Note:  $T_u$ , arrival time of passenger;  $T_{b_k}$ , arrival time of first bus; and  $T_{b_{k+1}}$ , arrival time of second bus

Figure 1 shows the picture of ALMD stop and the result of observations presented in minutes upon actual bus arrival for each route. The main factor of expected delay was found during observations of arrival time routine at the stops. The flowchart in Figure 2 shows the all delays due to the bus operation and flow or design process of passenger arrivals at random for the bus. The criteria of constraint involved two main factors such as the arrival of passengers at the station and the arrival of the bus. The average interval between the arrival time of the first bus and the next bus refers to a headway, one bus within 30 minutes, if the arrival time of the passenger is equal to or less than the arrival time of the first bus, then the waiting time is not long. However, if the passengers missed the first bus, they have to wait for the second bus.

In this case, the passengers are divided into two categories that is passengers who arrive within the first 30 minutes (0–29<sup>th</sup> minute) and passengers who arrive in the next 30 minutes (30<sup>th</sup>–59<sup>th</sup> minute). The calculation of the waiting time is as shown in the following equations 1–3. If,

$$T_u \leq T_{b_k} \rightarrow T_m = T_{b_k} - T_u \quad [1]$$

$$T_{b_k} < T_u \leq T_{b_{(k+1)}} \rightarrow T_m = T_{b_{(k+1)}} - T_u \quad [2]$$

$$T_u \geq T_{b_{(k+1)}} \rightarrow T_m = 60 - T_{b_{(k+1)}} + T_{b_k} \quad [3]$$

**Response Surface Methodology-Central Composite Design.** This study used a design expert response surface methodology-central composite design (RSM-CCD) to design a model passenger waiting time. RSM-CCD is used to model and generate a desired optimum value. There were several steps that had to be investigated especially in terms of criteria constraints so that problems that emerged could be solved accordingly in the study. The design was only for one stop (ALMD stop) and one route (off-peak hours) and categorized into two range periods referred to a bus headway (30 minutes). The proposed design was solely from the RSM-CCD with 54 experiments.

## RESULTS AND DISCUSSION

The results of this design used real data of bus arrival times at ALMD stop, and the results are only suitable for one route off-peak hour (L01) in Putrajaya or any route that has the same criteria.

### Waiting time design

The design summarizes the variables of factors A, B, C, D and responses Y1 and Y2 with their constraint values. Factor A is coded as TAP1 (arrival time of the first passenger), which is set in the arrival time in the range of minute 0 to the maximum minute 29, and factor B is coded as TAP2 (arrival time of the next/second passenger), which is set in the arrival time between the minimum minute 30 and the maximum minute 59. The factors C and D for the arrival time of the first and the next/second bus coded as TABL01-K and TABL01-K+n, respectively, use

the real observe data that first bus arrives between minute 0 and minute 2 and the next bus arrives in the range of minute 25–35. After that, the wait time of first and second passengers (Y1 and Y2) is keyed in according to the 54<sup>th</sup> experiment design with the waiting time from 0 to 33 minutes.

### Analysis of variance (ANOVA) RSM-CCD

The development of model waiting time is given in Table 1, which has presented  $F$  value of 19.013 for the first passenger and 14.815 for the second passenger. This shows that the model is significant. 0.01%  $F$  value is limited to permissible errors. Therefore, the value “Prob > F,” which is less than 0.05, shows that the model can be accepted. For this study, it was found that a significant model has a smaller value of 0.1000 while the larger more than 0.1 was the opposite. Criteria for the insignificant model would be disposed to improve the model. The determination of coefficient  $R^2$  is useful when the ratio of the variance as a variable can be expected from other variables, namely that  $-x$ -axis and  $y$ -axis values can be expected. A strong relationship between the two variants can be specified with the following. The model is fit or most appropriate when its  $R^2$  is equal to one. For example, correlated  $x$  and  $y$  in this study stated the analysis of three types of  $R$  squared:  $R^2$ , adjusted  $R^2$ , and predict  $R^2$ . The case study for random arrival time of passengers using time series data collection was very complex and difficult. Thus the value of  $R^2$  predictions is emphasized and in reasonable agreement. The  $R^2$  predictive model waiting time of the first and second passengers was 76.7% and 68.2%, respectively. Although the value mentioned was less than the actual  $R^2$  value of 87.2% and 84.2%, it gave the best results for the model in this study in terms of the extent to which the model was able to predict new observations. In statistics, it was able to verify the prediction model in the study. Anyway if the values of predict  $R^2$  and adjusted  $R^2$  were less than 50% or get negative value, it is recommended to reduce too many input variables or increase a parameter data sample size. In addition of model prediction evaluation, RSM-CCD also generates value of adequate precision or simplified as Adeq Precision (AP). AP measures the signal-to-noise ratio. A ratio greater than 4 is desirable and showed the model in terms of its accuracy and appropriateness. The AP ratio for models TWP1 and TWP2, respectively, is 15.3 and 14.5 and indicates an adequate signal. ANOVA results indicated that the model is selected for passenger waiting time and the most significant use of a quadratic model.

The result forecasting for the first and second passenger waiting time quadratic model (first passenger represents first headway and second passenger represents next or second headway) was presented by RSM-CCD in the form of coded equations 1 and 2 as follows:

$$\text{TWP1} = 13.72228 + 8(A) + 0.6667(C) - 5.222(D) - 11.8333(A)^2 + 2.6667(B)^2 + 2.667(C)^2 + 2.6667(D)^2 - 0.25(A)(C) - 6.5(A)(D) - 0.25(C)(D) \quad [1]$$

$$\text{TWP2} = 14.5556 + 0.759(A) - 7.75(B) + 1.52778(C) - 5.027778(D) + 2.916667(A)^2 - 12.58333(B)^2 + 2.916667(C)^2 + 2.916667(D)^2 - 0.84375(A)(B) + 0.84375(A)(C) + 0.84375(A)(D) - 0.59375(B)(C) + 5.65625(B)(D) + 0.59375(C)(D) \quad [2]$$

TWP1, model of waiting time of the first passenger for route L01.

TWP2, model of waiting time of the second passenger for route L01.

A, up-to-the-minute arrival of the first passenger at stop in the first 30 minutes (0–29<sup>th</sup> minute).

B, up-to-the-minute arrival of the second passenger at stop in the second 30 minutes (30<sup>th</sup>–59<sup>th</sup> minute).

C, up-to-the-minute arrival of bus L01 at stop in the first 30 minutes (0–29<sup>th</sup> minute).

D, up-to-the-minute arrival of bus L01 at stop in the second 30 minutes (30<sup>th</sup>–59<sup>th</sup> minute).

### Numerical optimization using RSM-CCD

The criteria of the six variables; arrival time of passenger 1, arrival time of passenger 2, arrival time of first bus, arrival time of next bus, waiting time of passenger 1 and waiting time of passenger 2 were set up their goal, limitation lower and upper and the weights. After that the 10 solutions recommended for optimum value. RSM-CCD design expert suggested that the interval in accordance with the actual data of the waiting time at the ALMD stop, Putrajaya be between 0 and 33 minutes to produce an optimum passengers 1 and 2 waiting time, which is between 8 and 24 minutes and 5 and 22 minutes, respectively. However, the range criteria are modified to the passenger waiting time interval of 0 and 15 minutes according to the headway of one bus within 30 minutes. The results showed a comparison before and after optimization and modifications proposed in Table 1b after the modified interval waiting time. The optimum value of waiting time for passengers 1 and 2 was 7 to 14.5 minutes and 0 to 14.5 minutes, respectively.

Table 1  
*Analysis of variance and criteria of numerical optimization and comparison of waiting time before and after optimization*

Response	Route L01	Sum of squares	DF	Mean square	F value	Prob > F
TWP1	Model	5420.777778	14	387.1984127	19.01324047	<0.0001
	Residual	794.2222222	39	20.36467236		
	Lack of fit	794.2222222	10	79.42222222		
	Pure error	0	29			
	Cor. total	6215	53			
	R-squared	0.872208814				
	Adj. R-squared	0.826335055				
	Pred. R-squared	0.766858125				
	Adeq. precision	15.29964421				

Table 1 (continue)

TWP2	Model	5144.243056	14	367.4459325	14.81549598	<0.0001
	Residual	967.2569444	39	24.80146011		
	Lack of fit	602.7569444	10	60.27569444	4.795597089	0.0004
	Pure error	364.5	29	12.56896552		
	Cor. total	6111.5	53			
	R-squared	0.841731663				
	Adj. R-squared	0.784917388				
	Pred. R-squared	0.682045622				
	Adeq. precision	14.49875436				
b) Comparison of wait time before and after optimization						
Criteria			Limit			
Factor	Code	Goal		Minimum	Maximum	
Arrival time of passenger 1 (minute 00–29)	TAP1	Is in range		0	29	
Arrival of passenger 2 (minute 30–59)	TAP2	Is in range		30	59	
Arrival time of first bus	TABL01-K	Is in range		0	2	
Arrival time of next bus	TABL01-K+1	Is in range		25	35	
Response Before optimization						
Wait time of passenger 1	TWP1	Is in range		0	33	
Wait time of passenger 2	TWP2	Is in range		0	32	
Wait time of passenger 1—adj	TWP1	Is in range		0	15	
Wait time of passenger 2—adj	TWP2	Is in range		0	15	
After optimization						
Wait time of passenger 1	TWP1			8–24 minutes		
Wait time of passenger 2	TWP2			5–22 minutes		
Wait time of passenger 1—adj	TWP3			7–14.5 minutes		
Wait time of passenger 2—adj	TWP4			0–14.5 minutes		

### Optimisation of graph

The optimum graph view in this study was set up for optimum waiting time by comparing the passenger arrival time on the *x*-axis with the first and second bus arrival times on the *y*-axis. The results in Figure 3 show that the forecasted waiting time of the first passenger is 8.7 minutes. The contour line assembles within the interval of 0–7.25 minutes between the first bus and the second bus. This means that the passenger must reach at stop in the duration of the accumulation contour line. The contour line gathers at the end of *x*-axis between the minute 51.75 and the minute 59.00 for the second passenger who has to wait 13.81 minutes, either for the second bus or for the next bus.

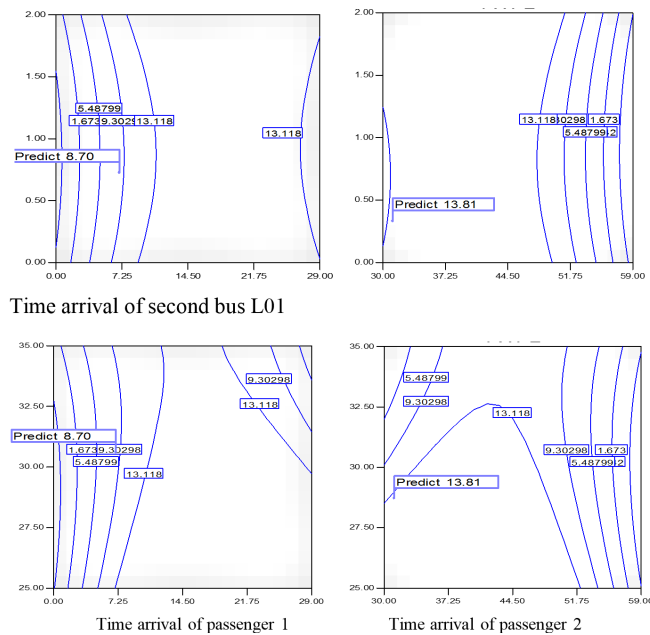


Figure 3. Optimisation of graph prediction waits time of passengers

## CONCLUSION

This project was conducted to design waiting time especially to random arrival passengers at bus stop. These findings used real data from observations, a combination of design and application of mathematical models developed in accordance with the prevailing problems. The study of a waiting time based on the random arrival times of passengers and buses is very useful not only for new designs but also for existing designs. Analysis of the computed results shows the following:

- This research used four factors to design the optimization model: arrival time of the first passenger, arrival time of the second passenger, arrival time of the first bus, and arrival time of the next bus, and it also created two reponse optimization models: waiting time for the first passenger and waiting time for the second passenger.
- The evidence from this study suggests that the interval of the waiting time at the ALMD stop, Putrajaya, according to the criteria design 0 and 15 minutes, the optimum value of waiting time for the first passenger (first headway 00–29 minutes) was 7–14.5 minutes, meanwhile the next passenger (second headway 30–59 minutes) was 0–14.5 minutes. In addition to the aforementioned suggestions to overcome the situation, increasing headways is also recommended to minimize waiting time. Therefore, this study could be expanded with an integrated combination of application design or simulation algorithms or forecasted applications such as artificial neural networks and adaptive neuro fuzzy inference system to enhance the optimum value.

## ACKNOWLEDGEMENTS

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## REFERENCES

- Ben-Akiva, M., & Morikawa, T. (2002). Comparing ridership attraction of rail and bus. *Transport Policy*, 9(2), 107-116.
- Berrebi, S. J., Watkins, K. E., & Laval, J. A. (2015). A real-time bus dispatching policy to minimize passenger wait on a high frequency route. *Transportation Research Part B: Methodological*, 1-13.
- Borhan, M. N., Syamsunur, D., Mohd Akhir, N., Mat Yazid, M. R., Ismail, A., & Rahmat, R. A. (2014). Predicting the use of public transportation: A case study from Putrajaya, Malaysia. *The Scientific World Journal*.
- Cats, O., & Loutos, G. (2016). Real-time bus arrival information system: An empirical evaluation. *Journal of Intelligent Transportation Systems*, 20(2), 138-151.
- Chang & Schonfeld, P. M. (1991). Multiple period optimization of bus transit systems. *Transportation Research Part B: Methodological*, 25(6), 453-478. doi:10.1016/0191-2615(91)90038.
- Chen, S., Zhou, R., Zhou, Y., & Mao, B. (2013). Computation on bus delay at stops in Beijing through statistical analysis. *Mathematical Problems in Engineering*.
- Chien, S. I., Dimitrijevic, B. V, Spasovic, L. N., 2003. Optimization of Bus Route Planning in Urban Commuter Networks. *Journal of Public Transportation*, 53-79.
- Chien, S. I., & Qin, Z. (2004). Optimization of bus stop locations for improving transit accessibility. *Transportation Planning and Technology*, 27, 211-227.
- Furth, P. G. & Muller, T. H. J. (2006). Service reliability and hidden waiting time – Insights from automatic vehicle location data. *Journal of the Transportation Research Board*, No. 1955, Transportation Research Board of the National Academies, Washington, D.C, (1955), 79-87.
- Huo, Y., Li, W., Zhao, J., & Zhu, S. (2015). Modelling bus delay at bus stop. *Journal of Public Transportation*, 4142, 1-10.
- Ibeas, Á., dell’Olio, L., Alonso, B., & Sainz, O. (2010). Optimizing bus stop spacing in urban areas. *Transportation Research Part E: Logistics and Transportation Review*, 46(3), 446-458.
- Liu, Z., Yan, Y., Qu, X., & Zhang, Y. (2013). Bus stop-skipping scheme with random travel time. *Transportation Research Part C: Emerging Technologies*, 35, 46-56.
- Mishalani, R., McCord, M., & Wirtz, J. (2006). Passenger wait time perceptions at bus stops: empirical results and impact on evaluating real-time bus arrival information. *Journal of Public Transportation*, 9(2), 89-106.
- Mohring, H., Schroeter, J., Wiboonchutikula, P. (1987). The Values of Waiting Time, Travel Time, and a Seat on a Bus. *The RAND Journal of Economics*. Wiley, 18, 40-56.

- Shimamoto, H., & Jan-Dirk Schmöcker, F. K. (2012). Optimisation of a bus network configuration and frequency considering the common lines problem. *Journal of Transportation Technologies*, 02(03), 220-229.
- Tirachini, A., Hensher, D.A., & Rose, J.M. (2013). Crowding in public transport systems: Effects on users, operation and implications for the estimation of demand. *Transportation Research Part A: Policy and Practice*, 53, 36-52.
- Wagale, M., Singh, A. P., Sarkar, A. K., & Arkatkar, S. (2013). Real-time optimal bus scheduling for a city using a DTR model. *Procedia – Social and Behavioral Sciences*, 104, 845-854.
- Wardman, M. (2001). Public Transport Values of Time. Institute for Transport Studies, University of Leeds.
- Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. *Transportation Research Part A: Policy and Practice*, 45, 839–848.
- Wu, Y., Tang, J., Yu, Y., & Pan, Z. (2015). A stochastic optimization model for transit network timetable design to mitigate the randomness of traveling time by adding slack time. *Transportation Research Part C: Emerging Technologies*, 52, 15-319.
- Yu, B., & Yang, Z. (2009). A dynamic holding strategy in public transit systems with real-time information. *Applied Intelligence*, 31(1), 69-80.



## Performance of High Strength Concrete Specimens with Square Section Using Steel Strapping Tensioning Technique

Hoong-Pin Lee<sup>1,2\*</sup>, Abdullah Zawawi Awang<sup>2</sup> and Wahid Omar<sup>2</sup>

<sup>1</sup>Department of Civil Engineering, Faculty of Engineering and Quantity Survey (FEQS), INTI International University, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia

<sup>2</sup>Faculty of Civil Engineering, University Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

### ABSTRACT

High strength concrete (HSC) has lower ductility, but higher in strength compared to normal strength concretes. The strength and ductility of HSC can be improved by applying external confinement, such as steel strapping tensioning technique (SSTT). However, SSTT was literately reported effective in confining circular specimens, but the effectiveness of SSTT on square cross section specimens are yet well investigated. This study focuses on HSC square cross section specimens with different corner ratio, which were right angle and rounded corner. In addition, the effect of different number of layer of steel straps confining around the specimens under optimum lateral pre-tensioning stress also been investigated. The number of layers was fixed to two layers and four layers. Fifteen HSC specimens with dimension of 88 mm x 88 mm x 200 mm, which consist of three unconfined specimens, six right angle specimens, and six rounded corner specimens were prepared and tested monotonically to failure. The experimental results show that the strength and ductility of HSC improved significantly by using rounded corner confined specimens and higher number of layer of confinements. This is due to more uniform confining pressure was exerted on entire surface of rounded corner confined specimens. The strength and ductility of the specimens can be improved up to 53.7% and 207.5% respectively

*Keywords:* Ductility and strength enhancement, high strength concrete (HSC), lateral pre-tensioning stress, rounded corner square cross section, steel strapping tensioning technique (SSTT)

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#### E-mail addresses:

hoongpin.lee@newinti.edu.my;

leehoongpin@hotmail.com (Hoong-Pin Lee),

abdullahzawawi@utm.my (Abdullah Zawawi Awang),

drwahid@utm.my (Wahid Omar)

\*Corresponding Author

### INTRODUCTION

Concrete with uniaxial compressive strength greater than what is ordinarily obtained in a region is generally used to definite as HSC (Catherine et al., 1998). But, the concrete with very high strength had lower ductility. This suggested concrete will have immediate

failure when it reaches the maximum resistance to the compressive strength which is applied (Maghsoudi & Shari, 2009). According to Hadi (2008), the brittleness problem is also considered as a challenge of using HSC, because high strength concrete is low in brittleness and can easily break when subjected to excessive uniaxial load. According to Galeota and Giammatteo (1992), the strength and ductility of HSC can be improved by applying confinement. Many confinement methods were used to increase the strength and ductility of HSC, such as concrete jacket, steel jacket, fibre reinforced concrete (FRC), steel strapping tensioning technique, etc. However, the usage of existing confinement methods are affected by its high costs, difficult practice, and need to interrupt use of structure during repairing work (Moghddam et al., 2009). Hence, SSTT was introduced because of its very low-cost method in replacing existing confinement methods (Moghddam et al., 2009). This technique utilizes lateral pre-tensioning stress to confine the concrete columns and was experimentally proved to enhance the compressive strength and ductility of concrete column, especially for low lateral dilates HSC.

Literately, external confinement applied on rectangular or square shaped concrete will be less effective compared to circular sections under the same degree due to the better uniform distribution capability of lateral confining pressure around circular concretes compared to square concretes (Sharma et al., 2005). To date, the application of this technique with different corner ratio specimens confined with optimum lateral pre-tensioning stress remains to be investigated. In this paper, the square cross section right angle and rounded corner HSC confined with two layers and four layers of steel straps under optimum lateral pre-tensioning stress are presented and investigated.

## **MATERIALS AND METHODS**

### **Specimen Preparation and Materials**

Fifteen square specimens with dimension of 88 mm x 88 mm x 200 mm were prepared, which consist of nine right angle square shaped specimens and six square specimens with rounded corner. All the specimens were cast according to the mixture proportions shown in Table 1. After 24 hours, all specimens were removed from formworks and undergone wet curing in water for 28 days. Then, all the specimens were externally confined by steel straps by using pneumatic tensioner with the optimum lateral pre-tensioning stress obtained from previous batch of study. The prescribed number of layer and the lateral pre-tensioning stress confined to all specimens were shown in Table 2. The spacing of steel straps were fixed at 10 mm along the centre of column and 5 mm in the end regions to avoid premature failure of HSC. The detail of confined specimens is shown in Figure 1.

### **Experimental Testing**

The monotonic compressive test was carried out at Geotechnical Laboratory of Faculty of Civil Engineering, University Teknologi Malaysia. The monotonic compressive test was carried out by using TINIUS OLSEN super "L" Universal Testing Machine, with a capacity of 3 MN and a constant rate of 0.4 mm/min as shown in Figure 2. All the specimens were tested until failure. Three linear variable differential transducers (LVDTs) were located at the top part of

load cell to determine the longitudinal axial deformation of the specimens, while two omega strain gauges were located at the centre of specimens in adjacent direction. The transverse deformations of the specimens were determined using two LVDTs that located at the centre of the specimens. The LVDTs with gage length of 25 mm were used and attached at the shaft of the machine. The transverse deformations for concrete and steel strap were determined using two strain gauges that installed at the centre part of specimens in adjacent side. The strain gauges and load cell were connected to the data logger and computer to measure the value of strain and applied load respectively for all specimens. The arrangement of all LVDTs and tool used on all specimens during testing were shown in Figure 3. Any cracking pattern, buckling, deformation, fail condition, etc, were recorded during tests for all specimens.

Table 1  
Concrete mixture proportion for 60 Mpa concretes

Materials	Quantity
Ordinary Portland cement (OPC)	550 kg
Fine aggregates	885 kg
Coarse aggregates	957 kg
Water	190 kg
Super-plasticizer (SP) - Glenium ACE388 (RM)	0.75 % of 100 kg cement

Table 2  
Number of steel strap layer and lateral pre-tensioning stress applied

Specimen	No. of specimens	Number of steel strap layer	Lateral pre-tensioning stress applied
Control	3	0	0
2PT – 5B	3	2	5 bars
2PT – 5B (CR)	3	2	5 bars
4PT – 4B	3	4	4 bars
4PT - 4B (CR)	3	4	4 bars

\*CR = Corner Radius

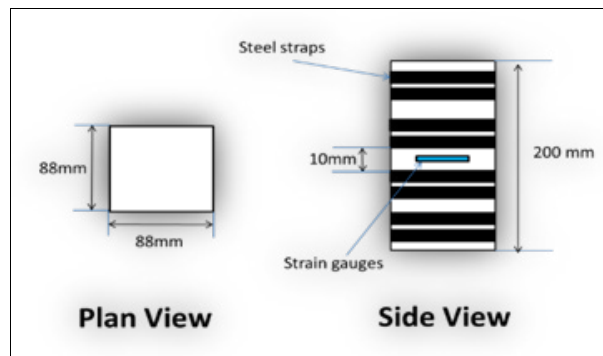


Figure 1. Arrangement of steel straps on specimens

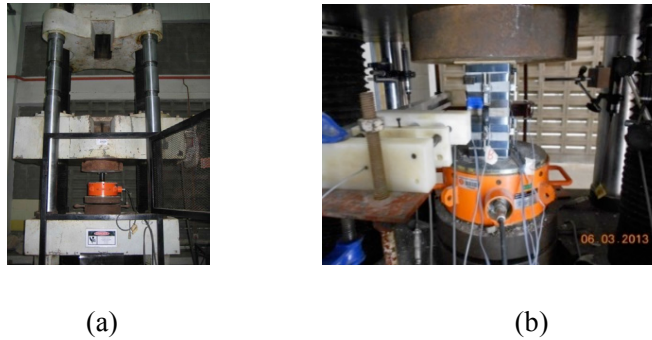


Figure 2. The Experimental Tools Used During Testing: (a) TINIUS OLSEN Super “L” Universal Testing Machine; and (b) Diagram for equipment (Lvdt's)

## RESULTS AND DISCUSSION

### Failure mode

Figure 3(a) to (e) show the failure mode of the representative specimens for each case. For unconfined specimens, C60-C-sqr-02 as shown in Figure 4(a) was used and discussed in this section. All the unconfined specimens were undergone serious failure or crushing, and undergone explosion with explosive sound after reaching the peak compressive strength during testing. Unconfined specimens collapsed in deep diagonal shear mode, so this type of failure was called diagonal failure. The average maximum compressive strength can be achieved by unconfined specimens were 54.3266 MPa. While, all confined specimens were shown in the Figure 4(b) to (e). Confined specimens were undergone diagonal shear crack and minor crush compared with unconfined specimens. During experimental testing, the specimens fail gradually without explosion when approaching maximum compressive strength of specimens. This phenomenon occurred due to the function of lateral pre-tensioning steel straps in preventing confined specimens to collapse steeply and behave more ductile compared with unconfined specimens. The maximum compressive strength can be achieved by right angle specimens confined with two layers and four layers of steel straps which were 60.6495 MPa and 61.4243 MPa, and which significantly improved by 11.8% and 13.1% compared with unconfined specimens respectively. On the other hand, the maximum compressive strength can be achieved by rounded corner specimens confined with two layers and four layers of steel straps were 77.4897 MPa and 94.3944 MPa, which significantly improved by 42.6% and 78.8% compared to unconfined specimens respectively.

### Experimental Results and Discussion

Table 3 shows the average experimental results obtained for all tested specimens, which consists of unconfined specimens and confined specimens with different layer of steel strap and lateral

pre-tensioning stress. From the table, the  $f_{co}$  and  $\epsilon_{co}$  are the peak compressive strength and peak compressive strain for unconfined specimens respectively. While,  $f_{cc}$  and  $\epsilon_{cc}$  are the strength and strain at the point of maximum compressive strength for confined specimens (specimens confined by two layers and four layers of steel strap with optimum lateral pre-tensioning stress, which is five bars for two layer confined specimen and four bars for four layer confined specimen). Lastly,  $\epsilon_{85}$  and  $\epsilon_{50}$  are the strain at 85% and 50% of maximum compressive strength after achieve the full peak compressive strength of specimens. Figure 4 and Table 3 clearly shows that the average maximum compressive strength achieved by all confined specimens was higher than the average maximum compressive strength for unconfined specimens. The average strength enhancement achieved by all confined specimens were 11.8%, 13.1%, 42.6%, and 73.8% for 2L5B, 4L4B, 2L5B (CR), and 4L4B (CR) respectively. It can be concluded that the average maximum strength of specimens able to be improved up to 73% by using corner radius specimens, because rounded corner specimens can help in increasing of confinement effectiveness of steel straps on confined specimens.

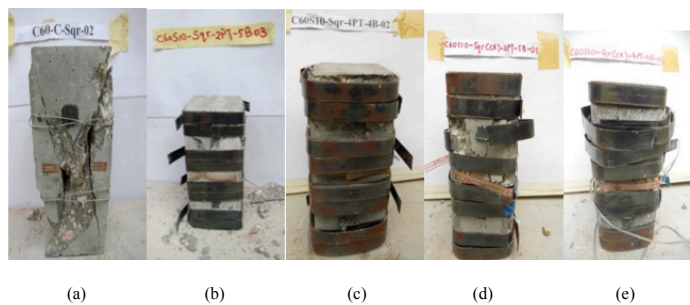


Figure 3. The cracking pattern of: (a) unconfined specimen; (b) two layers steel straps with four Bars confined specimen; (c) four layers steel straps with four Bars confined specimen; (d) rounded corner two layers steel straps with four Bars confined specimen; and (e) rounded corner four layers steel straps with four Bars confined specimen

Table 3  
Average experimental results for all specimen

Specimen	$f_{co}$	$\epsilon_{co}$	$f_{cc}$	$\epsilon_{cc}$	$\epsilon_{85}$	$\epsilon_{50}$	$f_{cc}/f_{co}$	$\epsilon_{cc}/\epsilon_{co}$	$\epsilon_{85}/\epsilon_{cc}$	$\epsilon_{50}/\epsilon_{cc}$
Control	54.3266	0.0081	-	-	-	-	-	-	-	-
2L5B	-	-	60.6495	0.0110	0.0127	0.0280	1.1184	1.3580	1.1604	2.5477
4L4B	-	-	61.4243	0.0081	0.0093	0.0134	1.1306	1.0000	1.1481	1.6543
2L5B (CR)	-	-	77.4897	0.0128	0.0346	0.0134	1.4264	1.5802	1.0664	2.6926
4L4B (CR)	-	-	94.3944	0.0089	0.0348	0.0412	1.7375	1.1481	1.1198	3.9401

Besides, Figure 4 and Table 3 also show that the rounded corner specimens able to achieve higher average compressive strength compared to right angle specimens and unconfined specimens under similar number of steel straps. For two layers steel straps and four layers confined specimens, there were up to 27.8% and 53.7% higher average compressive strength achieved by rounded corner specimens compared to right angle specimens respectively. While, Figure 5 and Table 3 show that the specimens confined with four layers steel straps able to achieve higher average compressive strength compared to two layers steel straps confined specimens under similar shape section. Average compressive strength enhancement between two layers and four layers confined specimens for both right angle and rounded corner confined specimens were 1.3% and 21.8% respectively. In short, the compressive strength of confined specimens is directly proportional to the number of steel straps confined on the specimens. Secondly, rounded corner confined specimens able to achieve higher compressive strength compared to right angle confined specimens under same level of pre-tensioning stress and layers of steel straps used, because more uniform confining pressure was exerted on entire surface of rounded corner confined specimens that more effective or fully confined. From Figure 6 and Figure 7, it can be clearly noticed that the mobilization of steel straps started immediately when the tests started. It shows that the optimum lateral pre-tensioning stress used in this study with different layers of steel strap can be effectively confined the low lateral dilates HSC, even with different corner ratio of square shape including right angle.

The plasticity ratio of confined specimens, defined as the ratio of two strains, which are  $\epsilon_{85}$  and  $\epsilon_{cc}$  (e.g.  $\epsilon_{85}/\epsilon_{cc} > 1$ ). Based on the Table 3, the average plasticity ratio for two layers and four layers steel straps confined right angle specimens are 1.1604 and 1.1481 respectively. While, the average plasticity ratio for two layers and four layers steel straps confined corner radius specimens are 1.0664 and 1.1198 respectively. This indicates the average plasticity ratio can be improved up to 16% and 12% for right angle and rounded corner confined specimens respectively. The ductility ratio of confined specimens, defined as the ratio of two strains, which are  $\epsilon_{50}$  and  $\epsilon_{cc}$  (e.g.  $\epsilon_{50}/\epsilon_{cc} > 1$ ). Based on Table 3, it can be clearly noticed that the average ductility for two layers and four layers steel straps confined right angle specimens were increased by 154.8% and 65.4% respectively. While, the average ductility for two layers and four layers steel straps confined rounded corner specimens were increased by 169.3% and 294% respectively, which were almost 3 times higher than average ductility of unconfined specimens. For comparison between two layers and four layers confined specimens, depletion in average ductility up to 109% happened on right angle specimens, but the average ductility for rounded corner confined specimens was improved up to 207.5%. For comparison between right angle and rounded corner confined specimens, depletion in average ductility up to 109% happened on two layers confined specimens, but the average ductility for four layers confined specimens was improved 207.5%. In short, SSTT can effectively improve the strength and ductility of four layers confined specimens and rounded corner confined specimens.

### High Strength Concrete Specimens with Square Section

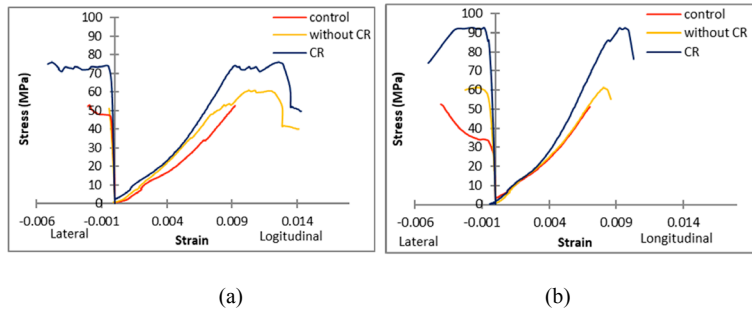


Figure 4. Stress-strain curves of unconfined concrete, concretes without rounded corner, and concretes with rounded corner confined with: (a) two layers of steel straps and five bars of lateral pre-tensioning stress; and (b) Four layers of steel straps and four bars of lateral pre-tensioning stress

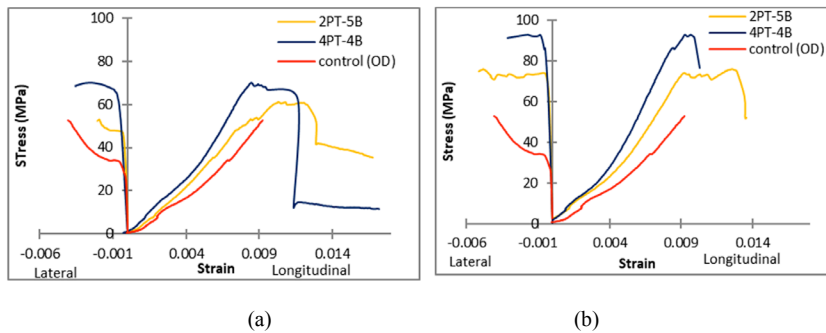


Figure 5. Stress-strain curves for specimens confined with two and four layers of steel strap: (a) Unconfined concrete and confined concrete without rounded corner; and (b) Unconfined concrete and confined concrete with rounded corner

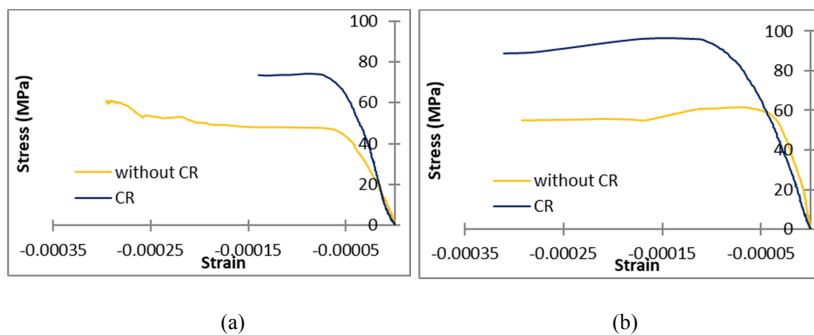


Figure 6. Stress-strain curves of unconfined concrete, concretes without rounded corner, and concretes with rounded corner confined with: (a) two layers of steel straps and five bars of lateral pre-tensioning stress; and (b) Four layers of steel straps and four bars of lateral pre-tensioning stress



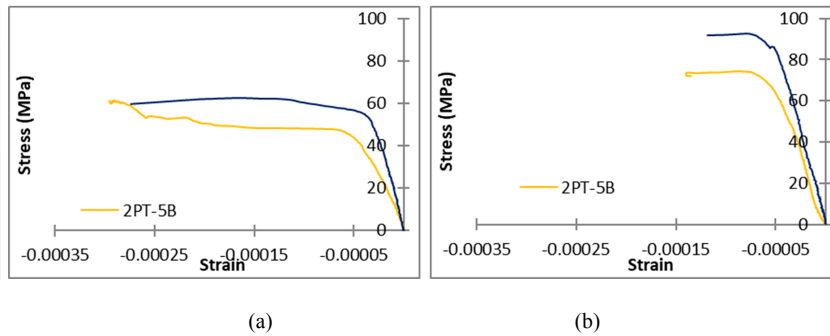


Figure 7. Stress-strain curves for specimens confined with two and four layers of steel strap: (a) Unconfined concrete and confined concrete without rounded corner; and (b) Unconfined concrete and confined concrete with rounded corner

## CONCLUSION

This study has been focused on performance of square HSC specimens using SSTT. All the experimental results obtained were analysed and presented together with the discussion on the experimental results and failure mode for all specimens. Hence, the following conclusion may be drawn from the results and observation obtained during experiments: The SSTT confined HSC able to achieve higher compressive strength and ductility compared to unconfined HSC. The average strength enhancement achieved by all confined specimens were 11.8%, 13.1%, 42.6%, and 73.8% for 2L5B, 4L4B, 2L5B (CR), and 4L4B (CR) respectively. While, the average ductility enhancement achieved by all confined specimens were 154.8%, 65.4%, 169.3%, and 294% for 2L5B, 4L4B, 2L5B (CR), and 4L4B (CR) respectively. Four layers steel straps confined specimens able to achieve higher strength and ductility compared to two layers steel straps confined specimens. For right angle specimens, the average strength enhancement between two layers and four layers steel straps confined specimens was 1.3%, but the results show depletion of 109% in ductility. While, for rounded corner specimens, the average strength and ductility for confined specimens were increased up to 21.8% and 207.5% respectively. The specimens with rounded corner able to achieve higher strength and ductility compared to right angle specimens. For two layers confined specimens, the average strength enhancement between right angle and rounded corner confined specimens was 27.8%, but the results show depletion of 109% in ductility. While, for four layers confined specimens, the average strength and ductility for confined specimens were increased up to 53.7% and 207.5% respectively.

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## REFERENCES

- Catherine, F. U., Mokhtarzadeh, A., Ahlborn, T., & Leon, R. (1998). High-strength concrete applications to prestressed bridge girders, *Construction and Building Materials*, 12(2-3), 105-113.
- Galeota, D., & Giammatteo, M. M. (1992). Strength and ductility of confined high strength concrete. *Earthquake Engineering tenth world conference @ 1992balkemaRotterdam*, ISBN90 5410 060 5.
- Hadi, M. N. S. (2008). Bond of high strength concrete with high strength reinforcing steel. *The Open Civil Engineering Journal*, 2, 143-147.
- Maghsoudi, A. A., & Sharifi, Y. (2009). Ductility of high strength concrete heavily steel reinforced members. *Journal of Scientia Iranica*, 16(4), 297-307.
- Moghddam, H., Mohebbi, S., & Samadi, M. (2009). Experimental and analytical investigation of concrete confined by external pre-stressed strip. *Concrete Repair, Rehabilitation and Retrofitting 2-Alexander et al. (eds)*, ISBN 978-0415-46850-3.
- Sharma, U. K., & Bhargava, P. (2005). Behavior of confined high strength concrete columns under axial compression. *Journal of Advanced Concrete Technology*, 3(2), 267-281.





## **Effect of Crumb Rubber on the Fresh Properties of Mortar and Concrete**

**N. M. Noor\*, M. H. Ahmad and N. H. Othman**

*Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia*

### **ABSTRACT**

The importance of the performance of concrete cannot be neglected since it is the early indicator of its physical and mechanical properties. It became more important when material with different physical properties than normal material such as rubber tire was used as concrete constituent. This paper presented apart of research result conducted on mortar and concrete with crumb rubber. Crumb rubber was replaced at 10%, 15% and 20% as sand replacement by volume. In addition, ordinary Portland cement was added to silica fume at 10% and 15% by weight. The properties measured in this study are air content and workability test. As for workability, superplasticizers were constantly used at 1% dosage for all mortar mixture, and 0.5% to 0.7% for concrete mixture. The air content was set at 4% to 6% and mortar flow test was conducted on a steel plate, shocked 15 times in 15 seconds and concrete slump test was carried out using slump cone equipment. Pressure method was used to measure air content. All mixes were done in a controlled room temperature. Results showed that when CR was added in the mixture segregation was observed in mortar requiring a high dose of superplasticizer to be added to improve the workability while air-modifying agent was used to reduce the mortar air content. In concrete mixture, low dosage of superplasticizers was required for workability and air-entrained agent was injected into the mixture to increase the air content between 4%-6%.

*Keywords:* Air content, concrete slump, crumb rubber, mortar flow

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*E-mail addresses:*

[nurazuwa@uthm.edu.my](mailto:nurazuwa@uthm.edu.my)/[nurazuwa@gmail.com](mailto:nurazuwa@gmail.com) (N. M. Noor),

[hilton@uthm.edu.my](mailto:hilton@uthm.edu.my) (M. H. Ahmad),

[hazurina@uthm.edu.my](mailto:hazurina@uthm.edu.my) (N. H. Othman)

\*Corresponding Author

### **INTRODUCTION**

Utilization of waste tire rubber as concrete material has been widely studied since 1990's. Waste tire rubber is a soft material with specific gravity ranging between 0.6 g/cm<sup>3</sup> to 1.3 g/cm<sup>3</sup> that contributes to low strength of concrete when used as concrete constituent. Nehdi (2001) in his discussion

stated that rubber may be viewed as voids in concrete mix and gave weak bonding between rubber particles and cement paste. It was reported that although no air-entrained is used in the mixture, higher air content was measure compared to control mixture made with air-entrained agent. This may due to the non-polar nature of rubber particles and its ability to entrap air on jagged surface texture.

Meanwhile, workability performance reported by Bigzoppi (2006) on tire waste rubber utilized in self-compacting concrete showed good slump flow and pass in the presence of obstacle. Erhan (2009) pointed out that the V-tunnels flow time increase gradually with the increasing of crumb rubber. But, when fly ash was added, it resulted in a steady decrease of V-funnel flow in comparison with the mixture without fly ash. However, there was agreement that in concrete, slump was decreased by increasing rubber content to the total aggregate volume (Topçu, 2010). In this paper, result of concrete and mortar fresh properties is reported from research on rubberized concrete conducted in Concrete Engineering Lab, Kyushu University.

## **MATERIALS AND METHODS**

In this research, waste tire rubber was classified as crumb rubber, CR which is a by-product produced from used vehicle tires received from recycle plant without undergoing any washing procedure. The size of the CR was combination of 1 mm to 3 mm with density of  $1.17 \text{ g/cm}^3$ , used as sand replacement. Ordinary Portland cement (OPC) and silica fume (SF) acted as binder, where a selected percentage SF was added to cement. Sea sand passing 5 mm sieve with water absorption of less than 3.5% as stated in *JSCE Standard Specification for Concrete Structures, 2007* was used as fine aggregate. Meanwhile, crushed stone with 20 mm maximum size was used as coarse aggregate. All aggregate were prepared under saturated surface dry condition. Details of the material physical properties are presented in Table 1.

### **Mix Proportion**

Table 2 and Table 3 shows the mix proportion of mortar and concrete respectively. Control parameter was the air content ranging between 4% to 6%. After several trial mixes, superplasticizers for workability was constantly used at 1% dosage for mortar and 0.5% to 0.7% dosage for concrete. Suitable chemical admixture was then decided to achieve target air content. Mortar flow test was conducted on a steel plate and shocked 15 times in 15 seconds. Concrete slump was measured using slump cone. Meanwhile, air content data was collected using pressure method. Mixing was done in a controlled room temperature at 200C according to JIS R 5201-1997 Physical Testing Method for Cement.

Table 1  
*Physical properties of materials*

Component	Physical properties	
Ordinary Portland Cement	Density, g/cm <sup>3</sup>	3.16
Silica fume	Density, g/cm <sup>3</sup>	2.20
Crumb Rubber	Density, g/cm <sup>3</sup>	1.17
Fine Aggregate	Density, g/cm <sup>3</sup> (SSD condition)	2.58
	Water absorption (%)	1.72
	Fineness modulus	2.77
Coarse Aggregate	Density, g/cm <sup>3</sup>	2.91
Ether-based polycarboxylate superplasticizer	Density, g/cm <sup>3</sup> at 20°C	1.07
Air entraining agent	Density, g/cm <sup>3</sup>	1.04
Air-modifying agent	Density, g/cm <sup>3</sup>	1.00

Table 2  
*Mix proportion of mortar*

Series	CR/ (S+CR)	SF/C	w/c	Water	Cement	Silica Fume	Sand	Crumb Rubber	Chemical Admixture
	(Vol %)	(%)		W	C	SF	S	CR	
Control	0	0	0.35	217	619	-	1514	-	1.0
0CR - 10SF	0	10				62	1442	-	1.0
0CR - 15SF	0	15				93	1406	-	1.0
10CR - 10SF	10	0				-	1364	69	1.0
10CR - 10SF	10	10				62	1292	69	1.0
10CR - 15SF	10	15				93	1255	69	1.0

Table 3  
*Mix proportion of concrete*

Description	CR/ (S+CR)	SF/C	w/c	Water	Cement	Silica Fume	Fine Aggregate	Crumb Rubber	Coarse Aggregate		Chemical Admixture
				W	C	SF	S	CR	G1	G2	
	(Vol %)	(%)				kg/m <sup>3</sup>					
Control	0	0	0.35	160	457	0.0	741	0	608	405	0.5
10CR - 0SF	10	0					667	34			0.5
15CR - 0SF	15	0					629	50			0.7
20CR - 0SF	20	0					594	67			0.7
10CR - 10SF	10	10	0.35	160	457	46	613	34	608	405	0.7
15CR - 10SF	15	10					575	50			0.7
20CR - 10SF	20	10					540	67			0.7

## RESULTS AND DISCUSSION

The main difference between mortar mix design and concrete mix design is the amount of chemical admixture that is added to control the air content. In this study air-entrained agent and air-modifying agent was introduced to control the air content. The purpose of the air-entrained agent is to increase the air content. In contrast in the case of the mixture air-modifying agent is used to decrease the amount of the air content.

Table 4 provides information of chemical admixture used in rubberized mortar and Table 5 shows the rubberized concrete. The absence of crushed stones in rubberized mortar provides very high air content despite the absence of air-entrained agent during trial mix. The amount of air reached almost 15% for mix with CR even without air-entrained agent. In order to overcome this problem air-modifying agent with 1.0% dosage was used to reduce the amount of air content in mortar. However, when the same mixture series of 10% CR without SF was conducted in the concrete mix, contrast behaviour was observed in comparison with 10% CR in mortar mix. Rubberized concrete produced air content that was lower than mortar mix, thus air-entrained agent was used to increase the air content. The different behaviour that was observed may be due to the high solid content of concrete due to the presence of fine-coarse aggregate mix in concrete as shown in Figure 1. Furthermore when SF was added to the concrete mixture, air content increased rapidly and an air-modifying agent had to be added in order to achieve the targeted level.

With regards to workability, both rubberized mortar and concrete using the same superplasticizer at different dosage level. Rubberized concrete required small amount of superplasticizer compared to mortar mix. Looking back to mix design proportion, mortar using totally fine aggregate as aggregate rather than coarse aggregate used in concrete. Thus, for the same total volume amount, mortar having larger replacement of CR which was 69kg/m<sup>3</sup> compared to concrete which was 34kg/m<sup>3</sup> at 10% sand replacement by volume. Thus, resulting in the low workability of mortar mix, requiring a high dose of superplasticizer.

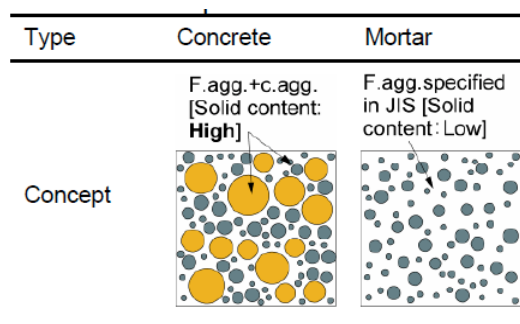


Figure 1. Concept of mortar and concrete

Table 4  
*Fresh properties of mortar with and without crumb rubber*

Series	CR/(S+CR)	SF/C	Chemical Admixture		Fresh Properties	
			Super-plasticizers	Air-modifying agent	Air content	Flow
	(Vol %)	(%)	(%)	(%)	(%)	(mm)
Control	0	0	1.0	1.0	5.2	226
0CR - 10SF	0	10	1.0	1.0	6.9	178
0CR - 15SF	0	15	1.0	1.0	8.0	171
10CR - 0SF	10	0	1.0	1.0	4.2	207
10CR - 10SF	10	10	1.0	1.0	7.8	175
10CR - 15SF	10	15	1.0	1.0	9.0	173

Table 5  
*Fresh properties of concrete with and without crumb rubber*

Description	Chemical Admixture			Fresh Properties	
	Super-plasticisers	Air-entraining agent	Air-modifying agent	Air Content	Slump
	(%)	(%)	(%)	(%)	(mm)
Control	0.5	0.8		4.7	7.0
10CR-0SF	0.5	0.8		5.1	6.0
15CR-0SF	0.7	0.8		4.5	19.5
20CR-0SF	0.7	0.7		4.0	19.5

## CONCLUSION

Several conclusions from the above maybe drawn:

1. In mortar mixture, 1% of superplasticizers was used to increase the flow performance of mixture. It decreases slightly when SF was added at 10% and 15% cement replacement.
2. Meanwhile, mortar air content increased with the presence of CR and SF. The rapid increment was controlled using 1% addition air-modifying agent.
3. Contradictory results were noted in concrete mixture; less than 1% superplasticizers was required for workability performance.
4. Concrete mixture with CR showed low air content; to control air content between 4%-6% air-entrained agent was used. However, when SF was added, air content rapidly increased requiring control with air-modifying agent.

Overall, when CR was added in the mixture, mortar showed light segregation and high superplasticizer was added to improve the workability together with air-modifying agent to reduce the ensuing rise in air content. For concrete mixture low dosage of superplasticizers

had to be added to improve workability and air-entrained agent injected to increase the air content to between 4%-6%.

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## REFERENCES

- Nehdi, M., & Ashfaq, K. (2001). Cementitious composites containing recycled tire rubber: An overview of engineering properties and potential applications. *Cement, Concrete and Aggregates*, 23(1). 3-10.
- Bignozzi, M. C., & Sandrolini, F. (2006). Tyre rubber waste recycling in self-compacting concrete. *Engineering Applied Science*, 36(4). 735-739.
- Guneyisi, E. (2010). Fresh properties of self-compacting rubberized concrete incorporated with fly ash. *Materials and Structures*, 43(8), 1037-1048.
- Topcu, U., & Tayfun, I. B. (2010). The role of scrap rubber particles on drying shrinkage and mechanical properties of self-consolidating mortars. *Construction and Building Materials*. 24(7). 1141-1150.
- Teranishi, K., & Tanigawa, Y. (2007). Development of mortar structure. *Proceeding of 32<sup>nd</sup> Conference on Our World in Concrete and Structure*. Singapore.



## Development of Adjustable Foot Corrective Device for Clubfoot Treatment

Shahrol Mohamaddan<sup>1\*</sup>, Chai Siew Fu<sup>1</sup>, Ahmad Hata Rasit<sup>2</sup>,  
Siti Zawiah Md Dawal<sup>3</sup> and Keith Case<sup>4</sup>

<sup>1</sup>Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia

<sup>2</sup>Faculty of Medicine and Health Science, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia

<sup>3</sup>Faculty of Engineering Building, University of Malaya, 50603 Kuala Lumpur, Malaysia

<sup>4</sup>Mechanical, Electrical and Manufacturing Engineering, Loughborough University, Leicestershire, LE11 3TU, United Kingdom

### ABSTRACT

Congenital talipes equinovarus (CTEV) or clubfoot is a complex deformity of the foot that is characterised by four main deformities; forefoot cavus and adductus, hindfoot varus and ankle equinus. Currently, the Ponseti method is the most general and recognized treatment with a high success rate of over 90%. The treatment involves gentle manipulation and serial casting. However, the casting method could create complications for the patients such as soft-tissue damage and inconvenience in following the treatment schedule especially for those living far away from hospital. The aim of this research is to develop an adjustable corrective device for clubfoot treatment based on the techniques in the Ponseti method and at the same time attempt to eliminate the side-effects. The prototype consists of six adjustable movements from six different mechanisms to correct the four deformities. The prototype was developed using 3D printing method and the main material used is polylactic acid (PLA), rubber, aluminium and cotton fabric with sponge. The total weight of the prototype is around 300 g.

*Keywords:* 3D printing, clubfoot, CTEV, design and fabrication, Ponseti method

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*E-mail addresses:*

mshahrol@feng.unimas.my (Shahrol Mohamaddan),

chai362@hotmail.com (Chai Siew Fu),

rahata@unimas.my (Ahmad Hata Rasit),

sitzawiahmd@um.edu.my (Siti Zawiah Md Dawal),

k.case@lboro.ac.uk (Keith Case)

\*Corresponding Author

### INTRODUCTION

Congenital talipes equinovarus (CTEV), commonly known as clubfoot, is one of the most common deformities involving the musculoskeletal system of the lower limb (Zeno & Sorin, 2014). It is estimated that one or two in a thousand of newborns are affected with this deformity (Bass, 2011). The congenital deformity has four main

components which are cavus, adductus, varus and equinus (CAVE) (Gray et al., 2014). Ultrasound screening is normally used in diagnosing the condition of the deformity at birth or prenatally (Novak, 2013). Some research has been done to study the etiologic of clubfoot such as genetic effects, environmental conditions, abnormal muscle insertion and vascular abnormalities. However, the cause of the deformity is still controversial (Hallaj-moghaddam et al., 2015). Clubfoot cannot be corrected spontaneously without treatment (Novak, 2013). The treatment of clubfoot can be separated into operative and conservative treatments (Maranho & Volpon, 2011). Among the treatments available, Ponseti management has been most widely accepted with a high success rate of over 90% for initial correction and low relapse rates of 10% to 30% (Bhaskar & Patni, 2013).

### **Ponseti Method**

The Ponseti treatment consists of a series of gentle manipulations of the foot followed by above-knee casting using plaster of Paris (POP) (Maranho & Volpon, 2011) as shown in Figure 1. After the treatment phase, the patients are required to wear the bracing and orthosis full-time for ten weeks to maintain the corrected result (Docker et al., 2007). Adherence to the foot adduction orthosis (FAO) is important to prevent clubfoot relapse (Bhaskar & Patni, 2013).



*Figure 1.* Ponseti casting method

Hui et al. (2014) indicated that the use of POP could cause injury to the skin of the foot and create difficulty in removing the cast for the next correction. Accidents might occur when sawing the cast for removal purpose. Besides, the exothermic reaction that occurs when curing might also lead to injury to the skin. Skin infection would affect the treatment as it would be unsuitable for the child to continue the casting method. This problem could be solved by changing the cast material for example to semi-rigid fibre-glass which is lighter, durable, has a fast curing time, has a low risk of thermal burn and is ease to remove. The research found that the alternative casting materials give the same results in terms of the number of casts required for successful clubfoot treatment.

Another study by Baidurashvili et al. (2012) showed that improper casting techniques and definitive pressure during the casting could cause soft tissue lesions in the children. Ponseti management usually takes more than five treatment sessions and the treatment is performed weekly. Commitment is needed in complying with the follow-up schedule. This could burden many parents associated with distance and transportation as well as in time management. Parents also worry when seeing their child receiving the manipulation and casting.

The objective of this research is to develop a new approach to eliminate the problem related to the Ponseti casting method. In this paper, the design and development of an adjustable foot corrective device is presented. The device consists of six movements that replicate the Ponseti serial manipulation sequences. The new approach is aimed at creating safe, sustainable and economical solutions for clubfoot treatment.

## MATERIALS AND METHODS

### Problem Identification and Data Collection

This study started with identifying the process related to the Ponseti method. As shown in Table 1, the Ponseti corrective technique should follow the sequences of cavus, adductus, varus and equinus (CAVE). Each correction technique consists of different types of foot manipulation with different week involved. In general, the foot manipulation has different degrees of rotation that need to be focused for the new approach. Besides that, sample of children foot size was measured. In this study, one child with the age of two years with normal leg and foot was selected as a sample. Table 2 shows the detail measurements conducted. The measurements are used later in the design process.

Table 1  
*Ponseti corrective technique*

Correction	Descriptions	Week Involved
Step 1: Cavus correction	<ul style="list-style-type: none"> <li>• Forefoot is supinated in relation to the hindfoot</li> <li>• First metatarsal is elevated</li> </ul>	1 – 2 weeks
Step 2: Adductus and Varus correction	<ul style="list-style-type: none"> <li>• The head of talus is pressed as the fulcrum of rotation</li> <li>• The foot is in slight supinated condition and in equinus</li> <li>• The forefoot is adducted up to 70 degrees without pronation</li> </ul>	3 – 4 weeks
Step 3: Equinus correction	<ul style="list-style-type: none"> <li>• The sole of the foot is being exerted pressure entirely and stretched gradually</li> <li>• A percutaneous tenotomy is performed</li> </ul>	3 weeks

Table 2  
*Foot measurements*

Part	Value (mm)
1. Foot sole length	115
2. Forefoot width	58
3. Hindfoot width	38
4. Foot height	60
5. Calf diameter	33.4
6. Thigh diameter	82
7. Leg length	150
8. Knee to thigh length	60

## Design Process

After the process of gathering all the related information about this project, the design of the Ponseti orthosis was conducted. The orthosis was designed by using CAD software. Design is an innovative and highly iterative process. When designing, words and pictures with written and oral forms are needed to assist the designers in explaining the designs to people of many disciplines (Budynas & Nisbett, 2015). The design process can be divided into several phases, namely conceptual design, embodiment design and followed by detail design (Dieter & Schmidt, 2013). The design process is shown in Figure 2.

The first phase in engineering design is the conceptual design. This phase consists of four steps which are defining the problem, gather information, concept generation and evaluation of concepts. Problem identification and information collection has already been described. After a concept was generated, a few basic ideas for designs were sketched by hand as shown in Figure 3. Sketching is an important element in design because it allows the designer to explore and convey abstract ideas to others quickly. A number of designs with different degrees of freedom (DOF), shape, mechanism of hinge or joint and appearance were generated during the stage of conceptual design. Orthographic, axonometric, oblique and perspective sketches were the example which designers routinely use to convey design ideas.

The second phase in engineering design is the embodiment design which consists of product architecture, configuration design, and parametric design. After the conceptual design, one of the designs was chosen and configurations were made. Arrangement of physical elements such as hinge and foot braces was decided. Preliminary selection of materials and manufacturing processes were made during this step.

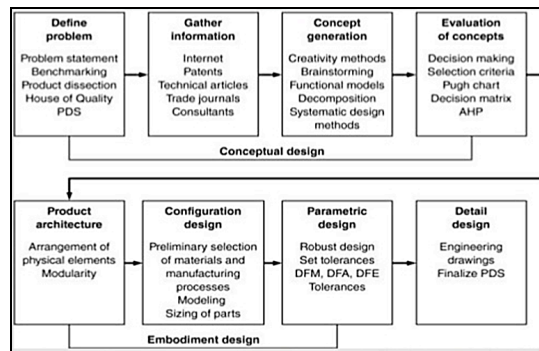


Figure 2. Engineering design process (Dieter & Schmidt, 2013)

In this phase, the design became more detailed and clearer in terms of structure, dimensions and tolerances. The drawings with specific dimensions were accomplished by using Computer-aided Design (CAD) software. The design of the prototype was drawn in 3D so that each view from different angle of the design can be shown clearly and in detail. Besides, the number of parts used in the design could be identified clearly from the drawing. In addition, CAD software features simulation functions that can be used for further presentation of the design.

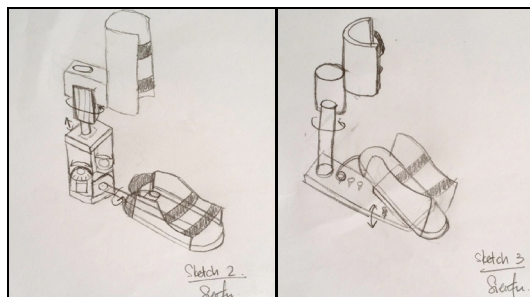


Figure 3. Example of ideas generation using sketching technique

### Prototype Fabrication

After the design was finalized, a prototype was fabricated using a 3D printer. The prototype used polylactic acid (PLA) and rubber filament as the 3D printing material. The prototype also made of aluminium, and cotton fabric with sponge for the selected parts. The idea is to have light, non-corrosive and good surface finished materials.

### RESULTS AND DISCUSSION

The final design and fabricated prototype of the adjustable foot corrective device is shown in Figure 4. The device can be divided into three areas which are the upper, middle and lower part. The upper part of the design is used to tighten up the thigh, providing more support to the leg when the foot is corrected. The upper part functions as the above knee casting that

is used in the Ponseti method. The middle part of the device constitutes the main working mechanism. The adductus, varus, and equinus corrections are performed in the middle part of the device. Lastly, the lower part consists of the shoes to cover and exert forces on the foot. Cavus correction is performed at the lower part.

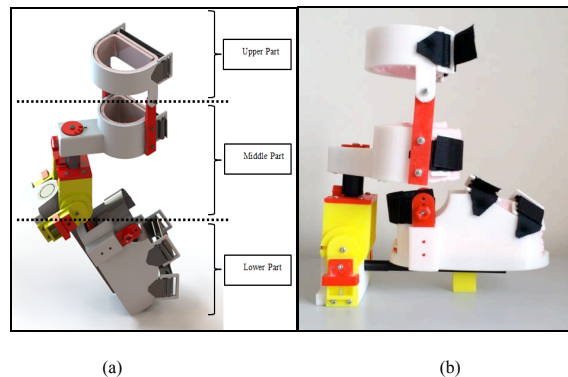


Figure 4. (a) The final design; and (b) the fabricated prototype

In general, the prototype consists of six mechanisms to replicate the Ponseti method movement as shown in Figure 5. The first mechanism is made up of a screw and nut with a connector between the thigh and shank brace. The second mechanism is focusing on the adductus correction. The mechanism consists of a bearing and shaft that can be adjusted and locked based on the desired measurement. The mechanism enables the foot to be adducted by up to 70 degrees similar to the requirement in the Ponseti method. The third mechanism focuses on the equinus correction. The mechanism consists of an extendable shaft that is locked by a screw. The extendable shaft is required to prevent the foot brace from colliding with the shank brace.

The fourth mechanism focuses on the varus correction. The working mechanism is similar to the adductus correction feature. A bearing is pressed fitted into the shaft and a lock which is taper drilled at one end is added to the mechanism to prevent the shaft from rotating after correction is performed. Similar to the shaft in the adductus corrector, the shaft in this feature also has a decagonal shape. This is to ensure that the angles of correction between adductus and varus correction are the same as both corrections are performed at the same time.

The fifth mechanism is developed for equinos correction. The mechanism consists of several holes that represent different angles of 90, 60, 30, 0 and -20 degrees that are needed for equinos correction. The correction is maintained by a lock which is made up of a knob, screw and spring. The screw will prevent the rotation when it is fitted to the 'holes' of the adjustor. The suspension of the spring will ensure this feature is always locked. When equinus correction is to be made, the spring will be pushed down to unlock the system. The sixth mechanism is for cavus correction. A plate with the size of the foot is put inside the shoes. The plate has three

segments which represent the forefoot, middle foot and hindfoot. These three segments are connected by masking tape. The forefoot plate is designed with the first metatarsal is extruded. It functions to elevate the first metatarsal of the foot during the cavus correction. The forefoot is supinated by using the wedge with several angles, which are 5, 10 and 15 degrees. This feature should be custom made based on the foot size of the patient. Based on the cost analysis conducted, the total cost for the prototype is around RM400. The total weight of the prototype is around 300 g.

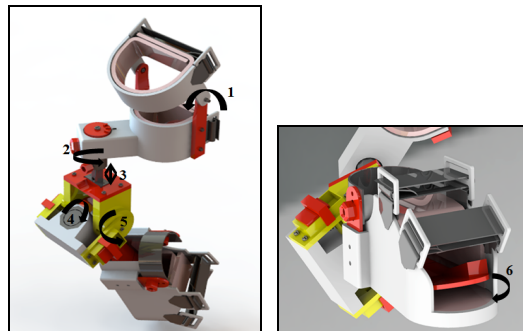


Figure 5. Six movement mechanism of the prototype

## CONCLUSION

This paper discussed the design and fabrication of an adjustable foot corrective device for clubfoot treatment. The prototype consists of six adjustable mechanisms that replicate the movement during clubfoot treatment using the Ponseti method. Each mechanism consists of a unique movement and is expected to reduce problems related to the Ponseti method. The prototype was developed using 3D printing and the main material used is PLA, rubber, aluminium and cotton fabric with sponge. The treatment using the prototype is considered cheaper compared to the existing method. However, further investigation needs to be conducted since the device has not been tested with real patients.

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## REFERENCES

- Baindurashvili, A., Kenis, V., & Stepanova, Y. (2012). *Soft-tissue complications during treatment of children with congenital clubfoot*. *EWMA Journal*, 12(3), 17–19.
- Bass, A. (2011). Update on club foot. *Paediatrics and Child Health*, 22(6), 239–242. <http://doi.org/10.1016/j.paed.2011.11.007>

- Bhaskar, A., & Patni, P. (2013). Classification of relapse pattern in clubfoot treated with Ponseti technique. *Indian Journal of Orthopaedics*, 47(4), 370–376.
- Budynas, R. G., & Nisbett, J. K. (2015). Shigley's mechanical engineering design (10<sup>th</sup> ed.). New York: Mc Graw Hill.
- Docker, C. E. J., Lewthwaite, S., & Kiely, N. T. (2007). Ponseti treatment in the management of clubfoot deformity: A continuing role for paediatric orthopaedic services in secondary care centres. *Ann R Coll Surgery England*, 89(1), 510–512. <http://doi.org/10.1308/003588407X187739>
- Gray, K., Pacey, V., Gibbons, P., Little, D., & Burns, J. (2014). Interventions for congenital talipes equinovarus (clubfoot) (Review). Retrieved from <http://www.thecochranelibrary.com>
- Hallaj-moghaddam, M., Moradi, A., Ebrahimzadeh, M. H., Reza, S., & Shojaie, H. (2015). Ponseti casting for severe club foot deformity: Are clinical outcomes promising? *Advances in Orthopedics*, 5(1), 1–5.
- Hui, C., Joughin, E., Nettel-aguirre, A., Goldstein, S., Harder, J., Kiefer, G., & Howard, J. (2014). Comparison of cast materials for the treatment of congenital idiopathic clubfoot using the Ponseti method: A prospective randomized controlled trial. *Canadian Journal Surgery*, 57(4), 247–254. <http://doi.org/10.1503/cjs.025613>
- Maranho, D. A. C., & Volpon, J. B. (2011). Congenital clubfoot. *Acta Ortopédica Brasileira*, 19(3), 163–169.
- Novak, B. (2013). Treating clubfoot (congenital talipes equinovarus). *In Brief: Topics in Pediatric Orthopedics*, 2(4), 1–3.
- Zeno, A. G., & Sorin, B. E. (2014). Idiopathic clubfoot treated with the Ponseti method: Historical analysis after Achilles tendon tenotomy in rats with clubfoot. *Jurnalul Pediatriei*, 17(67), 6–10.





## **An Overview of Bacterial Concrete on Concrete Durability in Aggressive Environment**

**JM. Irwan\* and T. Teddy**

*Jamilus Research Centre for Sustainable Construction (JRC), Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia*

### **ABSTRACT**

Concrete durability determines service life of structures. It can though, be weakened by aggressive environmental conditions. For instance, bio-corrosion process is due to the presence and activity of microorganisms which produce sulphuric acid to form sulphate deterioration of concrete materials. The problems related to durability and repair systems are due to lack of suitable concrete materials. The use bacteria for concrete repairing and plugging of pores and cracking in concrete has been recently explored. Previous studies had proved the possibility of using specific bacteria via bio concrete as a sustainable method for improving concrete properties. Thus, lack of information on the application of bio concrete exposed to extreme condition was the motivation for this research.

*Keywords:* Bacteria concrete, bio-concrete, concrete properties, durability, sea water

### **INTRODUCTION**

Concrete is the material of choice for the construction of structures that are exposed to extreme conditions such as those located near the sea as well as exposed to sulphates and chlorides. Concrete durability affects the service life of concrete structures significantly. The presence of steel reinforced bars in any structure exerts pressure arising from corrosion.

A typical problem in many concrete constructions is crack formation. Most cracks hamper structural integrity of the structures and give rise to durability problems and increase matrix permeability (Jonkers, 2012). Bio-concrete can solve durability problems using technology bacteria in order to seal cracks (Irwan et al., 2016). However, not all bacteria are able to tolerate extreme conditions (Ramachandran et al., 2001). This

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*E-mail addresses:*

hf140033@siswa.uthm.edu.my (T. Teddy),

irwan@uthm.edu.my (JM. Irwan)

\*Corresponding Author

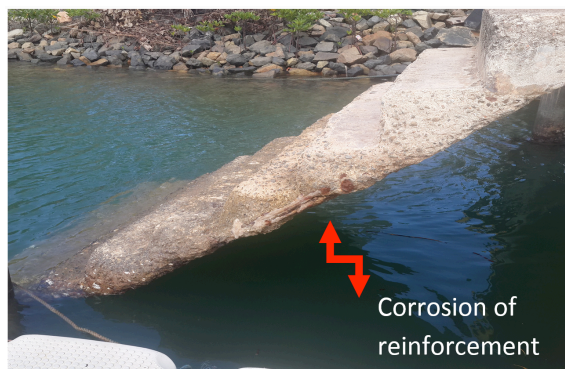
development has witnessed the use of certain bacteria which has the capability to grow in environments that are alkaline and without oxygen (Irwan et al., 2014).

### **Durability Concrete on Aggressive Environment**

Concrete durability is known as the ability of concrete to resist changes caused by environmental and chemical degradation. Factors affecting durability include material composition, proportioning, interactions, placing and curing procedures and the working environment. Therefore, different types of concrete require different degrees of durability.

According to Niyazi et al. (2016), cement paste which is too dense, low permeability and an environmental exposure like freeze-thaw-cycles are the major factors that influence durability of the concrete structure. Generally, fluctuations in concrete temperature and moisture do not affect the structure. However, alkali-aggregate reaction, sulphate attack, freeze-thaw cycles and reinforcement corrosion can adversely affect durability of structure. These factors may occur individually or simultaneously which lead to expansion and development of cracks in concrete.

The risk of corrosion is higher when concrete structures are exposed to an aggressive environment (seawater) or de-icing salts (as depicted in Figure 1). Corrosion is the single most prevalent factor causing deterioration of reinforced concrete structures. Findings of earlier studies indicate that corrosion is the main factor weakening steel bar in the reinforced concrete structure (Basheer, 1996). Environmental damages that lead to structural corrosion are caused by chemicals, sulphates, chlorides and coastal salts (Choi et al., 2015). The most significant corrosive constituents in coastal salts are sodium chloride, calcium chloride, and magnesium chloride, which are the same salts (chlorides) used for de-icing.



*Figure 1.* Failure of concrete due to structural corrosion as a result of aggressive environment (seawater) or de-icing salts (a case in one of the island)

Corrosion of reinforcement has been established as the principal factor causing widespread premature deterioration of concrete, especially structures located along the coast. The most important causes of corrosion initiation of reinforcing steel are chloride ions ingress and carbon dioxide exposure to steel surface. Corrosion initiation is triggered by iron oxides and hydroxides that are usually deposited in the restricted spaces in the concrete around the steel

(Song et al., 2007). Corrosion is an electro-chemical process with the basic mechanism at different areas of the same steel bar (anode and cathode). At the anode, steel releases ferrous ions (Kim & Ann, 2010). In contrast with the cathode, water in the presence of oxygen releases hydroxyl ions which increase alkalinity of the concrete (Broomfield, 1997).

The sulphate attack is a result of formation of gypsum (calcium sulphate) which in turn is due to specific reaction (Coppola et al., 1996). Sulphate ion from ground or seawater reacts with lime released during hydration process of portland cement and in the presence of calcium aluminate (Colleparidi, 2003). This results in the formation of sulphate compounds that occupy greater volume than the original concrete components causing expansion and eventual concrete deterioration.

### **Bacterial Concrete**

Bacteria is relatively simple, single-celled (unicellular) organisms. It can live and grow in organic matter and in plants and animals (Siddique, 2011).

The microbial precipitation of  $\text{CaCO}_3$  is determined by several factors including: concentration of dissolved inorganic carbon, pH, concentration of calcium ions and presence of nucleation sites (Tittelboom et al., 2010). Certain groups of bacteria have ability to precipitate calcium carbonate. Studies on bio-concrete have examined *Bacillus cohnii* to precipitate  $\text{CaCO}_3$  and *Bacillus sphaericus* to heal cracks in concrete (Wang et al., 2012). Meanwhile, Ramachandran et al. (2001) used different species of bacteria, *Bacillus pasteurii*, to precipitate calcium carbonate ( $\text{CaCO}_3$ ).

Therefore, there are possibilities that other bacteria strain can survive in extreme conditions. Consequently, a sulphate reduction bacteria (SRB) that heal micro-cracks (Irwan et al., 2016) show a potential for use in aggressive environments.

### **Literature on Bio-Concrete**

Concrete is mixtures of aggregate, cement, water and often chemical admixtures. Chemical and physical agents can attack the inert filler. The mineralogy of aggregate also plays a role in the chemical stability of hydrated cement paste, which ultimately leads to failure (Wiktor et al., 2011). The concrete structures have a certain capacity for autonomous healing of such micro cracks (Mindess et al., 2003; Reinhardt et al., 2003; Neville, 2004). The actual capacity of micro crack healing appears primarily related to the composition of the concrete mixtures. Mixtures based on a high binder content show remarkable crack-healing properties (Reinhardt et al., 2003). Autogenous self-healing of cracks traditionally occur in concrete with high-binder content mixtures and limited to cracks with a width smaller than 0.2 mm (Mindess et al., 2003; Reinhardt et al., 2003; Neville, 2004). The metabolic activity of bacteria is monitored by oxygen profile measurements, which reveal  $\text{O}_2$  consumption by bacteria-based samples.

The bonding behaviour with the concrete substrate is evaluated based on pullout tests and restrained shrinkage (Li et al., 2007). Bacteria *S. pasteurii* improves the compressive strength better than *B. subtilis* for both in water and sulphate solution. *S. pasteurii* also showed the least compressive strength loss compared with 28-day compressive strength, and represented the most relative compressive strength compared with the sulphate environment. (Guadalupe

et al., 2014). Nosouhian et al. (2015) had studied the durability of concrete in environments containing sulphate and found an improvement on concrete containing bacteria. The result at 28-days with 20% bacterial concrete was higher compared with the control. Isolated ureolytic and sulphate reduction bacteria strains are trained to survive in both alkaline and anaerobic condition to suit the concrete environment and have been proven to improve concrete properties (Irwan et al., 2014).

Table 1 shows majority of the researcher confirmed that bio-concrete resulted in an increase in concrete properties. However, there is limited information on the application of bio-concrete in other aggressive environments namely, chloride attack or other chemicals. Thus, future research should look examine optimum bio-concrete on aggressive environment. Adding the bacteria further confirms the mechanism or reactions by the bacteria inside the concrete. Microstructure and elemental analysis using Scanning Electron Microscope (SEM) show the appearance of distinct calcite crystals in concrete while X-ray defraction confirms the formation of complex calcium in the treated concrete (bio-concrete).

Table 1  
*Previous studies on bio-concrete*

Researchers	Findings	Type of Bacteria	Concentration of bacteria added
Nosouhian et al. (2015)	Carbonate producing bacteria to improve concrete characteristics	<i>S.pasteurii</i> (SP) and <i>Bacillus subtilis</i> (BS)	BS: $6 \times 10^9$ cells/mL SP: $9 \times 10^7$ cells/mL
Guadalupe et al. (2014)	Bio-based via bacteria-mediated calcium carbonate production improved mechanical properties and bonding strength of concrete	<i>Bacillus cohnii</i>	$1.2 \times 10^7$ bacterial spores/gr +15% calcium lactate
Irwan et al. (2014)	Survive in the alkaline environment with anaerobic conditions. Improve concrete properties	The Ureolytic bacteria (UB) and Sulphate Reduction Bacteria (SRB)	3% UB 0.1-0.5 mol/L & 5% SRB 0.1-0.5 mol/L
Wang et al. (2011)	Polyurethane has potential to be used as bacterial carrier for self-healing of concrete cracks	<i>Bacillus sphaericus</i>	$10^9$ cells/mL
Jonkers et al. (2011)	Self-healing capacity of concrete to seal the crack	<i>Bacillus cohnii</i>	$2.4 \times 10^8$ spores/cm <sup>3</sup> cement stone
Tittelboom et al. (2009)	Repair crack in concrete	<i>Bacillus sphaericus</i> (BS)	20 g/L BS+20 g/L urea
Ghosh et al. (2009)	Strength of bacteria modified mortar increases	<i>Bacillus hewanella</i> (BS)	$10^4$ - $10^6$ BS cells/ml
Muynck et al. (2008)	Improves the durability of cement materials	<i>Bacillus sphaericus</i>	$10^3$ spores/g mortar
Ramakrishnan et al. (2005)	Improvement of concrete durability	<i>Bacillus pasteruii</i>	$1 \times 10^8$ cells/ml

## CONCLUSION

This study examined the use of bacteria in concrete technology. Bio-concrete has better durability as it improves the properties of concrete. However, an extensive study on bio-concrete should be undertaken with the aim of adopting bio-concrete technology.

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## REFERENCES

- ACI Committee 201. (2001). Quid to durable concrete. *American Concrete Institute, Report of ACI Committee*, ACI 201.2R-7
- Bajza, A., & Zivica, V. (2001). Acidic attack of cement based materials - a review: Part 1 Principle of acidic attack. *Construction and Building Materials*, 15(8), 331-340.
- Basheer, P. A. M. (1996). Predictive models for deterioration of concrete structures. *Construction and Building Materials*, 10(1), 27-37.
- Basheer, P. A. M., Nanukuttan S. V., McCarter, W. J, Tang, L., Holmes. N., Chrisp, T. M., Starrs, G., & Magee, B. (2015). The performance of concrete exposed to marine environments: Predictive modelling and use of laboratory/on site test methods. *Construction and Building Materials*, 93, 831-840.
- Broomfield, J. P. (1997). Corrosion of steel in concrete, E & F.N. Spon. 7, DETER, Detroit, 1982, pp. 37.
- Choi, Y. K., Yi, Seong-Tae., Kim, M. Y., Jung, W. Y., & Yang, E. I. (2015). The performance of concrete exposed to marine environments: Predictive modelling and use of laboratory/on site test methods', in *Construction and Building Materials*, 93, pp 831-840.
- Collepardi, M. A. (2003). State-of-the-art review on delayed ettringite attack on concrete. *Cement Concrete Composite*, 25(4), 401-407.
- Coppola, L., Fratesi, R., Monosi, S., Zaffaroni, P., & Collepardi, M. (1996). Corrosion of reinforced concrete in sea water submerged structures", in *Proceedings of the Third International Conference on Performances of Concrete in Marine Environment*, pp 127-160. New Brunswick, Canada.
- Kim, S. H. K., & Ann, K. Y. (2010). Modeling steel corrosion in concrete structures-part 1: A new inverse relation between current density and potential for the cathodic reaction. *International Journal of Electrochemical Science*, 5(3), 302-313.
- Guadalupe Sierra-Beltran, M., Jonkers., H. M., & Schlangen, E. (2014). "Characterization of sustainable bio-based mortar for concrete repair". In *International Conference Delft University, of Technology, Faculty of Civil Engineering & Geosciences, Department of Materials and Environment, Stevinweg 1, 2628 CN Delft, The Netherlands*.
- Irwan, J. M., Faisal Alshalif, A., Othman, N., & Asyraf. R. M. (2014). Isolation of urateolytic and sulphate reduction bacteria: Acclimatize to concrete environment", in *International conference on civil, Biological and Environmental Engineering (CBEE), Istanbul, Turkey*.

- Irwan, J. M., Faisal, A., Othman, N., & Anezza, L. H. (2016). "Isolation of sulphate reduction bacteria (srb) to improve compress strength and water penetration of bio-concrete", in *International Conference on Civil and Environmental Engineering for Sustainability (IConCEES 2015), Melaka, December 1 – 2, 2015, MATEC Web of Conferences*, 47:01016.
- Jonkers, H. M. (2012). Bacteria-based self-healing concrete. In Department of Materials and Environment – Microlab, Delft, the Netherlands.
- Li, V. C., & Yang, E. (2007). Self-healing in concrete materials". In *self-healing materials – An alternative approach to 20 centuries of materials science* (ed. S. van der Zwaag), pp. 161–194. Springer, the Netherlands.
- Mindess, S., Young, J. Francis., & Darwin, D. (2003). Concrete, Upper saddle River Prentice Hall: NJ, pp. 644.
- Muynck, W. D., Cox, K., Belie, N. D., & Verstraete, W. (2008). Bacterial carbonate precipitation as an alternative surface treatment for concrete. *Construction and Building Materials*, 22, 875–885.
- Neville, A. (2004). The confused world of sulfate attack on concrete. *Cement Concrete Research*, 34(8), 1275-1296.
- Kockal, N. U., & Turker, F. (2007). Effect of environmental conditions on the properties of concretes with different cement types. *Construction and Building Materials*, 21, 634–645.
- Nosouhian, F., Mostofinejad, D., & Hasheminejad, H. (2015). Concrete durability improvement in a sulfate environment using bacteria. *Journal of Materials in Civil Engineering*, © ASCE, ISSN 0899-1561/04015064.
- Ramachandran, S. K., Ramakrishnan, V., & Bang, S. S. (2001). Remediation of concrete using micro-organisms. *ACI Materials Journal*, 98(1), 3-9.
- Reinhardt, H. W., & Jooss, M. (2003). Permeability and self-healing of cracked concrete as a function of temperature and crack width. *Cement and Concrete Research*, 33, 981-985.
- Siddique, R., & Chahal, N. K. (2011). Effect of ureolytic bacteria on concrete properties. *Construction and Building Materials*, 25, 3791-3801.
- Song, H. -W., & Saraswathy, V. (2007). Corrosion Monitoring of Reinforced Concrete Structures; A Review", in *International Journal Electrochemical. Sci.*, 1- 28.
- Tittelboom, K. V., Belie, N. D., Muynck, W. D., & Verstraete, W. (2010). Use of bacteria to repair cracks in concrete. *Cement and Concrete Research*, 40,157–166.
- Wang, J., Tittelboom, K. V., Belie, N. D., & Verstraete, W. (2012). Use of silica gel or polyurethane immobilized bacteria for self-healing concrete, *Construction and Building Materials*, 26, 532–540.
- Wiktor, V., & Jonkers, H. M. (2011). Quantification of crack-healing in novel bacteria-based self-healing concrete. *Cement and Concrete Composites*, 33, 763–770.



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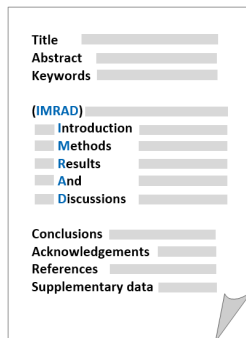
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Pertanika Editorial Office, Journal Division  
Office of the Deputy Vice Chancellor (R&I),  
1st Floor, IDEA Tower II,  
UPM-MTDC Technology Centre  
Universiti Putra Malaysia  
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