Lecture Notes in Civil Engineering

Mokhtar Awang
Lloyd Ling
Seyed Sattar Emamian *Editors*

Advances in Civil Engineering Materials

Selected Articles from the International Conference on Architecture and Civil Engineering (ICACE2021)

Springer

Lecture Notes in Civil Engineering

Volume 223

Lecture Notes in Civil Engineering (LNCE) publishes the latest developments in Civil Engineering - quickly, informally and in top quality. Though original research reported in proceedings and post-proceedings represents the core of LNCE, edited volumes of exceptionally high quality and interest may also be considered for publication. Volumes published in LNCE embrace all aspects and subfields of, as well as new challenges in, Civil Engineering. Topics in the series include:

- Construction and Structural Mechanics
- Building Materials
- Concrete, Steel and Timber Structures
- Geotechnical Engineering
- Earthquake Engineering
- Coastal Engineering
- Ocean and Offshore Engineering; Ships and Floating Structures
- Hydraulics, Hydrology and Water Resources Engineering
- Environmental Engineering and Sustainability
- Structural Health and Monitoring
- Surveying and Geographical Information Systems
- Indoor Environments
- Transportation and Traffic
- Risk Analysis
- Safety and Security

To submit a proposal or request further information, please contact the appropriate Springer Editor:

- Pierpaolo Riva at pierpaolo.riva@springer.com (Europe and Americas);
- Swati Meherishi at swati.meherishi@springer.com (Asia - except China, and Australia, New Zealand);
- Wayne Hu at wayne.hu@springer.com (China).

All books in the series now indexed by Scopus and EI Compendex database!

More information about this series at https://link.springer.com/bookseries/15087

Mokhtar Awang · Lloyd Ling ·
Seyed Sattar Emamian
Editors

Advances in Civil Engineering Materials

Selected Articles from the International Conference on Architecture and Civil Engineering (ICACE2021)

Springer

Editors
Mokhtar Awang
Department of Mechanical Engineering
Universiti Teknologi Petronas
Seri Iskandar, Perak, Malaysia

Lloyd Ling
Universiti Tunku Abdul Rahman
Selangor, Malaysia

Seyed Sattar Emamian
Delft, Zuid-Holland, The Netherlands

ISSN 2366-2557 ISSN 2366-2565 (electronic)
Lecture Notes in Civil Engineering
ISBN 978-981-16-8666-5 ISBN 978-981-16-8667-2 (eBook)
https://doi.org/10.1007/978-981-16-8667-2

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

This book presents a compilation of research works covering the fields of architecture and civil engineering. All the manuscripts in this volume were presented during the 5th International Conference on Architecture and Civil Engineering 2021 (ICACE 2021) which was conducted through a virtual presentation on August 18, 2021. ICACE is an annual event held in Malaysia where the main aim is to bring together researchers and industry players in architecture and civil engineering to share their knowledge and research findings. This book consists of 38 chapters covering from cultural values in architectural design to numerical modeling in civil engineering.

It is hoped that the content of this book will benefit the researchers and scholars who are looking for recent findings and breakthrough in civil engineering and architecture research works. The editors of the proceeding would like to express their utmost gratitude and thanks to all reviewers in the technical team for making this volume a success.

Seri Iskandar, Malaysia — Mokhtar Awang
Selangor, Malaysia — Lloyd Ling
Delft, The Netherlands — Seyed Sattar Emamian

Acknowledgment

The editors would like to thank all the members of the local organizing committee who helped organize the 5th International Conference on Architecture and Civil Engineering 2021 (ICACE 2021), which was conducted through a virtual presentation on August 18, 2021.

The editors are grateful to all the distinguished speakers who attended the conference and shared from their wealth of experience some exciting findings which have further propelled us to publish this book. We would like to thank the colleagues and staff members at the institutions and organizations that served as partners for the international conference. Their support in organizing a successful conference has helped the editors to gather ideas and papers presented in this book.

The editors also appreciate various people, including the production team at Springer, who helped and contributed to the creation of this book. We thank all the authors and contributors who presented at the conference and sent us their papers for peer-review. The editors would like to thank and appreciate the peer-reviewers for their suggestions, comments, efforts, and time spent to go over all the papers.

The editors appreciate the support of the leadership team of their respective institutions for the support, encouragement, and enabling environment created to prepare this book. The conference has inspired and brought the editors together from different disciplines and institutions across different countries and continents of the world to work on this book. The creation of this book has helped us to become a formidable team. The process has been enjoyable, challenging, inspiring, and more peaceful than we ever thought. We thank you all!

Contents

Substantiating Building Defect Cause Hypotheses Using SPSS Statistical Analysis on Quantitative Data

Roslan Talib and Mohd Zailan Sulieman

Abstract Construction defects take many forms, and they are a problem no one wants to deal with. Anything from poor workmanship to defective building materials or building products can be considered a construction defect. For this paper, the approach in doing the defects census is by having a quantitative research method approach through Google Form survey where 86 participants ($n = 86$) have been responded. Three building defects causal hypotheses have been formulated and the recent version (v24/v26) of SPSS statistical software has been used to test those hypotheses. The tests were done including x^2 (chi-square's Asymptotic Sig.), X-tab and HBG analysis. The result somehow indicated that it is vital to have centralized defects data, pay greater attention during the post-construction period where most defects occurred and build devotion to come up with fewer design detail mistakes; these are the recent proven facts that the industry players must pay attention-with; to produce better-finished building.

Keywords Building defects · Defects causal · Defects hypothesis · Quantitative method · SPSS · Google Form

1 Introduction

The construction industry all around the world is getting more up-to-date, advance, and growing day by day. Despite the development, the construction industry is dealing with one key problem i.e., building defects. Anyway, at the same time, the construction players are always motivated to overcome building defects challenges, but it is difficult to deal with them completely. But, somehow, as stipulated by [1], building defects do not appear to have been minimized despite even the recent advancements in building technology. Some common defects caused by proxies such as atmospheric pollution, poor workmanship or the use of inferior materials and climatic conditions

R. Talib (✉) · M. Z. Sulieman
School of Housing, Building & Planning, Universiti Sains Malaysia, 11800 Pulau, Pinang, Malaysia
e-mail: roslantalib@usm.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_1

are more frequent [2]. Defective building construction not only contributes to the final cost of the product but also to the cost of maintenance, which can be substantial.

2 Literature Research

Building defects are always the key apprehension in construction projects. An issue with a building only counts as a building defect if it is a result of defective design, faulty workmanship, substandard materials or non-compliance with the structural performance requirements of the **National Construction Code** (as for the country of Australia code term) [3]. Earlier research carried out found out that architectural and building defects are not recorded properly in such a way, the central database can not be created for all parties involved can be referred to [4] observed to record the highest number of construction defects that happened in almost all the building construction projects in Malaysia. Even, most defects are discovered long after the completion of a project. However, a good amount of defects mostly occurred during the post-completion period started where the tenant had just move-in inside the properties [5]. There may be also several reasons why most of the building defects has been identified to be started from the drawing table or during the design phase [6].

3 Methodology

Quantitative methods accentuate objective measurements and the statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating pre-existing statistical data using computational techniques [7]. This is the method being used for this study and this census also use Google Forms which is a tool within Google Drive for creating the online quantitative survey forms. One of the reasons for using Google Forms for the survey medium is because it is easy to learn and can access the form or the data from any computer connected to the internet [8]. Once you had enough respondent's feedback data (for this case $n = 86$), you need to choose the right and suitable statistical data analysis software to examine it.

Based on findings, [9] stated that a statistical test provides a mechanism for making quantitative decisions about a process or processes. The intent is to determine whether there is enough evidence to "reject" a conjecture or hypothesis about the process. Thus, for this exercise, the SPSS version 24/26 has been selected to run the tests (x^2, X-tab and HBG analysis). Anyway, SPSS is short for Statistical Package for the Social Sciences, and it's used by various kinds of researchers for complex statistical data analysis. Ahmad et al. [10] asserted that most top research agencies use SPSS to analyse survey data and mine text data so that they can get the most out of their research projects.

4 Results and Discussions

4.1 No Central Data Stage + Post-Construction Warranty Versus Work Experience–B3-Q30d, Q32/9 Histogram Breakdown Graphs (HBG)

Further to the section, this test will continue using 7 nos. of histogram charts (out of 9 boxes sample test) referring to the Questionnaire's no. 30d and 32 of Section B3 in the Google Forms online survey sheet, to demonstrate the research accounts. Statistically, a histogram determines to graphically recapitulate the distribution of a univariate data set.

For this statistic test, it is important to focus the graphs on the 3 most important histograms, starting to the rightest bottom (X_1 = Strongly Agree, Y_1 = Strongly Agree), middle chart (X_2 = Agree, Y_2 = Agree) and the most left top histogram (X_3 = Neutral, Y_3 = Neutral). For Fig. 1, the Independent (X) Variable (X_1, X_2 and X_3) representing the Working Experience variable with 8 classifications. Next, for the dependent (Y) variable, there will be 2 variables that have been draw-up for the test. Those are Y_1, Y_2 and Y_3 which are; post-construction period (during the warranty

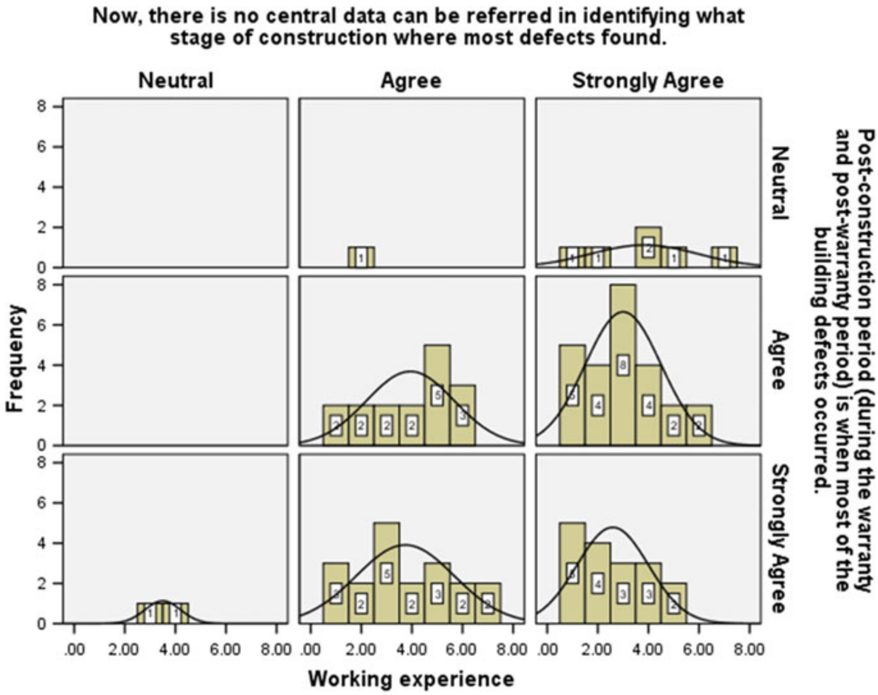


Fig. 1 Seven Histogram chart of 9 HBG–No Central data + Post-construction warranty versus working experience

and post-warranty period) is when most of the building defects occurred and there is no collected central data can be referred to in detecting at what stage of construction (where the most type of defects found) within the construction industry in Malaysia.

As far as the histogram distribution is concerned, again, it seems like it all has an asymmetric distribution pattern. [11] use dictation, a symmetric histogram means the cutline is down in the middle and the left-hand and right-hand sides resemble mirror images of each other. For the 1st chart (X_1, Y_1) located to the most lowermost right, with Frequency (*f*) total of 34 ([5 + 4 + 3 + 3 + 2] * 2) and with the addition of bottom middle graph (X_{-1}, Y_{-1}) with Frequency (*f*) of 38 ([3 + 2 + 5 + 2 + 3 + 2 + 2] * 2), it shows clearly most of the respondents (with n = 86) positively agreed on the variables statements. It represents an ideal data set.

As most of the active histogram charts concentrated at the Agree and Strongly Agree right bottom corner (with 4 and 5 in Likert Scale) which show the normal distribution where it means an ideal data set that has lots of numbers concentrated in the middle of the range, with the remaining numbers trailing off symmetrically on both sides. To enhance further on the test tabulation, the middlebox of the histogram (X_2, Y_2) shows more scores agreeing on the assertions with 50 ([5 + 4 + 8 + 4 + 2 + 2] * 2). This clearly shown that the test has a positive score and significantly contributed to the survey as it indicates that since there is no accumulated central data can be referred to in identifying what stage of construction (where the most type of defects found), thus most of the building defects can persistently be happening especially during the post-construction period. According to the test analysis, it is during the warranty and post-warranty period is when most of the building defects occurred. So, the task of getting the CDB (Centralized Database) is very essential.

4.2 Cross-Tabulation-90% Defects from no Proper Detail Versus Work Experience—Q33/Chi-Square

Moving on, the next statistical evaluation (Questionnaire 33/Section B3) concerning the respondents working experience years versus the hypothesis tabulation stated that proper architectural detailing in the design stage can prevent up to 90% of building defects; latent or non; to occur or re-occur (see Table 1). The survey revealed that 43% or 50% of $n = 86$ respondents chose the Likert Scale at 5.00 (Strongly Agree) agreeing on the statement. Out of this, 64.3% with 9/43 responses coming from the personnel having 6–10 years of experience in building construction while in 2nd, 57.9% or 11/43 respondents having 11–15 years working experience agreeing that proper architectural detail and reduce latent or non-latent building defects up to 90%. Next, at 4.00 Scale (Agree), 47.7% or 41/86 respondents total up with this decision were 8 of them representing from 3 different working experience groups total 16/41 players agree on the hypothesis. These people are from the group having 1–5, 11–15 and 16–20 years of working experience working within the construction industry agreeing that good architectural detail can prevent defects up to 90%.

Table 1 Cross-tabulation Frequency (f) table showing participants' working experience versus factor stated that 90% of defects can be prevented during proper detailing at the design stage

Crosstab										
			Working experience							Total
			1–5 year/s	6–10 years	11–15 years	16–20 years	21–25 years	26–29 years	More than 30 years	
Proper architectural detailing in the design stage can prevent 90% of building defects; latent or non to occur or re-occur	3.00	Count	0	0	0	1	1	0	0	2
		% within Working experience	0.0%	0.0%	0.0%	7.1%	7.7%	0.0%	0.0%	2.3%
	4.00	Count	8	5	8	8	6	4	2	41
		% within Working experience	50.0%	35.7%	42.1%	57.1%	46.2%	57.1%	66.7%	47.7%
	5.00	Count	8	9	11	5	6	3	1	43
		% within Working experience	50.0%	64.3%	57.9%	35.7%	46.2%	42.9%	33.3%	50.0%
Total		Count	16	14	19	14	13	7	3	86
		% within Working experience	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 2 Chi-square table showing the Significance 2-variables test (participants' working experience versus factor stated that 90% of defects can be prevented during proper detailing at design)

Chi-square tests			
	Value	df	Asymptotic significance (2-sided)
Pearson Chi-square	7.225[a]	12	0.842
Likelihood ratio	7.511	12	0.822
Linear-by-linear association	1.601	1	0.206
N of valid cases	86		

11 cells (52.4%) have an expected count of less than 5. The minimum expected count is 0.07

Further to the previous early part of Sect. 4.2, the Chi-square (χ^2) statistic appears as an option when requesting a cross-tabulation in SPSS (to note; for this case and all other cases; SPSS Version 24 or 26 has been used). The output is labelled Chi-square Tests; the Chi-square statistic used in the Test of Independence is labelled Pearson Chi-square. Further, on this test (Table 2 Sect.B3/Q33), the 2-sided Asymptotic Significance the *p* result show 0.842, 0.822 and 0.206 which all above 0.05 (>0.05) shows the less significant relationship between the two variables. All the 3 components of the *p* result indicated that the value >0.05 and the value determines that there is a less significant relationship between the 2 variables.

Sharpe [12] stress out, the fewer significance values that are *p*-value associated with Chi-square (χ^2) statistics meaning there is less strong evidence of rejecting the null hypothesis of no fit. It means a little less good fit. To add to the statistical information, χ^2 goodness of fit is a non-parametric test.

This set of crosstabs (X-tab) examination maybe not the ideal chose variables such as the first variable; proper architectural detailing within the design stage can prevent 90% of building defects and the second one; respondents' working experience, but it implicates at certain degree there may be better variable to test into. However, the χ^2's 2 variables result still can be considered valid as the number of year's respondents involved in the construction field (independent variable) seems quite important to match with proper architectural detailing within the design stage can prevent 90% of building defects (dependent variable). This is due to that the dependent variable involved the number of existences on the respondent's job experience in the construction-related field which carries quite an enormous variable.

Overall, this makes the tabulation analysis a little less valid and provisionally a little insignificant to the overall study on defects' stage causal issues scope but still shows the provisionally significant fair result.

5 Conclusion

Hypothesis testing is an indispensable procedure in statistics. A hypothesis test evaluates two reciprocally exclusive statements about a population to determine which statement is pre-eminently supported by the sample data. When we say that a finding is statistically significant, it is thanks to a hypothesis test [13]. For these cases, the SPSS statistical data analysis revealed that all the variables are proven to be in valid hypotheses mode. Thus, seriously, the industry players must pay inordinate attention to the fact that central defects data must be ready to be referred to at any time.

Next, it is during the post-construction period, the building defects mostly occurred, and the players must ensure defects warranty must be valid especially at this phase. Having the respondents within the working experience right range and tested with all the three variables including the 3rd one; validated that correct architectural detailing especially done during the design stage can prevent up to 90% of building defects to happen; latent or non-latent versions of them.

Lastly, proving building defects causes hypotheses measurement; for this case using the SPSS statistical analysis on a collected quantitative data; is immensely important, academically. For this paper, the three hypotheses variables proved meticulously valid and necessitate the industry players (particularly the Malaysian players) to pay further attention to the matters.

Acknowledgements The publication of this paper is made possible through Universiti Sains Malaysia research grant allocation no.: 10001 PPBGN 8016034. I would like to express my gratitude to my supervisor, Assoc. Prof. Dr. Sr Mohd Zailan Sulieman, who guided me well during this project. I would also like to thank all the people involved; directly or indirectly throughout the process of finalizing the research process.

References

1. James J, Douglas EH, Ransom WH (2013) Understanding building failures, 4th edn. Routledge, London and New York
2. Talib R, Ahmad AG, Sulieman MZ (2015) Practical building defect solutions; construction failures to be avoided—Real case studies selected from Malaysian buildings. Int J Emerg Trends Eng Res 3(7):44–49
3. Pinsent Masons LLP (2011) Defective work in construction projects. Out-Law.com. [Online]. Available: https://www.out-law.com/en/topics/projects--construction/construction-claims/defective-work-in-construction-projects/. Accessed 02 June 2019
4. Talib R, Ahmad A, Sulieman M (2015) Building design failure. Why did it fail? How it could have been avoided? Int. J Chem Env Bio Sci (IJCEBS) 3(5)
5. Faqih F, Zayed T, Soliman E (2020) Factors and defects analysis of physical and environmental condition of buildings. J Build Pathol Rehabil 5(1):1–15
6. Waziri BS (2016) Design and construction defects influencing residential building maintenance in Nigeria. Jordan J Civ Eng 10(3)
7. Creswell J (2014) Qualitative, quantitative, and mixed-method approaches. Research design, SAGE, London

8. Expedient T (2019) (902) google forms for project survey for thesis. Ph.D. report and MBA project feedback form questionnaire - YouTube
9. Rasli A (2006) Data analysis and interpretation: a handbook for postgraduate social scientists. Penerbit UTM
10. Ahmad WMAW, Halim NA, Aleng @ Mohamad NA, Hamzah MP (2019) Data analysis using SPSS: version 24. Penerbit USM
11. Aldrich J, Rodríguez H (2014) Building SPSS graphs to understand data, 1st edn. Kindle Edition
12. Sharpe D (2015) Your chi-square test is statistically significant: Now what? Pract Assessment Res Eval
13. Abowitz DA, Toole TM (2010) Mixed method research: fundamental issues of design, validity, and reliability in construction research. J Constr Eng Manag

Runoff Prediction Errors with Conjugate Curve Number

Lloyd Ling, Zulkifli Yusop, and Wei Lun Tan

Abstract The curve number (CN) rainfall-runoff model is widely adopted for runoff prediction. However, its practitioners seldom verify its validity according to the rainfall-runoff dataset. Conjugate CN was often used by mistake in the CN runoff predictive model for runoff prediction. This study compared runoff predictions of a calibrated CN model to the existing CN modelling approach and simulated the runoff prediction results from the inaccurate use of the conjugate CN. The calibrated CN model outperformed the other 2 models with the highest Nash–Sutcliffe model efficiency index of 0.917 without runoff over and under prediction tendency. When conjugate CN was wrongly used for runoff prediction, the model had the largest runoff depth under-prediction concern. Contrarily, the existing CN approach over-predicted runoff amount when it is not calibrated. On average, the model over-predicted runoff volume by 5 million liters/km^2 while the inaccurate use of conjugate CN under-predicted runoff volume by nearly 7.6 million liters/km^2 in Peninsula Malaysia.

Keywords Conjugate curve number · Runoff prediction · Inferential statistics

1 Introduction

Despite technological advancement in recent decades, flood related disasters continue to threaten mankind. Therefore, the United States Department of Agriculture (USDA), Soil Conservation Services (SCS), Curve Number (CN) runoff model was assessed by this study as it has been widely accepted since its inception in 1954. It has been incorporated in many types of software, adopted by government

L. Ling (✉) · W. L. Tan
Centre of Disaster Risk Reduction (CDRR) and Centre for Mathematical Sciences (CMS), Lee Kong Chian Faculty of Engineering & Science, Civil Engineering Department, Universiti Tunku Abdul Rahman, Jalan Sungai Long, Bandar Sungai Long, 43000 Cheras, Malaysia
e-mail: lingllloyd@utar.edu.my

Z. Yusop
Centre for Environmental Sustainability and Water Security (IPASA), Faculty of Civil Engineering Department, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_2

agencies in design and even appears in every hydrology textbook. However, studies around the world from recent decades reported its failure to predict consistent runoff results. Despite that, many recent studies still used the model to develop extended applications and involved the work with GIS software.

This study used the rainfall-runoff (*P*-*Q*) dataset from the Department of Irrigation and Drainage (DID), Hydro Procedure no. 27 (DID HP 27) [1] to assess the impact on runoff prediction using conjugate CN other than the conventional CN. In a different study, the existing SCS runoff model was not even valid for runoff modelling at alpha = 0.05 level in Peninsula Malaysia and therefore, the model was calibrated under the guide of inferential statistics with DID HP 27 dataset. SCS CN model cannot be adopted blindly for runoff prediction use. The impact of runoff prediction errors in Peninsula Malaysia and China were analyzed in past studies [2–4].

According to the SCS, the basic SCS CN theory is represented by the following equation:

$$Q = \frac{(P - I_a)^2}{P - I_a + S}$$

where
Q = Amount of runoff depth (mm)
P = Depth of rainfall (mm)
S = Watershed maximum water retention potential (mm)
I_a = Rainfall initial abstraction amount (mm)
Note: $I_a = \lambda S$.

2 The S General Formula

The SCS runoff theory introduced in 1954 can be re-arranged mathematically to solve for the $S_\lambda = f(P, Q, \lambda)$ known as the *S* general equation. Substitute $I_a = \lambda S$ into $Q = \frac{(P-I_a)^2}{P-I_a+S}$ and isolate *S* from all other parameters with completing the square technique will yield the S general formula used by this study as:

$$S_\lambda = \frac{\left[P - \frac{(\lambda-1)Q}{2\lambda}\right] - \sqrt{\left(PQ - P^2\right) + \left[P - \frac{(\lambda-1)Q}{2\lambda}\right]^2}}{\lambda}$$

Although previous researchers used a different form of the S general formula in their journal [5], they were not the first who derived the formula but presented a variant formula as reported by [6] (see full derivation steps below).

2.1 The S General Formula Derivation Process

From SCS basic theory model, the equation can be rearranged as below:

$$Q = \frac{(P - I_a)^2}{P - I_a + S}$$

$$QS = (P - I_a)^2 - Q(P - I_a)$$

Substitutes: $I_a = \lambda S$

$$QS = (P - \lambda S)^2 - Q(P - \lambda S)$$

$$PQ - P^2 = -2\lambda S\left[P - \frac{(\lambda - 1)Q}{2\lambda}\right] + (\lambda S)^2$$

Add $\left[P - \frac{(\lambda-1)Q}{2\lambda}\right]^2$ to both sides of the equation & completing the square on right hand side of the equation for further simplification as below,

$$\left(PQ - P^2\right) + \left[P - \frac{(\lambda - 1)Q}{2\lambda}\right]^2 = \left[P - \frac{(\lambda - 1)Q}{2\lambda}\right]^2 - 2\lambda S\left[P - \frac{(\lambda - 1)Q}{2\lambda}\right] + (\lambda S)^2$$

$$S_\lambda = \frac{\left[P - \frac{(\lambda-1)Q}{2\lambda}\right] - \sqrt{PQ - P^2 + \left[P - \frac{(\lambda-1)Q}{2\lambda}\right]^2}}{\lambda} \tag{1}$$

Formula simplification steps from the equation used by this study (Eq. 1) to the form of [5] then to the form of [6] are as below:

$$S_\lambda = \frac{P}{\lambda} - \frac{(\lambda - 1)Q}{2\lambda^2} - \frac{1}{\lambda}\sqrt{PQ - P^2 + \left[P - \frac{(\lambda - 1)Q}{2\lambda}\right]^2}$$

$$S_\lambda = \frac{P}{\lambda} + \frac{Q(1 - \lambda)}{2\lambda^2} - \frac{1}{2\lambda^2}\sqrt{Q^2(1 - \lambda)^2 + 4\lambda PQ} \qquad [5]$$

$$S_\lambda = (\frac{1}{\lambda})P + (\frac{1}{\lambda})\left[\frac{(1 - \lambda)Q}{2\lambda}\right] - (\frac{1}{\lambda})\frac{1}{2\lambda}\sqrt{Q^2(1 - \lambda)^2 + 4\lambda PQ}$$

$$S_\lambda = \frac{P}{\lambda} + \frac{(1 - \lambda)Q}{2\lambda^2} - \frac{1}{2\lambda^2}\sqrt{4\lambda PQ + [(1 - \lambda)Q]^2} \qquad [6]$$

These steps proved that different variants of the S general formulae can be solved to unity with the earliest version presented by [6]. The derivation of the S general formula also proves and supports the claim of [7] that when $\lambda \neq 0.2$, calculated curve number is called the "conjugate curve number" which is not the same as the conventional curve number introduced by the SCS which is derived from the λ = 0.2 framework.

$S_\lambda = f(P, Q, \lambda)$ derivation shows that even though the *P-Q* dataset remains the same, once λ value varies, the corresponding S_λ will change as well. Therefore, the S correlation equation between S_λ and $S_{0.2}$ must be established to convert the S_λ back to the equivalent scale of $S_{0.2}$ prior to the curve number calculation [2–4, 7]. Any work that calculates curve number directly with $CN = \frac{25{,}400}{S+254}$ using S_λ commits a conceptual error and the conjugate curve number has been wrongly identified as the conventional curve number. $CN_{0.2}$ will be used in this article to differentiate from the conjugate curve number CN_λ.

3 The Confusion Between Conjugate CN (CN_λ) and $CN_{0.2}$

When the λ value deviated away from 0.2, the S general formula (Eq. 1) will calculate S_λ value according to *P-Q* data pair. However, S_λ was often mistaken as $S_{0.2}$ and being used to calculate the conventional $CN_{0.2}$ value directly with $CN_{0.2} = \frac{25{,}400}{S_{0.2}+254}$. Results from a previous study [2] such as: Eq. 1, newly identified λ value of 0.051 and the S correlation equation ($S_{0.051} = 1.176{S_{0.2}}^{1.063}$ or $S_{0.2} = 1.096{S_{0.051}}^{0.89}$) were used by this study to analyze the impact on runoff prediction due to the confusion between $S_{0.2}$ and S_λ leading to the derivation of conjugate CN (CN_λ) and $CN_{0.2}$.

Using the 227 *P-Q* data pairs from DID HP 27 dataset, 227 $S_{0.2}$ and $S_{0.051}$ values can be calculated with Eq. 1 according to corresponding *P-Q* data pairs. Substitute each calculated $S_{0.2}$ value into $CN_{0.2} = \frac{25{,}400}{S_{0.2}+254}$. $CN_{0.2}$ value can be calculated as proposed by the SCS. SCS practitioners often made a mistake by substituting the S_λ value into the SCS CN formula directly without using the S correlation equation to convert the S_λ value into an equivalent $S_{0.2}$ and treated the conjugate CN (CN_λ) as $CN_{0.2}$ by mistake.

The SCS runoff predictive model was simplified and re-expressed in term of *P* and $CN_{0.2}$ in previous study (see [2] for derivation steps) as:

$$Q_{0.2} = \frac{\left[P - 50.8\left(\frac{100}{CN_{0.2}} - 1\right)\right]^2}{\left[P + 203.2\left(\frac{100}{CN_{0.2}} - 1\right)\right]} (\text{when } \lambda = 0.2) \tag{2}$$

When $\lambda = 0.051$, the derived $CN_{0.2} = 72.58$ while the S correlation was established in SPSS as: $S_{0.051} = 1.176{S_{0.2}}^{1.063}$ [2] to simplify and re-express the model as:

$$Q_{0.051} = \frac{\left[P - 21.606\left(\frac{100}{72.58} - 1\right)^{1.063}\right]^2}{\left[P + 402.547\left(\frac{100}{72.58} - 1\right)^{1.063}\right]} \tag{3}$$

Under this study, 227 $CN_{0.2}$ values were calculated with $S_{0.2}$ ($\lambda = 0.2$). On average, $CN_{0.2} = 74.1$. The average $CN_{0.2} = 74.1$ was used with Eq. 2 to estimate runoff as proposed by the SCS. Equation 2 became:

$$Q_{0.2} = \frac{\left[P - 50.8\left(\frac{100}{74.1} - 1\right)\right]^2}{\left[P + 203.2\left(\frac{100}{74.1} - 1\right)\right]} \tag{4}$$

To simulate the scenario that the conjugate curve number was wrongly used to predict runoff, this study calculated 227 $S_{0.051}$ (substitute $\lambda = 0.051$ into Eq. 1 with corresponding *P*-*Q* data pairs) and treated them as $S_{0.2}$ to find the curve number with $CN = \frac{25{,}400}{S+254}$ directly. The average $CN_{0.051} = 65.2$ was used with Eq. 2 and became:

$$Q_{0.2} = \frac{\left[P - 50.8\left(\frac{100}{65.2} - 1\right)\right]^2}{\left[P + 203.2\left(\frac{100}{65.2} - 1\right)\right]} \tag{5}$$

4 Results and Discussion

Under this study, 227 conjugate numbers $CN_{0.051}$ ($\lambda = 0.051$) were calculated and adopted directly for runoff prediction without the conversion through the S correlation equation to simulate the common mistake of SCS practitioners. When compared to the 227 $CN_{0.2}$ values ($\lambda = 0.2$), on average, $CN_{0.051} = 65.2$, it is almost 9 CN units less than the average $CN_{0.2} = 74.1$. As such, when $CN_{0.051}$ was treated as $CN_{0.2}$ by mistake, runoff estimation is likely to be under-predicted in Peninsula Malaysia. Using DID HP 27 dataset, runoff predictions from Eqs. 3–5 can be compared as shown in Table 1.

From Table 1, Eq. 3 (calibrated model with S correlation equation) achieved the highest model efficiency of 91.7% with the overall model bias almost equal to zero to imply that Eq. 3 is stable in runoff prediction without over or under prediction tendency. Equation 4 represented the existing SCS CN approach ($\lambda = 0.2$), it ranked as the worst performing model under this study. Equation 4 has runoff

Table 1 Runoff prediction comparison

Statistics	Equation 3	Equation 4	Equation 5
Overall $CN_{0.2}$ used	72.58	74.1	65.2
Nash–Sutcliffe model efficiency	0.917	0.874	0.904
Overall model BIAS (mm)	−0.034	5.034	−7.593
Average runoff depth (mm)	47.6	52.7	40.1
MIN predicted runoff depth (mm)	0.8	0.0	0.0
MAX predicted runoff depth (mm)	302.0	329.7	292.2

depth over-prediction tendency as its overall model bias = 5.03 mm with an average runoff volume over-prediction by 5.03 million liters/km^2. Equation 5 simulated the scenario when $CN_{0.051}$ was wrongly used as $CN_{0.2}$ for runoff prediction with DID HP 27 dataset. It has the second highest prediction accuracy of 90.4% however its overall model bias = −7.6 mm to imply that Eq. 5 has runoff depth under-prediction concern. On average, Eq. 5 under-predicted runoff volume by 7.6 million liters/km^2. On average, runoff depth prediction from Eq. 4 is 5.1 mm more than the average runoff depth from Eq. 3 while the maximum predicted runoff depth is 27.7 mm higher. Contrarily, for Eq. 5, the average predicted runoff depth is 7.6 mm lower than Eq. 3 while the maximum predicted runoff depth is 9.8 mm less.

It is noteworthy to highlight that the 1 mm runoff depth prediction variance = 1 million liters/km^2 runoff volume difference. This means that when the existing SCS CN runoff predictive model (Eq. 4) is not calibrated according to the DID HP 27 *P-Q* dataset, it over-predicted runoff volume by an equivalent of two Olympic size swimming pools on average (maximum over-predicted by 11 pools). If the conjugate CN ($CN_{0.051}$) was wrongly used as $CN_{0.2}$ for runoff prediction (Eq. 5), it under-predicted runoff volume by an equivalent of three Olympic size swimming pools on average (maximum under-predicted by 4 pools).

5 Conclusions

1. Equation 3 was formulated with calibrated $\lambda = 0.051$ and simplified with the S correlation equation from previous study [2] at alpha = 0.01 level. The overall model bias is near to zero to indicate that on average, the formulated runoff predictive model is stable without runoff over or under prediction tendency. It also achieved the highest runoff model prediction efficiency when compared to Eqs. 4 and 5.
2. The SCS CN model (Eq. 4) was found to be invalid for runoff prediction from previous study [2–4]. On average, blind adoption of Eq. 4 will over-predict runoff volume by 5.03 million liters/km^2 using DID HP 27 dataset. It was the worst runoff predictive model under this study.
3. Equation 5 simulated the scenario when conjugate CN ($CN_{0.051}$) was wrongly used as $CN_{0.2}$ for runoff prediction with the DID HP 27 dataset. On average, Eq. 5 under-predicted runoff volume by 7.6 million liters/km^2. Equation 5 also under-predicted maximum runoff depth when compared to the calibrated runoff predictive model (Eq. 3).

Acknowledgements The authors would like to thank Universiti Tunku Abdul Rahman IPSR/RMC/UTARRF/2019-C2/L07, IPSR/RMC/UTARRF/2016-C2/L13 and Brunsfield Engineering Sdn. Bhd., Malaysia (Brunsfield 8013/0002) for their financial support in this study.

References

1. DID, Hydrological Procedure No. 27 (2010) Design flood hydrograph estimation for rural catchments in Peninsula Malaysia. JPS, DID, Kuala Lum-Pur. https://www.water.gov.my/jps/resources/PDF/Hydrology%20Publication/Hydrological_Procedure_No_27_(HP_27).pdf. Accessed 30 April 2021
2. Ling L, Yusop Z, Ling JL (2021) Statistical and type II error assessment of a runoff predictive model in Peninsula Malaysia. Mathematics 9:812. https://doi.org/10.3390/math9080812
3. Ling L, Yusop Z, Chow MF (2020) Urban flood depth estimate with a new calibrated curve number runoff prediction model. IEEE Access 8:10915–10923. https://doi.org/10.1109/ACCESS.2020.2964898
4. Ling L, Yusop Z, Yap W-S, Tan WL, Chow MF, Ling JL (2019) A calibrated, watershed-specific SCS-CN method: application to Wangjiaqiao watershed in the three Gorges Area, China. Water 12:60. https://doi.org/10.3390/w12010060
5. Schneider L, McCuen RH (2005) Statistical guidelines for curve number generation. J Irrig Drain Eng ASCE 131:282–290
6. Chen CL (1982) An evaluation of the mathematics and physical significance of the soil conservation service curve number procedure for estimating runoff volume. In: Proceedings of the international symposium on 'rainfall-runoff relationship'. Littleton, pp 387–418
7. Hawkins RH, Ward T, Woodward DE, Van Mullem J (2009) Curve number hydrology: state of the practice. ASCE, Reston VA USA

Evaluation on the Potential Improvement of Construction Sector Companies in Malaysia with Data Envelopment Analysis Model

Shun Jinn Lim, Weng Hoe Lam, and Weng Siew Lam

Abstract As the unconscious of the efficiency on the construction sector in Malaysia, the financial performance of listed construction sector companies in Bursa Malaysia for year 2018 will be determined using DEA model to find out the efficiency each of the company. The results showed that MERGE is the most efficiency companies if compare to other 46 companies because it appeared 35 times as a reference set for inefficient companies. Also, the value of target improvement also had been figured so that the inefficient companies can be improved depending on the input or output.

Keywords Construction sector · Data envelopment analysis · Efficiency · Target improvement

1 Introduction

Construction industry in Malaysia playing the main role as the key of economic expansion as it involves in multiple areas such as designing, logistic, financing, etc. as well as provide different areas of job opportunity. In budget 2020, construction sector was expected increase about 2% GDP growth if compare to year 2019 [1] as construction sector also is an important sector for contribution on GDP in Malaysia. Currently, there are 15 different sectors distributed in main market, i.e.: closed-end funds, construction, consumer products & services, energy, financial services, healthcare, industrial products & services, plantation, real estate investment trusts, SPAC,

S. J. Lim
Centre for Bio-Diversity Research, Department of Physical and Mathematical Science, Faculty of Science, Universiti Tunku Abdul Rahman, Kampar Campus, Jalan Universiti, Bandar Barat, 31900 Kampar, Perak, Malaysia
e-mail: lsjinn@utar.edu.my

W. H. Lam (✉) · W. S. Lam
Centre for Business and Management, Department of Physical and Mathematical Science, Faculty of Science, Universiti Tunku Abdul Rahman, Kampar Campus, Jalan Universiti, Bandar Barat, 31900 Kampar, Perak, Malaysia
e-mail: whlam@utar.edu.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_3

technology, telecommunication & media, transportation & logistics and utilities. As the unconscious of the efficiency on the construction sector in Malaysia, the financial performance of listed construction sector companies will be determined using DEA model to find out the efficiency each of the company. Then, the potential of improvement for construction sector companies listed in Bursa Malaysia for year 2018 will be analyzed.

2 Literature Review

Data Envelopment Analysis (DEA) originate by [2] to study the efficiency of the non-profit organization which involved combination various of inputs and outputs in multi-criteria decision making (MCDM) problem. MCDM includes determining the best alternative or solution by considering multiple criteria [3–7]. Application of DEA was widely applied in banking sector, financial sector, plantation companies, healthcare sector as well as production sector in Malaysia and other countries to determine the achievement through the efficiency score. 50 selected shares which listed in Bursa Malaysia using DEA model were studies by [8]. In their finding, three efficiency companies respectively in year 2011 were NATWIDE, YTL and MUDA, while for year 2012 were NATWIDE, MUDA and BERNAS proposed for investors as references. Meanwhile, Genting Berhad, Maxis, and YLI were suggested for investors as these three companies obtained 100% efficiency score using DEA model [9]. Besides, a study on 14 publicly listed companies in Malaysia from year 2004 to 2008 with only one company was shown efficiency performed by [10]. This indicated that the rest of 13 companies must reduce unnecessary expenses in order to achieve efficiency score at 1.31 plantation companies in Malaysia for year 2012 were examined using DEA model with financial ratio resulted in five companies were efficiency as they obtained efficiency score at 1 [11].

On the other hand, three Indian construction companies were analyzed from year 2011 to 2014 using financial ratio analysis to investigate their financial performance respectively [12]. In their study, they found that ratio analysis might be affected the reliability due to the inflation. DEA model was integrated to evaluate the efficiency of 27 listed construction companies in Taiwan and provide suggestion for the companies to improve their performance [13]. They concluded that companies should focus on inventory turnover rate and also the stockholder's equity. Meanwhile, the technical efficiency of ten building construction sector companies which listed in Indonesia Stock Exchange Market were measured from year 2013 to 2017 using Stochastic Frontier Analysis were positively resulted on the technical efficiency score [14]. Regardless of lacking studies on the efficiency of construction sector in Malaysia using DEA with financial ratios, hence this study first is to identify the efficiency companies and follow by potential improvement for each inefficiency company through the benchmark from efficient companies.

3 Methodology

Michael James Farrell who was an academic economist published a paper related to the measurement on efficiency of productivity for economic policy maker in an organization [15]. Later [2] applied the theory from Farrell and introduce CCR Data Envelopment Analysis (DEA) for nonprofit decision making unit (DMU) using mathematical programming concept to identify their performance via the efficiency score, that is the ratio between multiple of outputs and multiple of inputs, which cover the range from 0 to 100%, that provide the information of the DMU's efficiency. Throughout this, efficiency score obtains 100% which represent the best performing DMU but not vice versa.

Further extended the CCR DEA Model by [16] as following:

$$\text{Max } h_k = \frac{\sum_{r=1}^{s} u_r y_{rk} + a}{\sum_{i=1}^{m} v_i x_{ik}} \tag{1}$$

$$\text{Subject to } \frac{\sum_{r=1}^{s} u_r y_{rj} + \alpha}{\sum_{i=1}^{m} v_i x_{ij}} \le 1;\ \ j = 1, 2, 3, \ldots, n \tag{2}$$

$$u_r, v_i \ge \varepsilon;\ \ r = 1, \ldots, s; i = 1, \ldots, m. \tag{3}$$

where
h_k is relative efficiency of DMU_k, s is the number of outputs.
u_r is the weights to be determined for output, m is the number of inputs.
v_i is the weights to be determined for input, n is the number of entities.
ε is the positive, α is the free variable.

Equation (1) is an objective function which maximizes the efficiency of DMU_k, while the (2) represent inequality constraint is true for $0 \le h_k \le 1$ for each DMU. By referring to [2, 17], the general output maximization BCC DEA model in linear programming form can be simplified as:

$$h_k = \sum_{r=1}^{s} u_r y_{rk} + \alpha \tag{4}$$

$$\text{Subject to } \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} - \alpha \ge 0;$$
$$j = 1, 2, 3, \ldots, n \tag{5}$$

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \tag{6}$$

$$u_r, v_i \ge \varepsilon;\ \ r = 1, \cdots, s; i = 1, \cdots, m. \tag{7}$$

Total of 47 companies that listed in Bursa Malaysia under construction sector in year 2018 had been studied. The utilization of the three input variables: debt to assets ratio, dept to equity ratio and current ratio; while the three output variables: earning per share, return on equity and return assets were performed in financial ratio analysis in order to obtain the efficiency score. The computational work is performed using LINGO software which can solve linear programming model, non-linear programming model, mixed integer programming model and integer programming model [18, 19]. Also, Microsoft Excel had been used to gather the data that extracted from the financial report of each company. Throughout this information, the input variables and three output variables can be figured so that the efficiency score can obtained via LINGO software.

4 Empirical Results

The ranking and efficiency score of the companies are presented in Fig.1 based on the optimal solution of DEA model.

Referring to Fig. 1, the companies such as BREM, GKENT, HOHUP, KERJAYA, MERGE, MUHIBAH, PTARAS, PEB, WCHEHB and ZECON achieved efficiency score at 1 with the highest ranking represented efficient companies. The other 37 companies are categories as inefficient companies as they obtained efficiency score less than 100%. In order to transform those inefficient companies become efficient companies, the existing efficiency companies with optimal coefficient are namely as reference set which used to be the criterion measurement. For example, AZRB is an inefficient company and needed MERGE and ZECON as benchmarking.

Figure 2 presents the potential improvement values of the three inputs and three outputs for the inefficient companies based on the optimal solution of DEA model.

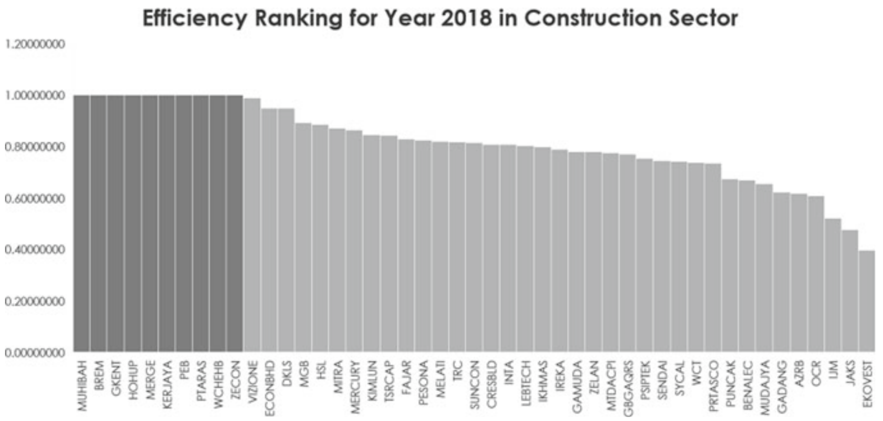


Fig. 1 Malaysia Construction sector Companies' data and efficiency score with ranking level

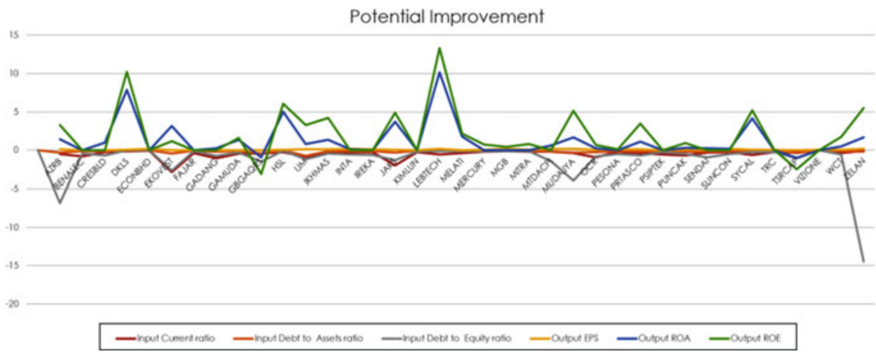


Fig. 2 Potential improvement values of the three inputs and three outputs for 37 inefficiency companies

AZRB company is advised to reduce their inputs, namely debt to assets ratio, dept to equity ratio and current ratio and increase their outputs, which are earning per share, return on equity and return assets so that it can be turn into efficiency company.

5 Conclusions

In overall, DEA is a mathematical programming concept for nonprofit decision making unit (DMU) to identify company's performance. The results showed that BREM, GKENT, HOHUP, KERJAYA, MERGE, MUHIBAH, PTARAS, PEB, WCHEHB and ZECON obtained efficiency score at 1 represented efficient companies among 47 companies. Meanwhile 72.73% of the construction companies are categorized as inefficiency companies. MERGE is the most efficiency companies if compare to other 46 companies because it appeared 35 times as a reference set for inefficient companies. Meanwhile, the value of target improvement also had been figured so that the inefficient companies can be improved based on Fig. 2. This study is significant as the potential of improvement for construction sector companies listed in Bursa Malaysia for year 2018 had been succeed computed.

Acknowledgements This study is supported by Universiti Tunku Abdul Rahman, Malaysia.

References

1. Yeo PE, Amarjeet S (2019) Take 5 for business: budget 2020 Malaysia. Ernest and Yong Malaysia
2. Charnes A, Cooper WW, Rhodes E (1978) Measuring the efficiency of decision making units. Eur J Oper Res 2(6):429–444

3. Liew KF, Lam WS, Lam WH (2016) Financial analysis on the company performance in Malaysia with multi-criteria decision making model. Syst Sci Appl Math 1(1):1–7
4. Lam WS, Liew KF, Lam WH (2017) Evaluation on the financial performance of the Malaysian banks with TOPSIS model. Am J Serv Sci Manage 4(2):11–16
5. Lam WS, Lam WH, Jaaman SH et al (2021) Performance evaluation of construction companies using integrated entropy–fuzzy VIKOR model. Entropy 23(3):320:1–16
6. Lam WH, Lam WS, Liew KF (2019) Performance analysis on telecommunication companies in Malaysia with TOPSIS model. Indonesian J Electr Eng Comput Sci 13(2):744–751
7. Lam WS, Liew KF, Lam WH (2019) Investigation on the performance of construction companies in Malaysia with Entropy-TOPSIS model. Earth Environ Sci 385(012006):1–7
8. Arsad R, Abdullah MN, Alias S (2014) A ranking efficiency unit by restrictions using DEA models. AIP Conf Proc 1635(1):266–273
9. Ong PL, Kamil AA (2010) Data envelopment analysis for stocks selection on Bursa Malaysia. Arch Appl Sci Res 2(5):11–35
10. Tahir IM, Naraini K, Ku C et al (2010) Company operation performance analysis using data envelopment analysis approach: a study on publiclisted companies in Malaysia. Int J Global Business 3(1):43–52
11. Abdul-Hamid AW, Dzuljastri AR (2015) Relative efficiency of plantation companies in Malaysia: a financial ratio based data envelopment analysis approach. Kuala Lumpur Int Business, Econ Law Conf 6(1):132–142
12. Gaurav RD, Abhay MJ (2015) Evaluation of Indian construction companies using financial tool. Int J Sci Technol Eng 1(11):210–216
13. Chiu CY, Wang MW (2011) An integrated DEA-based model to measuring financial performance of construction companies. WSEAS Trans Business Econ 8(1):1–15
14. Riko H, Pramudya PU (2020) Efficiency measurement of building construction sector companies listed on Indonesia stock exchange: stochastic frontier analysis approach. Asian J Manage Sci Educ 9(2):1–15
15. Farrell MJ (1957) The measurement of productive efficiency. J Roy Stat Soc. Ser A (General) 120(3):253–290
16. Banker ARD, Charnes A, Cooper WW (1984) Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manage Sci 30(9):1078–1092
17. Martić M, Novaković M, Baggia (2009) A data envelopment analysis: basic models and their utilization. Organizacija 42(2):37–43
18. Lam WS, Jaaman SH, Ismail H (2015) The impact of different economic scenarios towards portfolio selection in enhanced index tracking problem. Adv Sci Lett 21(5):1285–1288
19. Chen JW, Lam WS, Lam WH (2019) Optimization and comparison of bank financial management in Malaysia with goal programming model. J Adv Res Dyn Control Syst 11(12S):39–46

Analysis on Recognizability and Legibility of Urban Virtual Environment in Virtual Reality Through Cognitive Maps

Atta Idrawani Zaini, Raja Nur Syaheeza Raja Yazit, Nurakmal Abdullah Goh, Zayn Al-Abideen Gregory, and Mohamed Rashid Embi

Abstract Schematizing the most optimum level of details (LOD) in virtual environments (VEs) is a relevant endeavour as scale in virtual reality (VR) is not provisional but instead is locked at full scale. This paper compares recognizability and legibility of four 3D models of the same site in Melaka each with a different LOD. This informs whether different VEs' LOD can lead to different cognitive readings among respondents. Free-recall technique was used to evaluate cognitive knowledge of $N = 96$ respondents, with $N = 24$ respondents in each of the four VEs. Each respondent was asked to draw a map indicating visual cues from their minds. The cognitive maps in each treatment were then analysed using content analysis. The first coding scheme derived word frequencies to imply recognizability. The second scheme derived quality and relationships between elements to imply legibility. The contents were then compared among the different groups. We suggest that LOD may have some influence on cognitive understanding to varying degrees depending on the task and stage of navigation taken place.

Keywords Virtual environments · Cognitive mapping · Virtual reality · Urban legibility · Level of details

A. I. Zaini (✉) · R. N. S. R. Yazit · N. A. Goh · Z. A.-A. Gregory
Faculty of Built Environment, Universiti Malaysia Sarawak, Samarahan, Sarawak, Malaysia
e-mail: izatta@unimas.my

R. N. S. R. Yazit
e-mail: rmysyaheeza@unimas.my

N. A. Goh
e-mail: anurakmal@unimas.my

Z. A.-A. Gregory
e-mail: agzayn@unimas.my

M. R. Embi
Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, Skudai, Malaysia
e-mail: b-rashid@utm.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_4

1 Introduction

Though still in its infancy, virtual reality (VR) technology from any straight-off-the-shelf brands today can create a sufficiently immersive user experience leading to mass adoption and normalization of the technology. Although this consumer-facing VR technology was designed mostly for videogames, the benefit of it for real application cannot be ignored. This study attempts to focus on what can be considered as optimized level of details (LOD) for an operational urban VE for VR simulation, subsequent to the conventional model acquisition process often used by architects and urban designers. This presents the question of how detailed an urban VE in VR should for it to be considered recognizable and legible enough. This can be known through recording observers' cognitive reading of the VE. Such an enquiry needs to be done independent from the pursuit of realism. The finding will inform whether different treatments of LOD on VEs can lead to different cognitive readings among observers. The objectives of this study are:

1. To model a 3D VE of an urban area with different LOD;
2. To compare cognitive maps from observers experiencing the VE in VR;
3. To analyze the cognitive maps in relation to urban recognizability and legibility.

1.1 Literature Review

Cognitive mapping is a process of forming the spatial memories using the information gathered from successive viewpoints within an environment which are based on the process of encoding elements from the environment [13]. It is therefore closely linked to the legibility of an environment. As there is no actual concept to measure legibility itself [6], it can be determined through the degree of complexity of spatial layout and the recognizability of landmarks (which commonly are buildings). According to [15], landmarks are instrumental in communicating route information, becoming the anchor points for structuring overall environmental knowledge in cognitive maps. Although a landmark is prominent in a region, it will not be helpful if it is not visible or not located along the route of wayfinding. The contrast of landmarks to the contextual characteristics is likely more salient due its quality relative to the area towards the facade itself [5, 14]. The relativity between landmarks' juxtaposition and characteristics are organized along three dimensions: building form, building visibility and building symbolic significance or use [2]. Appleyard [1] as cited in [2] defines building form by the movements around buildings and clarity of the details.

Thus, an ideal 3D model of a VE for cognitive reading should be developed upon spatial layout and architectural details. This aligns with [8] who, apart from landmarks, also taxonomizes urban structure into other components of paths, nodes, edges and districts which to a varying degree are recognized by visual information derived from spatial layout and architectural details. Many studies conducted on VR agree that movements in VEs are analogous to that of the real environments

[9, 10]. Clear spatial layout is key for navigating in VE while architectural details can be used to assess recognizability of buildings. In the digital interface, there is no consistency in the interface to make the scale of representations accessible in computing [11]. In VR however, VEs are viewed in full-scale. Schematizing the most optimum LOD in VE is deemed relevant, as the idea of scale is no longer provisional in VR. Therefore, it is best to schematize architectural characteristics of buildings in leveraging the optimum LOD.

2 Methods

The VE is modelled after the city of Melaka's core zone. Melaka is on the intersection of cultural amalgamations spanning 500 years [7], that gave its unique characters and identity. The fine grain of the building blocks in the zone making the environment more heterogeneous, which according to [12], provides more information as compared to navigating in a homogeneous environment. Based on assessments on its accessibility, townscape quality and architectural characteristics of buildings, the selection of this site as a reference seems appropriate. Four 3D models with different LOD schematization were then created as illustrated in Fig. 1, varied based on polygon geometry, colour and texture.

The research employed a free-recall technique modified from [1] to evaluate cognitive knowledge of an environment by asking non-specialist respondents with no prior experience being in Melaka to draw a map recalled from their VR experience. An Oculus Rift Development Kit 2 VR system was stationed at various sites with $N = 24$ respondents experiencing VR navigation in each VE ($N = 96$ overall respondents).

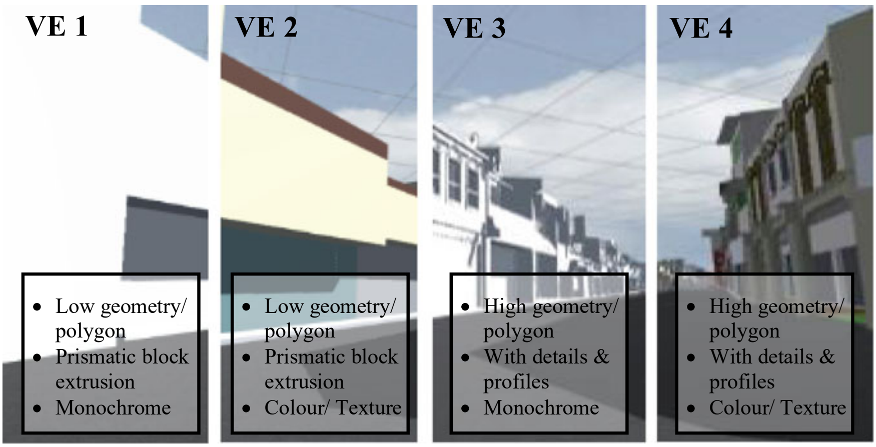


Fig. 1 The different LOD schematization of VEs

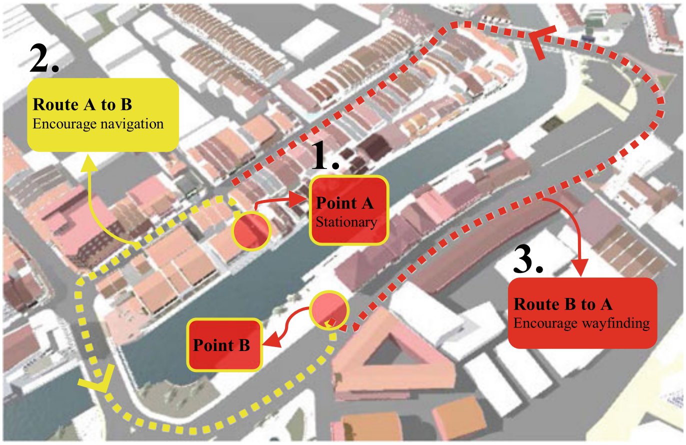


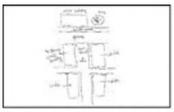
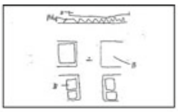
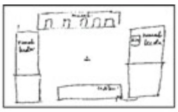
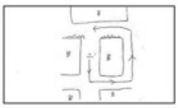
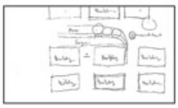
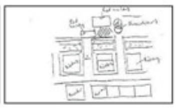
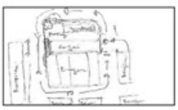
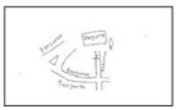
Fig. 2 Point/route and instructions given to the respondents

Respondents were asked to complete the navigation process using information gathered by themselves. The specific route taken and instructions given is presented in Fig. 2. A coding scheme was used to organize the large amounts of information from the cognitive maps into much fewer content categories, following the basic coding process derived from [4].

3 Discussion

The information presented in the maps as shown in Table 1 which later were coded for word count analysis. The coding discriminates mislabelled elements, elements with one count and landscape elements such as trees. Respondents were allowed to

Table 1 Map samples drawn by respondents

'Point A'				
'Route A to B'				
'Route B to A'				

assume the types of buildings. Similar words, such as shoplots and shophouses, were coded as the same element.

The architectural elements recalled inform recognizability, with more elements recalled meaning more visual cues recorded cognitively, as presented in Table 2. From the table, VEs with higher details tend to give clearer readings on building use, significance and form.

Architectural components are not significantly recalled, with respondents tend to regard 'buildings' as a blanket term to refer to the surrounding. This occurrence is also similar to the element of colour, where 'white' is recalled almost throughout all VEs. Unsurprisingly, other colours are recalled mostly in VEs where buildings are non-monochromatic (VE 2 and VE 4). This suggests that the element of non-monochromatic colour may shape recognizability of building form, independent from the geometrical character of buildings. However, building use and symbolic significance (i.e. 'church', 'station', etc.) tend to be highlighted in VEs with richer geometrical character (higher LOD). Building use and symbolic significance is evident in high LOD and may have shaped recognizability independent from the element of colours.

The second analysis is on the legibility quality of the VEs, measured through weighted values implying correctness which are drawn from element acknowledgment, position, orientation and so on. Inexplicit elements such as district, was measured by the correct acknowledgment of elements opposite of the river that suggest other territory. The radar chart in Fig. 3 summarizes the legibility quality in each point and route throughout all VEs, with high values suggesting high quality. These values only reflect correct and accepted elements.

Legibility readings in general are inconsistent throughout different tasks, but almost coherent between different VEs. 'Route A to B' is unique in that legibility qualities are noticeably higher in VE 1, where buildings were monochrome with lowest LOD. Landmarks, nodes and path are more noticeable during stationary viewing at 'Point A' throughout all VEs. The district elements received more attention along 'Route A to B' and back through 'Route B to A'. It should also be noted that edges along 'Route A to B' are less noticeable in VE 4 which has the highest LOD. Edges may have been saturated with the rich geometrical and colour saliency of the environment itself. This is then improved along 'Route B to A', where edges are much more relied upon in VE 4. We suggest that edges are less relied upon in guided navigation. The whole legibility of environments throughout all VEs along 'Route B to A' generally improved, may have been constructed through cognitive familiarization. A significant decrease in path elements throughout all VEs is noticeable along 'Route B to A', suggesting that unguided wayfinding task may rely less on paths explicitly but rather more on other legibility elements leading to the destination.

Table 2 Architectural elements recalled in cognitive maps

Words	Weighted percentage (%)											
	Point A				Route A to B				Route B to A			
	VE 1	VE 2	VE 3	VE 4	VE 1	VE 2	VE 3	VE 4	VE 1	VE 2	VE 3	VE 4
Building architectural characteristics												
Building	25.51	36.76	25.51	30.56	18.60	30.06	21.80	26.16	20.34	32.74	22.50	28.42
Shophouse	–	–	4.08	1.39	–	–	–	5.81	–	–	2.50	6.01
Station	–	–	–	1.39	–	–	–	1.16	–	–	–	1.09
Clocktower	–	–	–	–	–	–	4.51	1.74	–	–	–	–
Church	–	–	–	–	–	–	–	–	–	–	5.83	4.37
Factory	–	–	–	–	–	–	2.26	–	–	–	–	–
Building form												
Arches	–	–	2.04	1.39	–	–	2.26	–	–	–	1.67	–
Window	–	–	2.04	1.39	–	–	–	–	–	–	–	–
Door	–	–	–	3.47	–	–	–	–	2.54	–	–	–
Two-storey	2.04	–	–	–	–	–	2.26	–	–	–	–	–
High-rise	–	–	–	–	–	–	–	–	–	–	–	1.09
White	6.12	5.15	6.12	6.94	2.33	2.45	–	4.65	–	5.95	2.50	2.73
Red	–	15.44	–	13.89	–	16.56	–	12.21	–	–	–	–
Grey	–	2.94	–	–	–	1.23	–	–	–	1.19	–	1.09
Yellow	–	–	–	–	–	–	–	1.16	–	1.19	–	1.64
Orange	–	1.47	–	1.39	–	–	–	–	–	–	–	–
Blue	–	–	–	1.39	–	–	–	–	–	–	–	–
Green	–	–	–	–	–	1.23	–	1.16	–	–	–	–
Pink	–	–	–	–	–		–	–	–	1.19	–	–

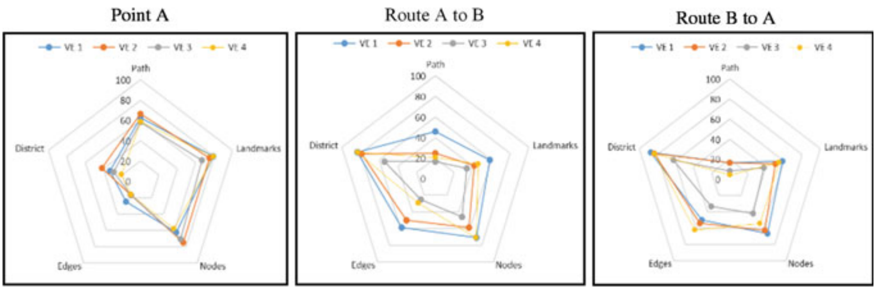


Fig. 3 Legibility in ‘Point A’, ‘Route A to B’ and ‘Route B to A’

4 Conclusions

Throughout all tasks, respondents tend to codify elements through simplification. There was no significant difference despite the incremental complexity of the three tasks within each VEs. However, once the characteristics are schematized, it can be deduced that VEs with higher geometrical characters may promote better recognizability of building use and symbolic significance, while VEs with non-monochromatic colours may be useful for improving recognizability of building form. Combination of both high and non-monochromatic colours may be ideal in creating better recognizability of an environment experienced in VR. In terms of legibility, VEs with high LOD and non-monochromatic colours can endure saturated urban legibility elements, while low LOD and monochromatic colours are by now sufficient for guided navigation. We suggest that when performing unguided wayfinding in VR, people tend to rely more on other legibility elements apart from the paths leading to their destination, regardless of LOD.

References

1. Appleyard D (1969) Why buildings are known: a predictive tool for architects and planners
2. Evans GW, Smith C, Pezdek K (1982) Cognitive maps and urban form. J Am Plann Assoc 48(2):232–244
3. Hill RW Jr, Han C, Van Lent M (2002) Applying perceptually driven cognitive mapping to virtual urban environments. AI Magazine 23(4):69
4. Hsieh H-F, Shannon SE (2005) Three approaches to qualitative content analysis. Qual Health Res 15(9):1277–1288
5. Kao CJ (2014) Landmarks selection in street map design. IOP Conf Ser Earth Environ Sci 18(1):6–11
6. Koseoglu E, Onder DE (2011) Subjective and objective dimensions of spatial legibility. Procedia—Soc Behav Sci 30:1191–1195
7. Lawless JW (2015) Melaka as a cultural landscape. J Space Commun 1(1):37–45
8. Lynch K (1960) The image of the city. The M.I.T Press, pp 1–103
9. Natapov A, Fisher-Gewirtzman D (2016) Visibility of urban activities and pedestrian routes: an experiment in a virtual environment. Comput Environ Urban Syst 58:60–70

10. Orellana N, Al Sayed K (2013) On Spatial Wayfinding: agent and human navigation patterns in virtual and real worlds. In: Ninth international space syntax symposium (p 77)
11. Seichter H (2004) Augmented reality urban design, pp 1–10
12. Shushan Y, Portugali J, Blumenfeld-lieberthal E (2016) Using virtual reality environments to unveil the imageability of the city in homogenous and heterogeneous environments. Comput Environ Urban Syst 58:29–38
13. Vinson NG (2003) Design guidelines for landmarks to support navigation in virtual environments, p 9
14. Winter S, Raubal M, Nothegger C (2004) Focalizing measures of salience for wayfinding, pp 129–139
15. Xi D, Fan Q, Yao XA, Jiang W, Duan D (2016) A visual salience model for way fi nding in 3D virtual urban environments. Appl Geogr 75:176–187

Minimalism and Essentialism in Manila: Architecture and Urban Wellbeing in the Post GFC and New Normal

Cecilia May S. Villanueva, Thomas E. Mical, and Juanito M. Malaga

Abstract Minimalism and essentialism in Manila looks at examples of Thomasian Architects on design and urban architecture (through built projects and photography). This study catalogues approaches to austerity, financial considerations such as frugal innovation, adaptive reuse, and new forms of minimalism in the material and spaces of contemporary Manila (since the 2008 Global Financial Crisis). Findings show that prioritizing natural wind flow in interior and urban spaces are a common attribute that in the selected works discussed of Thomasian Architects post GFC, which is an essential consideration in addressing pandemics in the built environment.

Keywords Minimalism · Essentialism · Urban architecture

1 Introduction

Urban wellbeing is a common ingredient of minimalism and essentialism. Urban wellbeing is the combination of social, economic, environmental, cultural, and political conditions identified by individuals and their communities as essential for them to flourish and fulfill their potential [1]. Wellbeing has strong linkages with ecosystems services and the materiality of architecture and urban spaces as established by the Millennium Ecosystem Assessment (2005). Provisioning services are directly linked with wellbeing needs for shelter and other activities that are necessary for man to achieve values of doing and being.

The global financial crisis and the covid-19 pandemic events are a decade apart, the call for conservation that can be traced to the modern movement in architecture where Mies Van Der Rohe's aphorism of "less is more" is anchored on. In 2019, UK Architects have declared that the twin crises of climate breakdown and biodiversity loss are the most serious issue of our time. Infrastructure and construction industry contribute to almost 40% of energy-related carbon dioxide (CO_2) emissions that significantly impact on our natural surroundings [2]. This calls for designers

C. M. S. Villanueva (✉) · T. E. Mical · J. M. Malaga
College of Architecture and the Research Center for Culture, Arts and Humanities, University of Santo Tomas, Manila, Philippines
e-mail: csvillanueva@ust.edu.ph

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_5

to be more innovative and conscious of material selections, spatial disruptions and biodiversity implications. Tall buildings in city centers are now half empty with those who can return to the regions have gone back to their hometowns.

However not all activities are able to adapt to telecommuting and still require human physical presence in the public realm. These events underscore the need for "*pagiging malikhain*" (innovative) in the design of architecture interiors and urban space.

Schools and public spaces today are serving as temporary shelters to front liners, stranded transients and less fortunate people. They have adapted to the absences of pupils and the need for isolation and resting spaces. The endless call for a paradigm shift has finally stood still and inevitably calls everyone to reassess their essentials and basic necessities in the symbiosis of our web of life.

Infrastructure optimization is the key to wellbeing in urban spaces. Residences now demand flexibility and adaptability to answer the calls for social distancing, work, study and exercise at home. Space saving, measures have been pushed further for activities that were once accommodated in public spaces.

2 Methodology

The study catalogues approaches to austerity, financial considerations such as frugal innovation, adaptive reuse, and new forms of minimalism in the material and spaces of contemporary Manila (since the 2008 Global Financial Crisis). The catalogue looks into works of graduates of the University of Santo Tomas, the oldest university in South East Asia with core values of competence, commitment and compassion (Fig. 1).

3 Thomasian Architecture

Thomasian Architecture refers to those licensed and registered architects who obtained their bachelor's degree from the University of Santo Tomas, the oldest university in South-East Asia. Most outstanding are Philippine National Artists for Architecture from Leandro Locsin's floating volumes and Francisco Mañosa's innovations in materiality. Locsin Architecture have been strongly characterized as poetry in space, with metaphors referring to the lightness of the Philippine bahay kubo with an expansive roof structure supported by flimsy stilts. Mañosa features a palace made mostly from the coconut tree products showcasing the textural sophistication of the native genre.

Locsin and Mañosa's descendants are still very visible in the 21st century domain that is strongly characterized by social architecture and minimalism, bridging the gap that architecture serves the underserved and equalizing the community and interior spaces.

Fig. 1 Conceptual Framework on Minimalism and Essentialism in Manila -Architecture and Urban Wellbeing (*Source* Authors, 2020)

4 Catalogue of Minimalist Architecture in the Post GFC

William Ty and Associates rendition of the first "The Book Stop Project" is an open and modern structure that sits in front of the Manila Cathedral, inviting passersby to take respite in the articulated metal shelves. There have been recorded expansive impacts on the number of book readers that have visited the book stop project. This miniscule facility has nomadic roots that have been travelling around the cities of Manila such as Quezon City, Taguig and others Architecture and Urban Wellbeing locations. The project won the Excellent Communications Design (Architecture) at the German Design Award 2018 [3].

The outdoor museum similar has engaged numerous viewers in art appreciation. The setting allows diverse visitors in a casual setting to learn more on featured visual curations that are usually enclosed in highly secured museums. These outdoor facilities are relevant in these times of pandemic insecurity and social distancing. It allows earthly delights in the recent normal for a better new normal. The project is a WAF Finalist for Display Category, and an Architizer A+ Awards finalist for Popular Choice Awards under the Museum category WTA thru [3] (Figs. 2, 3).

In the new chapel of Buensalido+Architects has succeeded in translating belief into material form [4]. This open plan design like paper cuttings are formed in

Fig. 2 Urban space and "The Book Stop Project" by WTA architecture and design studio (*Source* Bluprint 2018)

Fig. 3 Urban space and the El Museo del Prado by WTA architecture and design studio (*Source* Bluprint 2018)

Fig. 4 Interiors of the Amara Chapel of Buensalido + Architects (*Source* Simon, 2017)

an asymmetrical and irregular sequence that allows natural wind and light in the semi-sheltered space. The fan formation is founded on the culture of lattice cuttings that allow semi-transparency and oneness in interior and exterior space. Being grounded on pavement level allows minimal intimidation for physically vulnerable users (Figs. 4, 5).

Locsin Partners + Furunes + Boase, together with the Streetlight stakeholders collaborated on the design process through a number of workshops that employed drawing, poetry, model making, mapping, and physical prototyping. This method is vital in forming a strong sense of ownership of the project and empowering the organization to find their own voice. It taps the Filipino culture of 'bayanihan' or communal cooperation, rooted in the practice of helping neighbors carry and relocate their thatched houses. This post-Haiyan community facility was ideated and designed with local residents in an equitably transformative process (LVLP and Furunes, 2017).

The November 2013 super-typhoon Haiyan has stricken the city of Tacloban, Leyte with one of the most devastating typhoons to have visited the Philippines. Streetlight is among the local community stakeholders, that takes in orphans and less privileged children. The new Streetlight orphanage provides staff residences and an outdoor recreation grounds. The facility consists of two major groupings for the offices, clinic, and function hall and study center. The park provides a much needed space for the relocated families to mix with the existing Tagpuro community (LVLP and Furunes, 2017).

These above projects showcase the Thomasian core values of commitment in exemplifying inclusive architecture that benefits all members of society. Architecture is not only enjoyed in the abstract forms from urban spaces, but are also scaled at a

Fig. 5 Urban space and the Amara Chapel of Buensalido + Architects (*Source* Simon, 2017)

human level allowing communities to take part in all phases from conceptualization, design and construction (Figs. 6, 7).

House No. 10 by Edwin Uy is an architectural and interior design project created for a family of four: a couple and two young boys (FuturArc, 2016). The family was mentioned to be on a strict budget and was willing to experiment with unconventional

Fig. 6 Doors of the streetlight Tagpuro Study Center (*Source* LVLP and Furunes 2017)

Fig. 7 Interiors of the streetlight Tagpuro (*Source* LVLP and Furunes 2017)

building materials. The use of motor oil containers seemed something quite unusual but opens the possibilities of upcycling and frugal innovation. This gives new life to products which might seem no longer useful or might be reused in other ways other than wall paneling.

Edwin Uy's design ethic shows Thomasian core values of commitment to explore frugal innovations in extending the lifecycle of materials as possible building elements to lessen extractive activities of natural resources for wall paneling and building envelope (Figs. 8, 9).

5 Catalogue of Essential Architecture in the New Normal

The covid19 pandemic is still at present time is still disrupting normal day to day activities as most communities remain in quarantine, to prevent the widespread of the virus. The shortage of health care facilities had Thomasian architects innovating on the most doable interventions with limited resources (Figs. 10, 11).

The emergency quarantine facility by William Ty had expanded the bed capacity of primary medical facilities, with the need to isolate patients affected by the covid19 virus. This is representative of compassionate architecture the third of the core values of the University. With overwhelming number of covid19 positive patients, several government buildings have also been converted for in-patient care. Dan Lichauco oversaw the adaptive reuse of Philippine International Convention Center, the Rizal Memorial Sports Complex, and the World Trade Center.

Fig. 8 Upcycling Motor oil containers (*Source* Kathryn Jill Ablaza, July 2013)

6 Findings and Conclusion

Thomasian architects have collaborated with community partners in creating built environments in society today. William Ti, Jason Buensalido, L V Locsin and Partners are among Manila's prestigious firms with commitment to social design in uplifting the lives of Filipinos from all walks of life. The most distinct in the feature of the above catalogued examples is the utilization of natural wind flow to sanitize interior and urban spaces. This is a major consideration in designing for pandemics which target the respiratory functions of users.

Dan Lichauco's conversion/adaptive re-use of the Philippine World Trade Center, Philippine International Convention Center, Rizal Memorial Sports Complex among manifestations of true Thomasian core values of compassion. While Edwin Uy's House No. 10 features competence in pursuing frugal innovations in upcycling materials for architectural purposes. These are strategies are vital in achieving a cyclical transformation of urban space in community wellbeing [5].

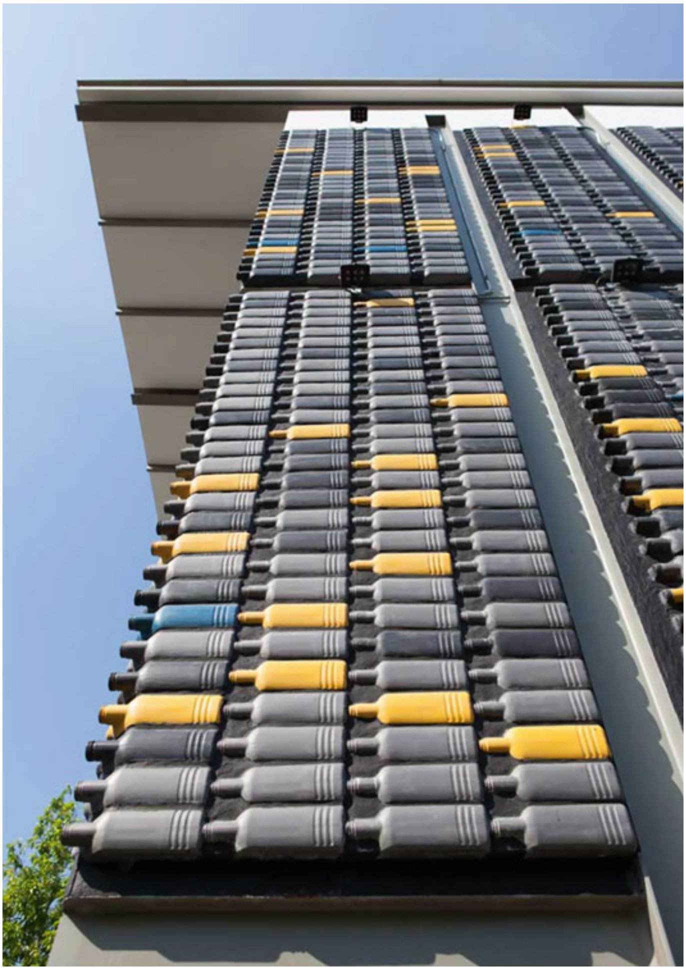


Fig. 9 Upcycling Motor oil containers ([3] *Source*)

Fig. 10 The emergency quarantine facility (EQF) (*Source* WTA Architecture and Design Studio, 2020)

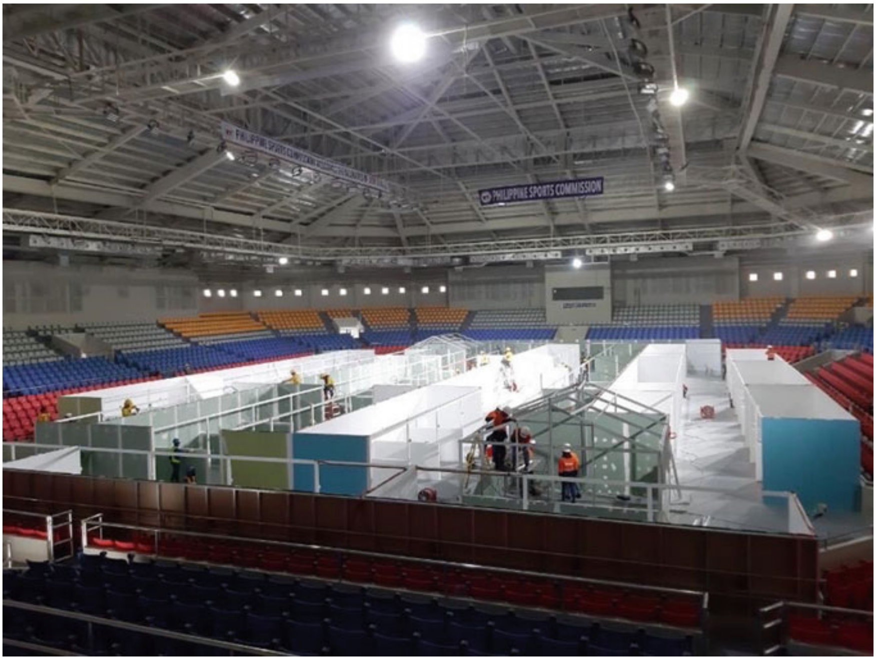


Fig. 11 Quarantine facility at Rizal Memorial (*Source* DPWH Esquire, 2020)

References

1. Wiseman and Brasher (2008) Community wellbeing in an unwell world: trends, challenges, and possibilities. J Public Health Policy 2008(29):353–366. https://doi.org/10.1057/jphp.2008.16
2. Architects Declare (2019) UK architects declare climate and biodiversity emergency. Retrieved from https://www.architectsdeclare.com/. Accessed on 22 June 2021
3. Bluprint (2018) These 3 internationally recognized projects embody social architecture. Retrieved from https://bluprint.onemega.com/wta-social-architecture-projects/. Accessed on 15 Dec 2019
4. Llona M (2017) God, man, nature: Amara Chapel by Buensalido+Architects. Retrieved from https://bluprint.onemega.com/amara-chapel-buensalidoarchitects/. Accessed on 15 Dec 2019
5. Villanueva C (2019) Transformations of urban space in community and pedestrian wellbeing. In: IOP conference series: materials science and engineering, vol 636, 3rd international conference on architecture and civil engineering (ICACE 2019) 26–27 June 2019, Kuala Lumpur, Malaysia IOP Conf. Ser.: Mater. Sci. Eng. 636 012002
6. Locsin, LV + Partners, Furunes E (2017) 'Bayanihan' in designing streetlight Tagpuro orphanage. Retrieved from https://bluprint.onemega.com/streetlight-tagpuro-waf/. Accessed on 15 Dec 2019

Influence of Waste Oils on the Extracted Aged Binder Properties and Dosage Optimisation

Md Zahid Hossain Khan, Ali Mohammed Babalghaith, Suhana Koting, Mohd Rasdan Ibrahim, Herda Yati Binti Katman, and Obada Asqool

Abstract Asphalt binder loses its properties due to oxidation and becomes stiffer over time. Restoring the properties of the aged asphalt binder is a major challenge to recycle asphalt pavement. Waste engine oil (WEO) and waste cooking oil (WCO) were used in this study as rejuvenators to restore the extracted aged binder properties. The physical and rheological properties of the rejuvenated aged binder were analysed, and optimum dosages were determined. Binder test results showed that the WEO and WCO effectively rejuvenated the extracted aged binder. The optimum dosages of WEO and WCO that returned the aged binder with penetration 11 dmm to its reference penetration value (58 dmm) were 18% and 12%, respectively. The rheological properties in terms of rutting resistance of the aged binder could also be regained to a normal level with different contents of WEO or WCO.

Keywords Waste oils · Aged binder · Rejuvenator · Rheological

1 Introduction

The most challenging aspect of recycling the reclaimed asphalt pavement (RAP) is its' aged binder ingredient because the aged binder could reduce workability and compatibility of mixes [1, 2]. The maltenes-to-asphaltenes ratio in aged binder could increase due to the use of RAP in the asphalt mix. In addition, the utilisation of RAP could increase the stiffness and viscosity and decrease the penetration of the blended binder [3, 4]. Therefore, asphalt mix with RAP could reduce the fatigue resistance [5–7] and the workability of the mix [8, 9].

Rejuvenator could serve as a principal catalyst to restore the aged binder's properties [10–15]. It increases the aged binder penetration grade, decreases the softening

M. Z. H. Khan · A. M. Babalghaith · S. Koting (✉) · M. R. Ibrahim · O. Asqool
Centre for Transportation Research, Department of Civil Engineering, Faculty of Engineering, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
e-mail: suhana_koting@um.edu.my

H. Y. B. Katman
Department of Civil Engineering, Universiti Tenaga Nasional (UNITEN), Putrajaya campus, Jalan Ikram-Uniten, 43000 Kajang, Selangor, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_6

point, and consequently decreases the viscosity. However, a part of the aged binder stays inherent to the RAP aggregate and acts like a black rock [16–19]. The selecting proper type and dosage of rejuvenator is a critical issue [20–23] because excessive levels of a rejuvenator are not suitable for stripping, adhesion, rutting, heat cracking, and inadequate dosages can stiff the mix [24–26].

Waste oils, namely, waste engine oil (WEO), waste cooking oil (WCO), waste engine oil bottom, and waste vegetable grease are the rejuvenators that have been investigated in several studies. It was found that the inclusion of waste oils would significantly restore the physical and chemical properties of the aged asphalt binder. The rheological tests showed that waste oils would significantly soften the binder and lower the $G^*/\sin\delta$ [15, 27], and softening point temperature, and increased penetration [28]. Moreover, as waste oils withstand high temperatures (above 200 °C) in production processes compared to fresh bio-oil, their volatile amount is much lower. As a result, they are inherently highly qualified to be used in the hot mixing operation [9]. Yan et al. [29] investigated the physical and chemical properties of the WEO and WCO-rejuvenated aged binder. The study results indicated that the waste oils could recover the aged binder properties (penetration, ductility, softening point, and viscosity) to their virgin level when the optimum content of waste oils was used because waste oils could reduce the sulfoxide and carboxyl groups in the aged binder. Besides, the waste oils are the most harmful to the ecosystem among all rejuvenators, as they are usually disposed of in rivers and landfills [30, 31]. It is well recognised that a huge amount of waste oils is generated every year and they have caused significant environmental problems due to improper disposal. Thus, they are more effective to use as recyclables in high RAP mixes considering the environmental implications.

WEO acts as a vital tool for softening the aged binder [32]. It can change the rheological and physical properties of the aged binder [33]. Fernandes et al. [34] studied crumb rubber, and WEO modified binder with penetration, softening point, and viscosity tests. It was revealed that the laboratory-modified binder had the same penetration values as the commercially modified binder but had higher softening points. Romera et al. [32] showed that adding 18% WEO to an aged binder could modify the aged binder to resemble a new binder of 60/70 grade. Dokandari et al. [35] found that higher RAP content could be used in recyclable asphalt mixes using WEO. Moreover, Silva et al. [14] used WEO to restore the properties of the aged binder of 14 mm penetration and 68 °C softening point. They reported that by adding 5% WEO to the aged binder, the penetration grade could be reduced to 20/30 and the softening point to 63 °C. The authors concluded that the performance of the asphalt mix incorporating RAP was better than the conventional HMA mix due to the usage of WEO [14, 36].

WCO mainly comes from food frying oil from food industries, families, restaurants, and hotels [37]. Several researchers used WCO to restore the properties of the aged binder [20, 38–43]. It has been shown that WCO is a feasible rejuvenating agent. It can work to restore the volatiles and diffuse oil of the aged binder and re-establish its rheological properties [30, 44]. Yu et al. [45] illustrated that the WCO-rejuvenated aged binder could restore the rheological properties of the aged binder while also reproducing the surface microstructures. According to M. Zargar et al. [43], the properties of a 40/50 grade aged binder could be restored to the properties of the initial 80/100 binder in the case of 3–4 percent of WCO.

Most studies investigated how waste oils affected the properties of the laboratory-made aged binder, whereas this study used RAP-extracted aged binder at how the waste oils change the properties of the aged binder. In the first step, the characteristic of the modified binder, extracted aged binder, and rejuvenated aged binder were examined. The second stage concentrated to determine the optimum dosage of the waste oils to meet the desired penetration value.

2 Materials and Method

2.1 Materials

This study used the modified binder as a reference binder. The reference binder was prepared with asphalt binder 60/70 penetration grade and 6% crumb rubber modifier (CRM) (by % of binder mass) of 80 mesh size. It was prepared using a propeller mixer at a speed of 200 rpm for two hours at the temperature of 160 °C [36, 46]. The modification aimed to enhance the rheological properties of the virgin binder [9]. Moreover, crumb rubber is more resistant to low temperature cracking compared to other modifiers [47]. Table 1 shows the physical and rheological properties of the reference binder and extracted aged binder.

RAP used in this study was collected from Kuala Lumpur, Malaysia. Two different rejuvenators, namely, WEO and WCO were used in the study (Fig. 1). Table 2 shows some common elements and generic identities that describe waste oils in a nutshell.

Table 1 Binders' properties

Properties	Unit	Temp. (°C)	Standard	Reference binder	Extracted aged binder
Penetration (100 g, 5 s.)	dmm	25	ASTM D5	58	11.0
Softening point	˚C	–	ASTM D36	53	71
Dynamic viscosity (20 rpm)	cP	135	ASTM D4402	644	3513
		165		200	632
G*/sin δ (10 rad/s)	kPa	58	AASHTO D7175	3.8	95.9
		64		1.8	42.0
		70		0.9	22.1

Note Penetration was measured in decimillimetre (dmm) or in units of 0.1 mm; G* = complex modulus; δ = phase angle; cP = centipoise

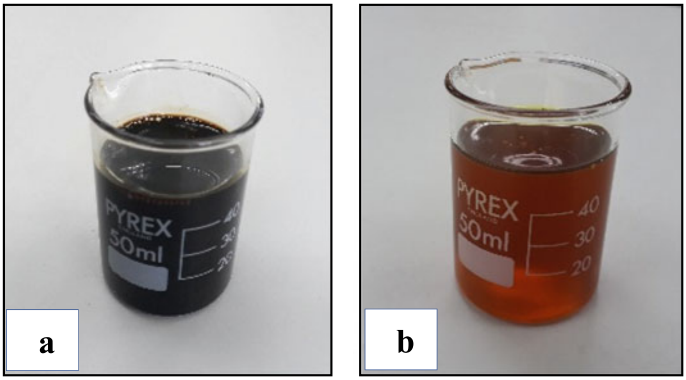


Fig. 1 Rejuvenators: **a)** WEO, **b)** WCO

Table 2 Basic characteristics and generic descriptors of waste oils

Rejuvenators	Specific gravity	Water content (%)	Engineered or generic	Petroleum or organic	Refined or waste
WEO	0.87	0.34	Generic	Petroleum	Waste
WCO	0.91	0.21	Generic	Organic	Waste

2.2 Methods

The flowchart for the experimental process used in this study is shown in Fig. 2. Consecutively, the aged binder was extracted and recovered from the RAP following the ASTM D 2172 [48] and ASTM D 1856 [49] method. It was found that RAP aggregates contained 4.1% aged binder (by % of RAP aggregate mass). The extracted aged binder was then rejuvenated with 10 and 18% of both WEO and WCO (by % of aged binder mass). During the rejuvenation process, the extracted aged binder was

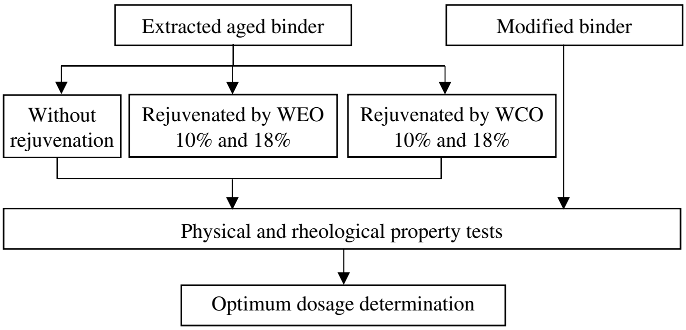


Fig. 2 Experimental flowchart

first heated at 160 °C temperature for one hour. Then rejuvenators were mixed using a propeller mixer at 800 rpm for 30 min. Finally, the rejuvenated binder samples were kept in the laboratory for further testing.

2.2.1 Binders Property Tests

A penetration test was conducted following the ASTM D5 [50] to determine the consistency of the rejuvenated aged binders and the optimum rejuvenator dosage. Softening point test was carried out following ASTM D36 [51] to determine the softening point temperature of the asphalt binder. It's used to classify the behaviour of binders at increasing temperatures. A viscosity test was conducted following ASTM D4402 [52] to determine the binder's flow resistance and internal friction. This value is an indication of workability. It was also used to determine mixing and compaction temperatures during sample preparation. A dynamic shear rheometer (DSR) was conducted to characterise the aged binder's rheological property following ASTM D7175 [53]. This test was performed to determine the rutting resistance factor of the rejuvenated aged binder at medium to high temperatures and compared with the unrejuvenated reference binder using $G^*/\sin\delta$ value.

2.2.2 Rejuvenator Dosage Determination

Optimum dosages of WEO and WCO were determined to meet the target penetration value of the reference binder (58 dmm) at 25 °C because the best approach for selecting optimum rejuvenator dosage is to determine the rejuvenated binder penetration value [14, 54–56]. Another important element of this test is that the outcomes can be forecasted with a simple exponential equation using only two data points [54].

3 Results and Discussion

3.1 Physical Properties Tests of Binders

3.1.1 Penetration

Figure 3 shows the effect of waste oils on the penetration at 25 °C of the rejuvenated and unrejuvenated aged binders. The penetration of the extracted aged binder (before rejuvenation) was 11 dmm which was significantly lower than that of the reference binder (58 dmm). It shows that the values of the penetration increased exponentially by adding both WEO and WCO. It implies that the rejuvenators can soften aged binder by reducing its consistency.

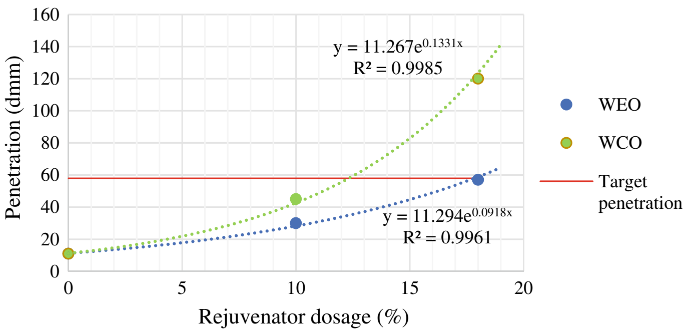


Fig. 3 Influence of waste oils on penetration at 25 °C

Furthermore, the effect of WCO on penetration was greater than WEO. The increase in penetration values indicated a change in the consistency of the aged binder. It was observed that 18% of WEO returned the extracted aged binder from 11 to 58 dmm penetration which was 12% in the case of WCO. Therefore, the waste oils softened the binder.

3.1.2 Softening Point

Figure 4 shows the softening point changes due to the use of WEO and WCO on the extracted aged binder. It shows that softening point of rejuvenated aged binder decreased as the amount of waste oils increased. WCO-rejuvenated aged binder had lower softening points than the WEO-rejuvenated aged binder. Softening points of 64 °C and 54 °C, respectively, were obtained using 18% of the WEO and 12% of the WCO, which recovered the aged binder to 58 dmm penetration. These new softening points were lower than the extracted aged binder (71 °C). This reduction in softening point was due to the waste oils' effect, which causes the aged binder

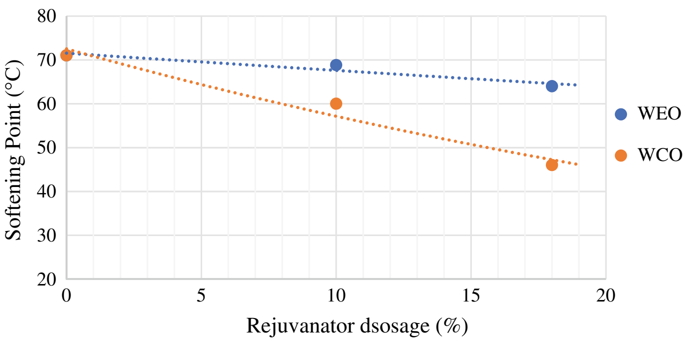


Fig. 4 Influence of waste oils on softening point

to be more temperature susceptibility than the aged binder without rejuvenation. Waste oils reduced the softening point because they softened the aged binder in a similar way to the penetration tests. The maximum reduction in the softening point of the aged binder was observed while WCO was used. It was also observed that the penetration values and softening points decreased in a similar pattern for both waste oils.

3.1.3 Viscosity

Figure 5 presents the value of dynamic viscosity, at 135 °C, for extracted aged binder and rejuvenated aged binder. The extracted aged binder had viscosity value 3513 centipoises (cP) at 135 °C. All the viscosity values decreased with the increment of WEO and WCO. This was due to the effect of both waste oils on the aged binder.

From the figure, it can be seen that at 18% of WEO and 12% of WCO (optimum dosage), the viscosity was about 738 cP and 1000 cP, respectively. These new viscosity values were higher than the reference binder's viscosity (644 cP) at 135 °C. It indicates that the workability that will be achieved when using these two rejuvenators will be lower than the original mix. Therefore, the mixing and compaction temperature will also be required higher. While more WEO or WCO could increase the frictional resistance of aged binder, too much oil would affect the binder's other properties. The asphalt mix would be segregated if the viscosity of the aged binder is too low, which would harm the mix's performance. The asphalt roads would be vulnerable to fatigue failure if the viscosity of the aged binder becomes too poor. Therefore, the rejuvenator dosage should be within a sufficient range to fulfil the adhesion efficiency of the aged binder. Moreover, in the case of SUPERPAVE™ specification, the maximum viscosity of the asphalt binder for storage and pumping during construction must be less than 3000 cP. Therefore, the optimum dosages were precisely determined and considered acceptable.

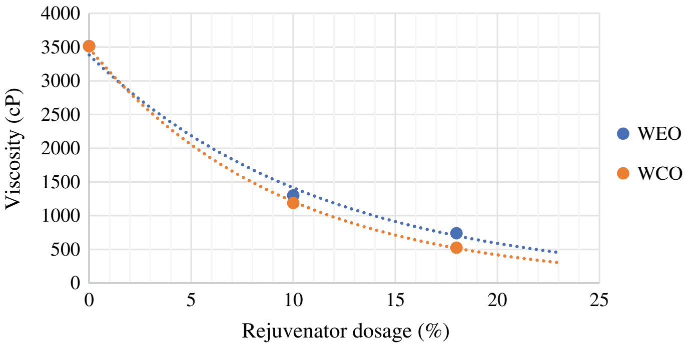


Fig. 5 The viscosity of the rejuvenated aged binders at 135 °C

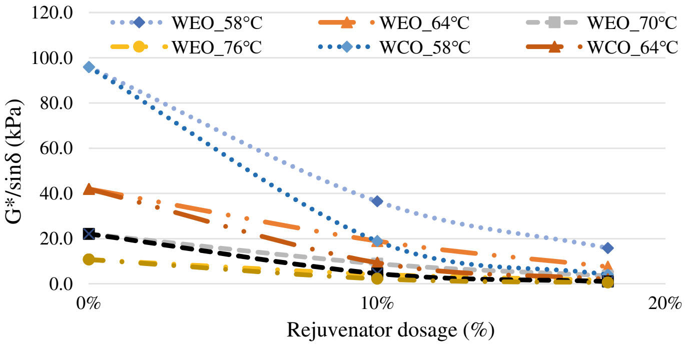


Fig. 6 Influence of waste oils on G*/sinδ

3.2 Rheological Property Test

3.2.1 G*/sinδ (Rutting Resistance Factor)

Based on the asphalt binder properties, the dynamic shear rheometer test can indicate the major stresses observed in asphalt paving through the rheological parameters, which are complex modulus (G*) and phase angle (δ). The factor G*/sinδ was used to control the permanent deformation or rutting resistance. Figure 6 displays the effect of rejuvenator dosages on G*/sinδ. It shows that G*/sinδ decreased rapidly until it reached a dosage of 10%, then slowly decreased to a dosage of 18%. As a result, an increase content of waste oils did not result in a higher G*/sinδ. Furthermore, at the same temperature and dosage, the value of G*/sinδ of the WCO-rejuvenated aged binder was less than the WEO-rejuvenated aged binder. Therefore, these results indicate that the increased level of rejuvenator could have a poor rutting resistance, which is consistent with the softening point and viscosity results.

Meanwhile, both the WEO and the WCO could recover the performance of the aged binder, but the WCO could do so with less content. The results support prior findings that WCO had a greater rejuvenation effect than WEO. Although the WEO and WCO were far more important for restoring the aged binder's property, a rational choice should be made based on the asphalt performance requirements and maximum temperature in the construction site.

4 Conclusions

The following conclusions are obtained from this study:

1. The use of waste oils as a rejuvenator increased the extracted aged binder's penetration values while lowering viscosity and softening points.

2. The optimum dosages of WEO and WCO that returned the aged binder with penetration 11 dmm to its reference penetration value (58 dmm) were 18% and 12%, respectively.
3. As a rejuvenating agent, a less amount of organic rejuvenator (WCO) was required to restore the properties of the extracted aged binder than the petroleum rejuvenator (WEO).
4. The DSR outcome indicated that the rutting resistance factor of the aged binder decreased with increased content of WEO and WCO. The rheological properties of the aged binder could also be regained to a normal level with different contents of WEO or WCO.

Acknowledgements The authors would like to acknowledge The Association of Commonwealth Universities (ACU) for providing Early Career Conference Grant (ECCG2021-Application number #32f0f04) to present this paper. The authors would like to acknowledge Universiti Malaya for providing the laboratory facilities to carry out the experimental works. Finally, the first author gratefully acknowledges the Local Government Engineering Department, Bangladesh, for the financial support.

References

1. Artamendi I, Phillips P, Allen B (2009) Workability of bituminous mixtures incorporating reclaimed asphalt. In: Sixth international conference on Maintenance and Rehabilitation of Pavements and Technological Control (MAIREPAV6). Transportation Research Board
2. Mogawer W et al (2012) Performance characteristics of plant produced high RAP mixtures. Road Mater Pavement Des 13(sup1):183–208
3. You L et al (2019) Investigation of adhesion and interface bond strength for pavements underlying chip-seal: effect of asphalt-aggregate combinations and freeze-thaw cycles on chip-seal. Constr Build Mater 203:322–330
4. Zaumanis M, Mallick RB, Frank R (2013) Use of rejuvenators for production of sustainable high content RAP hot mix asphalt. in The XXVIII Int Baltic Road Conf
5. Al-Qadi I et al (2012) Impact of high RAP contents on structural and performance properties of asphalt mixtures, in Report Number FHWA-ICT-12-002. 2012, FHWA-ICT
6. McDaniel R et al (2000) Recommended use of reclaimed asphalt pavement in the SuperPave mixture design method, in NCHRP Final Report 2000, TRB, Washington, DC
7. Han S et al (2019) Laboratory performance of hot mix asphalt with high Reclaimed Asphalt Pavement (RAP) and Fine Reclaimed Asphalt Pavement (FRAP) content. Materials 12(16):2536
8. Hidalgo AE et al (2020) The influence of reclaimed asphalt pavement on the mechanical performance of bituminous mixtures. An analysis at the mortar scale. Sustainability 12(20):8343
9. Majidifard H, Tabatabaee N, Buttlar W (2019) Investigating short-term and long-term binder performance of high-RAP mixtures containing waste cooking oil. J Traffic Transp Eng 6(4):396–406
10. Elkashef M et al (2017) Preliminary examination of soybean oil derived material as a potential rejuvenator through Superpave criteria and asphalt bitumen rheology. Constr Build Mater 149:826–836

11. Taherkhani H, F Noorian (2018) Comparing the effects of waste engine and cooking oil on the properties of asphalt concrete containing reclaimed asphalt pavement (RAP). Road Mater Pavement Des 2018:1–20
12. West RC, Copeland A (2015) High RAP asphalt pavements: Japan practice-lesson learned. In: National Asphalt Pavement Association (NAPA), Federal Highway Administration: NAPA Building, 5100 Forbes Blvd, Lanham, MD 20706-4407, pp 1–62
13. Shen J, Amirkhanian SN, Lee S-J (2007) HP-GPC characterization of rejuvenated aged CRM binders. J Mater Civ Eng 19(6):515–522
14. Silva HM, Oliveira JR, Jesus CM (2012) Are totally recycled hot mix asphalts a sustainable alternative for road paving? Res Conserv Recycl 60:38–48
15. Bilema M et al (2021) Performance of aged asphalt binder treated with various types of rejuvenators. Civil Eng J 7(3):502–517
16. Nguyen VH (2009) Effects of laboratory mixing methods and RAP materials on performance of hot recycled asphalt mixtures. The University of Nottingham
17. Zaumanis M, Mallick RB, Frank R (2016) 100% hot mix asphalt recycling: challenges and benefits. Transp Res Proc 14:3493–3502
18. Al-Qadi IL et al (2009) Determination of usable residual asphalt binder in RAP. Illinois Center for Transportation (ICT)
19. Ma T et al (2015) Evaluation of the diffusion and distribution of the rejuvenator for hot asphalt recycling. Constr Build Mater 98:530–536
20. Chen M et al (2014) Physical, chemical and rheological properties of waste edible vegetable oil rejuvenated asphalt binders. Constr Build Mater 66:286–298
21. Nayak P, Sahoo UC (2017) Rheological, chemical and thermal investigations on an aged binder rejuvenated with two non-edible oils. Road Mater Pavement Des 18(3):612–629
22. Reyes-Ortiz O et al (2012) Evaluation of hot mix asphalt mixtures with replacement of aggregates by reclaimed asphalt pavement (RAP) material. Proc-Soc Behav Sci 53:379–388
23. Zaumanis M, Mallick RB, Frank R (2014) 100% recycled hot mix asphalt: a review and analysis. Res Conserv Recycl 92:230–245
24. Zaumanis M (2014) 100% recycled hot mix asphalt and the use of rejuvenators, in civil & environmental engineering. Worcester Polytechnic Institute
25. Im S, Karki P, Zhou F (2016) Development of new mix design method for asphalt mixtures containing RAP and rejuvenators. Constr Build Mater 115:727–734
26. Cong P et al (2016) Investigation of diffusion of rejuvenator in aged asphalt. Int J Pavement Res Technol 9(4):280–288
27. DeDene CD (2011) Investigation of using waste engine oil blended with reclaimed asphalt materials to improve pavement recyclability. Michigan Technological University
28. Villanueva A, Ho S, Zanzotto L (2008) Asphalt modification with used lubricating oil. Can J Civ Eng 35(2):148–157
29. Yan Z et al (2017) Investigation on physical properties and structure of rejuvenated asphalt with different waste oils. J Wuhan Univ Technol (Transport Sci Eng) 41:104–108
30. Dinh BH, Park D-W, Le THM (2018) Effect of rejuvenators on the crack healing performance of recycled asphalt pavement by induction heating. Constr Build Mater 164:246–254
31. Jahanbakhsh H et al (2020) Sustainable asphalt concrete containing high reclaimed asphalt pavements and recycling agents: performance assessment, cost analysis, and environmental impact. J Cleaner Prod 244:118837
32. Romera R et al (2006) Rheological aspects of the rejuvenation of aged bitumen. Rheol Acta 45(4):474–478
33. Jia X et al (2015) Influence of waste engine oil on asphalt mixtures containing reclaimed asphalt pavement. J Mater Civ Eng 27(12):04015042
34. Fernandes SR, Silva HM, Oliveira JR (2018) Developing enhanced modified bitumens with waste engine oil products combined with polymers. Constr Build Mater 160:714–724
35. Dokandari PA et al (2017) Implementing waste oils with reclaimed asphalt pavement. In: Proceedings of the 2nd World Congress on Civil, Structural and Environmental Engineering (CSEE'17).

36. Khan MZH et al (2021) Performance of high content Reclaimed Asphalt Pavement (RAP) in asphaltic mix with crumb rubber modifier and waste engine oil as rejuvenator. Appl Sci 11(11):5226
37. Zhang H, Wang Q, Mortimer SR (2012) Waste cooking oil as an energy resource: review of Chinese policies. Renew Sustain Energy Rev 16(7):5225–5231
38. Asli H et al (2012) Investigation on physical properties of waste cooking oil–rejuvenated bitumen binder. Constr Build Mater 37:398–405
39. Azahar WNAW et al (2017) Mechanical performance of asphaltic concrete incorporating untreated and treated waste cooking oil. Constr Build Mater 150:653–663
40. Eriskin E et al (2017) Waste frying oil modified bitumen usage for sustainable hot mix asphalt pavement. Arch Civil Mech Eng 17(4):863–870
41. Su J-F et al (2015) Investigation the possibility of a new approach of using microcapsules containing waste cooking oil: in situ rejuvenation for aged bitumen. Constr Build Mater 74:83–92
42. Wen H, Bhusal S, Wen B (2013) Laboratory evaluation of waste cooking oil-based bioasphalt as an alternative binder for hot mix asphalt. J Mater Civ Eng 25(10):1432–1437
43. Zargar M et al (2012) Investigation of the possibility of using waste cooking oil as a rejuvenating agent for aged bitumen. J Hazard Mater 233:254–258
44. Chen M et al (2014) High temperature properties of rejuvenating recovered binder with rejuvenator, waste cooking and cotton seed oils. Constr Build Mater 59:10–16
45. Yu X et al (2014) Rheological, microscopic, and chemical characterization of the rejuvenating effect on asphalt binders. Fuel 135:162–171
46. Mashaan NS et al (2013) Performance evaluation of crumb rubber modified stone mastic asphalt pavement in Malaysia. Advances in Materials Science and Engineering (AMSCE)
47. Babalghaith AM, Alsoliman HA, Al-Suhaibani AS (2016) Comparison of rheological properties for polymer modified asphalt produced in Riyadh. Int J Civil, Environ Struct Constr Arch Eng 10(2):197–201
48. ASTM (2011) D-2172: Standard test methods for quantitative extraction of bitumen from bituminous paving mixtures. ASTM West Conshohocken, PA
49. ASTM (2009) D-1856: Standard test method for recovery of asphalt from solution by Abson method. ASTM
50. ASTM (2013) D., Standard test method for penetration of bituminous materials. USA, ASTM International
51. ASTM (2020) D-36: Standard test method for softening point of bitumen (ring-and-ball apparatus). American Society for Testing and Materials
52. ASTM (2015) D, Standard test method for viscosity determination of asphalt at elevated temperatures using a rotational viscometer. American Society for Testing and Materials.
53. ASTM (2008) D-7175: Standard test method for determining the rheological properties of asphalt binder using a dynamic shear rheometer. American Society for Testing and Materials
54. Zaumanis M, Mallick RB, Frank R (2015) Evaluation of different recycling agents for restoring aged asphalt binder and performance of 100% recycled asphalt. Mater Struct 48(8):2475–2488
55. Tran NH, Taylor A, Willis R (2012) Effect of rejuvenator on performance properties of HMA mixtures with high RAP and RAS contents. 2012, National Center for Asphalt Technology, Auburn University, Auburn, Alabama
56. West RC, Willis JR, Marasteanu MO (2013) Improved mix design, evaluation, and materials management practices for hot mix asphalt with high reclaimed asphalt pavement content. Transport Res Board 752:2013

Typology of Design Concepts for Luxury Car Showrooms

Mervyn Wong Hsin Jyi, Atta Idrawani Zaini, Dona Rose Amer Koesmeri, and Ruzanah Abu Bakar

Abstract This paper attempts to characterize the typology of luxury car showrooms in Malaysia. The architectural design of luxury car showrooms is subject to changes and development of the economy, technology and behavior of the consumers in the market. It is also dependent on the brand's Corporate Identity (C.I.), which is formed by cultural adaptations from its country of origin, competitors in the industry and the demands of car owners. Each brand must incorporate their own C.I. into the design of the showrooms to maintain standard requirements and safeguard the outlook and operation of the showrooms. This paper employs a case study approach as its main research method. The study is mainly based on observation on built examples and draws conclusion from the input of architects who are specialized in designing car showrooms in Malaysia. The findings indicate that the design typology of luxury car showrooms is an expression of the values of the brand's C.I., integrates lounge spaces with the showroom area, constructed with premium quality materials and at times, be shaped by the design guidelines provided by the brands to comply with their international identity.

Keyword Luxury car showroom

M. W. H. Jyi (✉) · A. I. Zaini · D. R. A. Koesmeri · R. A. Bakar
Faculty of Built Environment, Universiti Malaysia Sarawak, Kota Samarahan, Malaysia

A. I. Zaini
e-mail: izatta@unimas.my

D. R. A. Koesmeri
e-mail: akdona@unimas.my

R. A. Bakar
e-mail: abruzanah@unimas.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_7

1 Introduction

Luxury cars often inspire a sense of ambition and desire in consumers. It becomes a lifestyle goal to own one. Therefore, luxury brand managements must effectively identify the target consumers and strive to continuously attract, grow and maintain brand relationships in order to establish credibility and stay relevant in such a competitive and volatile market [5]. Consequently, the requirement of a prestigious showroom becomes one of the considerations in purchasing a luxury car. The concept of luxury is normally associated with higher prices, exceptional quality, pleasure, exclusivity, aesthetic beauty and strong emotional and symbolic attachments [1]. According to Manoukian [6], consumers are more likely to invest in luxury-branded cars over other brands due to greater perceived value, exclusivity and elevated consumer experience. Thus, the design of a showroom to display the cars and as a platform where consumer relationships are built, then becomes essential as it will reflect the quality and branding of the company. This paper will reveal some case studies of showrooms belonging to different luxury car brands located in Malaysia and the design strategies employed to translate the concept of 'luxury' into the showrooms' design. The objective of this paper is to provide clear characterization of showrooms based on the C.I. This includes the design concepts, materials and space organizations of the showroom.

2 Research Method

This paper observes the case study run by foreign car makers operated by local car dealers. Targeted locations are in prominent cities in the country as these regions have the busiest service centers. This research is a case study expecting to review critical understanding, originality and creativity in theories and practices to frame new findings that challenge conservative thinking in industrial design that will be exceedingly valued in education and the automotive industries. This method is best used when the research focuses on theory and concept development that emerge from actual life events and settings.

3 Case Study—Showrooms

This paper examines 3 luxury car showrooms in Malaysia. The 3 sites have the same similarity in terms of climate, material availability and authority's compliance. This provides clear comparison of the focus, thinking and design strategies of the designer/architects in the same region. The table below shows the location of the 3 showrooms.

	Brand	Location
1	Volvo showroom	Kuching, Sarawak
2	Mercedes Benz showroom	Balakong, Kuala Lumpur
3	Lexus showroom	Kuching, Sarawak

3.1 Volvo Showroom

Since 2013, Volvo has initiated their new C.I. called the Volvo Retail Experience (VRE), which embodies their core brand expression; "Scandinavian luxury that understands people". Inspired by the Swedish culture of 'Lagom', which means the art of living a balanced, leisurely life, the design concept of Volvo's showrooms aims to create a calming environment for customers to work, relax and enjoy refreshments or to browse their latest car models [2, 8]. The showroom conceptualized as a living room incorporates elements of calm, clean lines and features bespoke Scandinavian furniture to create a space that is both cool on the outside and warm on the inside [3]. Unlike most car showrooms which are constructed with full transparent glass façades, the contemporary exteriors of the new VRE showrooms uses white translucent glass panels with only the transparent ones located strategically where display cars are parked. The design strategy of the façade not only creates a visual landmark for customers but also to direct the eyes of onlookers to the models on display [3] (Fig. 1).

The warm interiors of the VRE showrooms create an inviting contrast to the cool exterior and are demarcated into two zones; namely the Street Area and the Living Room Area. The Street Area contains all product displays, the Car Studio, Accessories Hub, Car Delivery Area and Consultation Points, all evenly spread throughout the Street to provide various points of interest in the customers' journey [3, 8]. At the heart of the showroom is the Living Room Area which forms a cozy haven for a more casual approach for Sales Consultants and customers to meet. Located here are different living room spaces with varying seating options, the Reception Area, the Coffee Bar Area, the Lifestyle Shop and the Kid's Lounge. For both customer experience and practicality, the space planning must integrate both the sales and service areas completely, to design an open and comprehensive setting. The layout must maximize efficient interaction between the Showroom Entrance, the Living

Fig. 1 Transparent glass windows set against translucent glass panels highlight the cars on display

Fig. 2 *Left*- The Street Area with product display; *Right*- The Living Area where customers can relax

Room and the Workshop Areas so the staff can work effectively whilst ensuring that customers are attended to swiftly. The Swedish culture of transparency expressed in the usage of glass partitions also enable customers to see their cars being serviced in the Workshop from the comforts of the Living Room Area [8]. The showrooms are also furnished with bespoke furniture from Scandinavian interior-design company, Senab. Each piece of furniture including the reception table, light fixtures, seating, display panels and standalone pantry were designed to reflect the Volvo brand, unique for its showrooms and are owned by Volvo. The interior design features the clean and warm outlook of the Scandinavian scheme, mainly using the colors of white and light oak timber (Fig. 2).

3.2 Mercedes Benz Showroom

Germany is a haven for car enthusiasts. Luxury brands such as Volkswagen, BMW, Audi and Mercedes Benz originated from this country. For Mercedes Benz, the showroom consists of the essential areas such as sales, product display, customer lounge, service and shop. The showroom and adjacent rooms with customer access are parts of the dealership where the corporate design needs to make the greatest impression. Every element of the Mercedes Benz showroom, from structural features, furniture, fittings, down to the choice of materials and color, serve to determine its ambience. The design is composed of several brand-defining elements such as the thin roof edge, horizontal structure of the glass façade, the row of columns, wall star bearing the logo and the main entrance element [7]. The exterior of the showroom features a horizontal glass façade topped with a thin, horizontal roof which together, produces a homogenous design. The overhanging roof with a slim edge not only forms a prominent feature but also functions to protect the glass façade from sun and rain. A row of black columns is also placed in front of the glass exterior, which has become the signature architectural element of the Mercedes Benz showrooms. In addition to that is the wall star on which the brand logo is displayed, designed

Fig. 3 Exterior design of Mercedes Benz showroom

Fig. 4 Mercedes Benz showroom at Balakong featuring glass facades and courtyards as elements of sustainable design

so that its size and placement on the façade is perceived as exclusive, reflecting the exclusivity of the Mercedes Benz brand. Alternatively, the wall star can also be integrated as part of the row of columns (Fig. 3).

The main entrance of the Mercedes Benz showroom is designed to contrast the glass façade. The entrance features a clean design with a projecting roof, highlighted with a black outer surface and a white inner surface to create a welcoming effect whilst being instantly noticeable to visitors. Sustainable design strategies had been greatly implemented into the showrooms. This includes maximizing the usage of natural daylight to reduce the energy consumed for artificial lighting. A combination of glass facades and courtyards served to optimize the usage of natural light which also has a major impact on the well-being and productivity of the employees (Fig. 4).

3.3 Lexus Showroom

The Lexus automotive brand, headquartered in Japan, is owned by Toyota Motor Corporation. Although Lexus can be classified as the luxury division of the company, the brand operates independently to bring quality luxury cars to the market [4]. Unlike Volvo and Mercedes Benz, the Lexus dealerships do not require any specific design

Fig. 5 Lexus showroom in Kuching, Sarawak designed by Design Network Architects with facade featuring advertising billboard

requirements to its external architecture, giving the architect freedom to design the building forms and façades. However, the brand only demands that the exterior of the showrooms feature a large advertising board installed as part of the façade, in which it will be used for product advertisements which are changed regularly. The interior design places more emphasis on expressing the concept of luxury to the customers. Seating areas and lounges are positioned in prominent areas to integrate them into the exhibition space more strongly. The lounge areas are also required to include an adjacent open pantry for the convenience of customers. It is important that the lounge areas express generosity while at the same time, with the type of furniture used and its spatial layout, the lounge also provides a space of retreat without interrupting the customers' view of the vehicle display. The interior design also requires a mix of black and timber elements. Finishes in dark walnut and the usage of timber flooring at customer lounges not only convey elegance but also create a warm and welcoming space. Lexus sets a high standard for the quality of interior finishes and fittings that are to be incorporated into their showrooms, including the brand of the tiles and sanitary wares used. This is to ensure that the end product of the showroom reflects Lexus' image as a luxury brand (Figs. 5 and 6).

4 Conclusion

The design typology of luxury car showrooms is greatly influenced by the brand's Corporate Identity (C.I.), development of technology and economy, industry competitors and consumer demands. From the three case studies of luxury car showrooms above, it can be concluded that the luxury car brands have similar design requirements for their showrooms so as to fulfil their respective C.I.'s conditions. One of the main design characteristic of luxury car showrooms is the integration of a comfortable and well-equipped customer lounge area with an attractive and engaging showroom where products are displayed. The typology of the dealerships is also shaped by the obligatory design requirements set by each individual brand's C.I. as it

Fig. 6 *Left*- Lexus premium merchandise display in black and timber colors. *Right*- A Mark Levinson audio system installed in an acoustical room for guests to experience the real-life sound systems provided in Lexus vehicles

carries international identity. For brands like Volvo and Mercedes Benz, guidelines for the exterior and interior design of the dealerships were provided by the companies and must be strictly adhered to as representatives from the brand's company headquarters are sent to audit the showrooms. It is also essential that designers incorporate high-end construction materials to create an end product that is more premium, thus, befitting the concept of luxury. The design of luxury car showrooms is bound to evolve along with the growth of the brand it represents and the experience it wishes to provide to its consumers.

References

1. Choo HJ, Moon H, Kim H, Yoon N (2012) Luxury customer value. J Fash Mark Manag: Int J 16:81–101. https://doi.org/10.1108/13612021211203041
2. Health.com. (2021). 6 Ways to Practice Lagom, The Swedish Secret to a Balanced, Happy Life. https://www.health.com/condition/stress/swedish-lagom-tips-for-balanced-happy-life
3. ID Malaysia (2017) Giving car retail a homely feel. http://www.idmalaysia.com/2017-volvo-vre-showroom-feature
4. Lexus of Albuquerque (2021). Who Manufactures Lexus? Retrieved from Who Manufactures Lexus? | Is Lexus Owned by Toyota? (lexusofalbuquerque.com)
5. Loureiro SM, Kaufmann HR, Wright LT (2016) Luxury values as drivers for affective commitment: the case of luxury car tribes. Cogent Bus Manag 3(1):1–2. https://doi.org/10.1080/23311975.2016.1171192
6. Manoukian J (2019) The Psychology of Luxury Car Buyers: 7 Considerations. https://www.limelightplatform.com/blog/psychology-luxury-car-buyers-considerations
7. Mercedes Benz (2015) Architecture specifications in retail. Author, Stuttgart, Germany
8. Volvo Car Group (2016) Volvo retail experience: guidelines manual. Gothenburg, Sweden

Significance of Illuminance Level in Hafazan Learning Task

Raja Nur Syaheeza Raja Mohd Yazit, Elina Mohd Husini, Atta Idrawani Zaini, and Mohd Khedzir Khamis

Abstract Light is sacred and important in major monotheistic religion: Islam, Christianity, and Judaism. One example dedicated for light in the Quran is surah An-Nur. Daylight considerations are also viewed as important in designing educational spaces to reduce visual discomfort to ensure students' optimal reading and writing task performance. This paper focuses on specific educational space that are used for reading and writing task for memorizing (hafazan) the Quran. This paper highlights the relationship between acceptable illuminance level and students' learning task for hafazan. Various research proven that efficient daylighting in educational spaces influences the students' learning task performance positively. The recommended illuminance level for educational spaces is between 300 to 500 lx. In the pilot study, the illuminance level is below than minimum recommendation of 300 lx. However, the lower illuminance level increases the students' hafazan task performance. Further study is required to test the theory that hafazan learning task requires lower illuminance level. This shows that efficient illuminance level is an important consideration in different education system that uses different tools.

Keywords Illuminance level · Hafazan · Learning task performance · Daylighting

R. N. S. R. M. Yazit (✉) · A. I. Zaini
Architecture Department, Faculty of Built Environment, Universiti Malaysia Sarawak, Jln Datuk Mohammad Musa, 94300 Kota Samarahan, Sarawak, Malaysia
e-mail: rmysyaheeza@unimas.my

A. I. Zaini
e-mail: izatta@unimas.my

E. M. Husini
Architecture Department, Faculty of Engineering and Built Environment, Universiti Sains Islam Malaysia, 71800 Nilai, Negeri Sembilan, Malaysia
e-mail: elina@usim.edu.my

M. K. Khamis
Interior Design Programme, Faculty of Built Environment and Regenerative Design, Raffles University, Menara Kotaraya, Level 9, #09, 01, Jalan Trus, Bandar Johor Bahru, 80000 Johor Bahru, Johor, Malaysia
e-mail: mohdkhedzir@raffles-university.edu.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_8

1 Introduction

One of the important renewable resources for human to progress with daily routine is daylight. A research relates the light with major monotheistic religion by transcribing Islam, Christian and Judaism holy scriptures mentioning its sacredness [1]. In the Quran, surah An-Nur, ayah 35 mentioned that God exemplified as light in a lamp providing a guidance to the believers. This is an example of light sacredness in Islam. Both photobiology studies and religious point of view shows that light is essential for human being. Reading and writing are basic tasks in learning spaces. Buya Hamka described that the first word "READ!" in surah Al-Alaq is to magnify that Islam encouraged Muslims to learn through reading. The relationship of this two surah An-Nur and Al-Alaq can be translated in scientific field, where studies proven that efficient daylight improves the students' performance such as reading and writing.

2 Literature Review

The process of extracting visual stimulus information from retinal image and transmit it to the optic nerve is by the retina, which influenced by the sufficiency of light received by the cornea [2]. In Islam civilisation, Ibn Al-Haytm studied the relationship between human eye's physiology and anatomy with the theory of light introduced by Plato, Aristotle, and Euclid. The theory of extra-mission by these philosophers however was contradicted by Ibn Al-Haytm's deduction. His observation of human pain sensation due to exposure of intense light shows that lights that enters the eye and change the eye's structure. Thus, this causes visual discomfort [3]. Understanding visual discomfort requires various lighting aspects such as insufficiency of light and flickering of artificial lighting. Other aspects are shadows, veiling reflections, uniformity, and glare [2]. Glares exist in two conditions, which are direct glare and reflected glare. Uncontrolled glare from lighting source combined with brightly coloured surface causes direct glare. Reflected glare in another hand are caused by walls, floors, and ceilings high light reflective surfaces. A handbook mentioned that inappropriate position of the artificial light and windows design can causes reflected glare [2, 4]. Quoting from Figuero and Rea (2010), the loss of concentrations is due to eye fatigue caused by visual discomfort [5].

Long-term and short-term are two types of memory retention, where psychologists have identified Quranic hafazan is considered as long-term memorization. The recitation of the holy Quran triggers the activity of the brain that requires long-term memory retention [6]. Wahdah (reading/reciting), Kitabah (writing), Sama'i (listening) and Jama' (recite together) are the four basic hafazan method, where the most common method used are Wahdah (reading) and Sama'i (listening).\, while the most easing and preferred method by students is Wahdah (reading/reciting) [7, 8]. Panipati memorization method originated from Pakistan requires the students to repeatedly read and recite the verses of the Quran throughout their day [9]. The

Table 1 Illuminance level recommendations

Learning space	Guidelines and standards					
	IESNA	MS1525	JKR	OSHA	ZUMTOBEL	EFM
General	300–500	300	300	300	300	215–430
Labs	500	300	300			
Library	300	300–500	300			

Othman method initially uses the ten-time Khatm, where the students are required to read and recite the full Quran ten times before memorizing it. Other techniques are Chi (new memorization), Xor Pismis, Kolay Pismis, Tekrar, Tekrar Hepsi Seyfa and Has [10].

Daylighting that provides efficient illuminance level in classrooms influences the students' performance [11], where this is due to improvements of students' health affected by sufficient daylighting [5]. Providing efficient daylighting can increase the factor of optimal learning performance such as subjective moods, physical activities, cognitive performance, sleep quality, alertness, psychology, health, and attention span [12, 13]. Abundant daylight with chances of low glare, included with high quality artificial lighting improves the visual environment [14]. Other study shows the same result where students that attended schools with efficient daylighting had improved their learning performance and health. However, providing high illuminance level does not improve visual acuity, thus reduces their learning performance due to glare [15].

Most referred to daylighting guidelines is the Illuminating Engineering Society of North America (IESNA) handbook, where the identified range of illuminance level has been specified for specific spaces and specific tasks, such as 300 lx to 500 lx for educational spaces [4, 16]. Table 1 shows the various recommendations for learning spaces in schools based on various guidelines.

3 Pilot Study

Effort to identify the correlation between illuminance level and students' performance in Malaysia, a pilot study was done in Kolej Genius Insan, Universiti Sains Islam Malaysia (USIM), Nilai. The school integrates Islamic education in the curriculum including hafazan. The selected PNP-001 and PNP-019 classroom differences is the orientation, where other variables such as the floor area, location, level (ground floor) and the window design are similar. Students aged 13 to 17 we randomly selected by the schools' administration, where this age group have the intellect to give feedback based on perceptions and experience. Windows and openings are controlled at 20% WFR, which follows the recommended value (Fig. 1).

The illuminance level for each classroom is measured using data loggers located in a 1 m × 1 m grid at 900 mm working plane height from floor level (table and

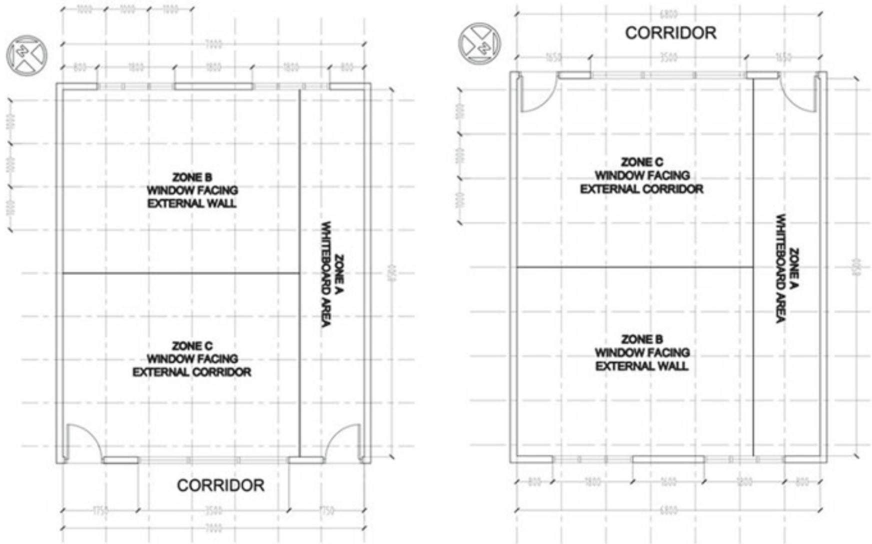


Fig. 1 Floor plan of classroom PNP-001(left) and PNP-019 (right) [17, 18]

window height). The measurements show that PNP-001 received a lower average illuminance level of 281 lx, meanwhile PNP-019 received illuminance level within the recommended range, which is 340 lx, shown in Fig. 2.

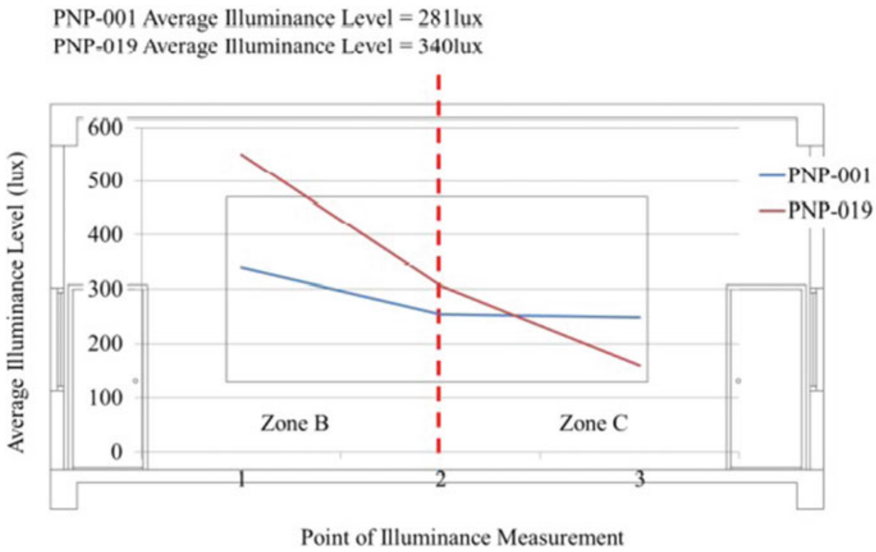


Fig. 2 Average illuminance level comparison between two PNP classrooms

Modified LogMAR chart for visual acuity test was used to evaluate the students' reading and writing task performance. The 30 students were arranged in three rows, where 10 students seated in each row. The LogMAR chart was read and rewritten with the additional of questionnaires to identify the students' perception on their performance of the LogMAR chart test. The students are required to record their writing performance speed based on the provided timer in front of the classroom. The questionnaire also included with their perception on the classrooms' daylight condition during the test. Result shows that both classrooms perceived by the students as having a comfortable and suitable daylighting condition for reading task.

The average time speed recorded for the students to rewrite the LogMAR chart shows the average Arabic writing performance of the students, as shown in Fig. 3. The average time speed for students in classroom PNP-001 is 87 s (1 min 27 s) and students in classroom PNP-019 is 108 s (1 min 48 s). This shows that the learning performance of students in classroom PNP-001 is better than students in classroom PNP-019. This contradicts the theory where students seated in the classroom that achieved recommended illuminance level have better learning performance.

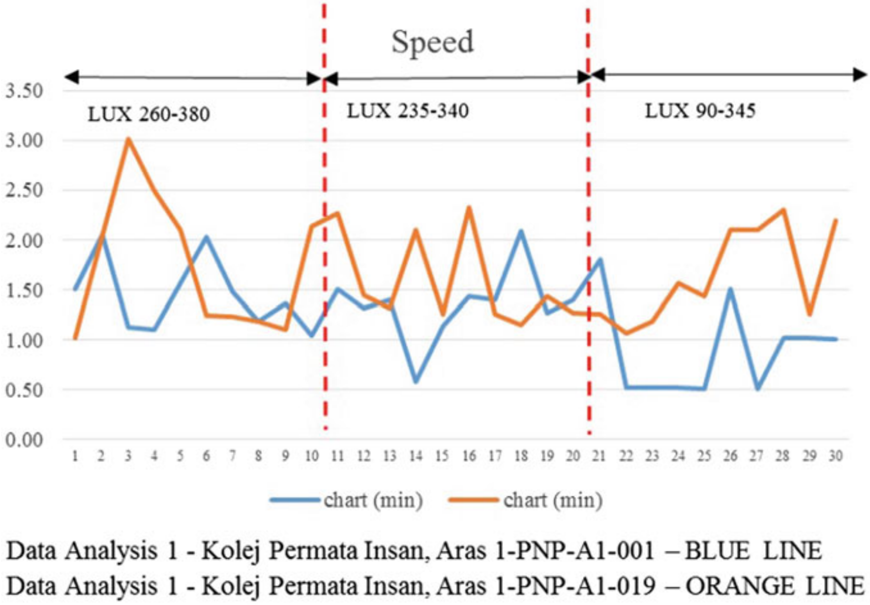


Fig. 3 Average handwriting performance between two PNP classrooms

4 Conclusion

A clear correlation can be seen between acceptable illuminance level and students' learning performance in the provided literature review, strengthen with the by the pilot study. Since the one of the preferred methods of hafazan is reading, it is highly recommended that the classroom design should considers the windows and openings for adequate illuminance level. The ranges of acceptable illuminance level for students should be revised and requires further study, proven where the students in classroom PNP-001 that received lower than recommended illuminance level performs better in reading and writing performance. Therefore, providing acceptable illuminance level in a classroom for hafazan education can improves the students' hafazan performance. This study encourages architects to consider daylighting in designing classrooms for schools that integrates Islamic education such as hafazan in the curriculum.

References

1. Gilavand A, Gilavand M, Gilavand S (2016) Investigating the impact of lighting educational spaces on learning and academic achievement of elementary students. Int J Pediatr 4:360–369
2. Boyce PR, Hunter C, Howlett O (2003) Human factors in lighting, lighting research centre. Rensselaer Polytechnic Institute
3. Gorini S (2003) Al-Haytam the man of experience. first steps in the science of vision. J Int Soc Hist Islam Med (ISHIM), pp 53–55
4. ZUMTOBEL (2017) The lighting handbook, Zumtobel Lighting GmbH
5. Ibrahim SM, Ahmad AD (2013) Impact of sustainable school environment on student's health and academic performance. J Sci Tech Edu 2:34–41
6. Fadhilah WA, Ashaari MF (2015) The concept of recitation (Hafazan) and rational in teaching and learning in Western and Islamic perspective. In: Proceeding of the international seminar and conference
7. Hashim A (2015) Correlation between strategy of Tahfiz learning styles and students performance in Al-Qur'an Memorization (Hifz). Mediterr J Soc 6:82–95
8. Al Hafiz MM, Yusof MF, Ghazali MA, Sawari SSM (2016) Descriptive qualitative teaching method of memorization in the institution of Tahfiz Al-Quran Wal Qiraat Pulai Condong and the students' level of academic excellence. Mediterr J Soc Sci 7:79–85
9. Ariffin S, Abdullah M, Ahmad K (2014) Implementation of Panipati method on memorization the Quran in Malaysia: a study in Tahfiz institute. In: Paper proceeding innovative trends in multidisciplinary academic research (ITMAR), vol 1, pp 406-413
10. Ariffin S, Abdullah M, Ahmad K (2015) Method on memorization the Quran in Malaysia: a study in Darul Tuba institute. In: Malaysia proceedings of the international conference on global business, economics, finance and social sciences, pp 1–9
11. Le V, Gillott MC, Rodrigues LT (2016) The case for hybrid ventilated primary schools in Ho Chi Minh City in Vietnam. In: 36th international conference on passive and low energy architecture
12. Mirrahimi S, Ibrahim NLN, Surat M (2013) Estimation daylight to find simple formulate based on the ratio of window area to floor area rule of thumb for classroom in Malaysia. Res J Appl Sci Eng Technol 6:931–935
13. Shishegar N, Boubekri M (2016) Natural light and productivity: analyzing the impacts of daylighting on students' and workers' health and alertness. Int J Adv Chem Eng & Biol Sci (IJACEBS) 3:72–77

14. Barret P, Davies F, Zhang Y, Barret L (2015) The impact of classroom design on Pupil's learning: results of a holistic, multi-level analysis. Build Env 89:118–133
15. Plympton P, Conway S, Epstein K (2000) Daylighting in schools: improving student performance and health at a price schools can afford. The American Solar Energy Society Conference
16. DiLaura DL (2011) The lighting handbook: reference and application. Illuminating Engineering Society of North America (IESNA)
17. Arabi F, Husini EM, Yazit RNSRM, Dodo YA, Kandar MZ (2018) Acceptable illuminance level attributes to learning satisfaction in classroom. Int J Manag App Sci 4(3):61–66. ISSN: 2394–7926
18. Yazit RNSRM, Husini EM, Arabi F, Ismail WNW, Kandar MZ (2018) Secondary school classrooms daylighting evaluation in Negeri Sembilan, Malaysia. IOP Conf Ser Mater Sci Eng 401:012–024

The Method of Measuring Students' Arabic Handwriting Performances in Classrooms

Raja Nur Syaheeza Raja Mohd Yazit, Elina Mohd Husini, Awang Hasim bin Awang Sulong, and Ruzanah binti Abu Bakar

Abstract A design that uses passive design strategies usually optimizes daylight source for occupants' visual comfort. Through literature review, it suggested that the students' performance is influenced by the daylight level of the space. Many methods have been introduced to identify students' English writing performance in relation to the daylight level in classrooms, not so many for Arabic writing. The aim of this paper is to review the Arabic writing performance assessment that were used to develop Syaheeza's Daylight Rule of Thumb (DRT). The Arabic writing performance were measured in word per minute (wpm), which is similar with the Handwriting Speed Test (HST). Therefore, this paper proposes a method to measure students' Arabic handwriting performance in a daylit classroom by using the modified Balsam Alabdulkader-Leat (BAL) eye chart. This benefits schools that uses Arabic writing as a teaching medium in a daylit classrooms.

Keywords Daylight · Illuminance level · Reading and writing performance · Daylight rule of thumb

1 Introduction

The quantity and quality of the daylight in building assessment tools identifies its effects on students' visual comfort [1]. There is various recommendation by standards and guidelines for acceptable illuminance level in learning spaces such as Malaysian Standard 1525 (MS1525). This paper reviews the suitability of method used to evaluate students' Arabic writing performance in daylit classrooms, which is the modified BAL eye chart [2] that identifies the students' Arabic handwriting

R. N. S. R. M. Yazit (✉) · A. H. A. Sulong · R. A. Bakar
Architecture Department, Faculty of Built Environment, Universiti Malaysia Sarawak, Jln Datuk Mohammad Musa, 94300 Kota Samarahan, Sarawak, Malaysia
e-mail: rmysyaheeza@unimas.my

E. M. Husini
Architecture Department, Faculty of Engineering and Built Environment, Universiti Sains Islam Malaysia, 71800 Nilai, Negeri Sembilan, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_9

performance in relation with the illuminance level of the classroom. The Arabic handwriting performance were measured based on the word per minute (wpm). Studies that use modified BAL eye chart were selected for this paper.

1.1 Aim and Objectives

The aim of this study is the review of the modified BAL eye chart in measuring students' Arabic handwriting performance as a reliable tool. First objective is to review the BAL eye chart based on references of other handwriting performance assessments. Second objective is to analyse the results and outcome of modified BAL chart from previous research.

2 Literature Review

Studies highlighted that daylight intensity influenced the students' visual stimuli, thus influenced the students' learning performance in classroom [3]. The eye strain experienced in classroom can be reduced by providing adequate daylight [4]. Malaysian standards follow Illuminating Engineering Society of North America (IESNA) recommendations on classrooms illuminance level, which is between 300 to 500 lx [5].

The comprehensive sentences in the Minnesota Near Reading Test (MNREAD) acuity charts allows it to extensively evaluate the handwriting performance results [6]. A logarithmically scaled chart known as Colenbrander evaluates the reading acuity score, maximum reading speed and mean reading speed to identify the respondents' visual performance [7]. The BAL eye chart is currently the only developed Arabic acuity eye chart [2].

A handwriting performance assessments principle has three tasks, which are copying, dictated writing and narrative or free writing [8]. Another principle requires five tasks, which are 'Best' copy, 'Fast' copy, Writing alphabets, 10-min free writing, and non-language-based tasks [9]. Test of Legible Handwriting (TOLH) assess the students' handwriting by recording the students' time [10], which determines the students' word per minute (wpm) score [11].

Handwriting Proficiency Screening Questionnaire (HSPQ) uses Likert scale type questionnaires to indicate students' performance, which consist of three domains (legibility, performance time, well-being) [12]. The most used standardised assessment is the Detailed Assessment Speed Handwriting (DASH) [13] for English, while Hebrew Handwriting Evaluation (HHE) is the standardised Hebrew handwriting performance assessment tool [14]. Additionally, the BAL eye chart was developed for Arabic alphabet eye acuity test [2].

3 Case Study of Arabic Handwriting Performance Assessment

Syaheeza's DRT is developed for Islamic Religious schools that uses Arabic language as teaching and learning medium. Thus, to evaluate students' Arabic handwriting performance, the BAL eye chart was modified to fit the function of handwriting performance assessment tools as shown in Fig. 1. Both case studies use the same method that utilizes the modified BAL eye chart.

Students aged 13 to 17 were selected in the Kolej Genius Insan due to their age capabilities to give feedbacks based on perceptions and emotions. The students were seated in three rows with eight students in each with a normal school table (Fig. 2).

Higher illuminance level recorded resulted in lower students' performance (Fig. 3) proves that daylight intensity in the classroom correlates with the students' learning performance. This correlation also proves that the method used to evaluate students' Arabic handwriting performance are reliable for similar research scope and scale.

Fig. 1 Modified Balsam Alabdulkader-Leat (BAL) eye chart [15]

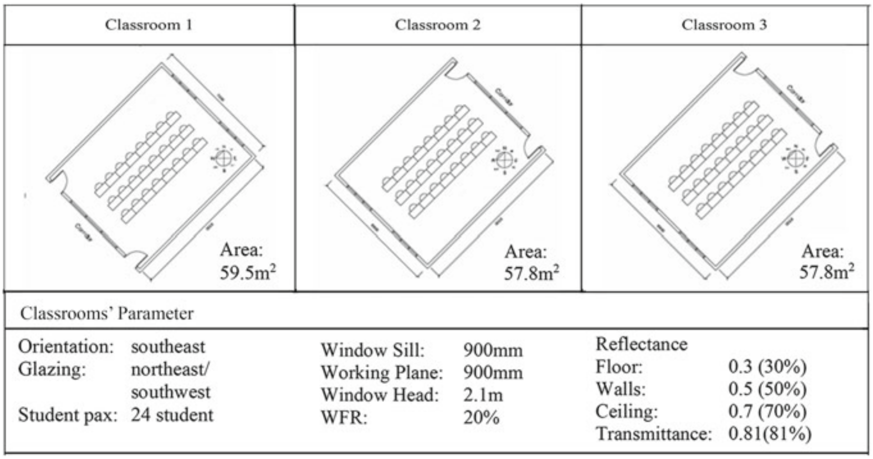


Fig. 2 Information of Kolej Genius Insan selected classrooms [15]

Fig. 3 Correlation; illuminance level and Arabic handwriting performance [15]

The diagram shows a direct correlation between students' performance and illuminance level, where the increment of illuminance level at working plane height decreases the students' performance. However, session one results shows that when the illuminance level is slightly lower than 300 lx recommended, the students' performance exceeds the average performance for their same age group. Setup for the second case study in MJIIT is as shown in Fig. 4.

The students are arranged in four rows with five students in each row. the students were seated facing the windows instead of having the windows on both or either side

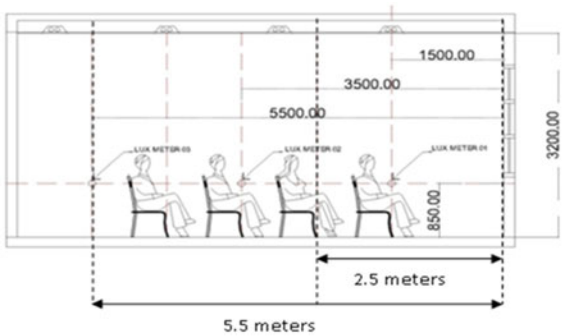


Fig. 4 Setup for Arabic handwriting performance assessment in MJIIT [16]

Table 1 Arabic handwriting performance based on word per minute (wpm)

Range of Acceptable illuminance level (in daylighting; lux)		Percentage above Average Score (%)	The Fastest Speed (Time)	Word per minute (wpm)
MJIIT	401–599	50	8 min 52 s–10 min 30 s	15.7–13.3
Kolej Genius Insan	280–446	35	7 min 45 s–9 min 50 s	18.1–14.3

*Average wpm for age 13 to 17 years old is 14.7

of the classroom. Table 1 shows the results of the Arabic handwriting performance assessment for both case studies.

50% of the students in MJIIT session scores higher than the average wpm in their age group, while only 35% students in Kolej Genius Insan sessions wpm scores are above average. The difference of modified BAL eye chart wpm scores shows that the range of different illuminance level in the classrooms highly influences the students' performance. Since that both studies show correlation between the average illuminance level and the Arabic handwriting performance as literature review suggested, this proves that the modified BAL eye chart is reliable to be used in daylighting evaluation research and studies in relation to students' handwriting performance assessment.

4 Conclusion

Eye charts such as MNREAD, Jaeger and Colenbrander chart are suitable to be used to identify the correlation between students' handwriting performance (wpm) and illuminance level (lux). However, these eye charts emphasized the use of English alphabetical system instead of other languages such as Arabic. The modified BAL eye chart used to develop Syaheeza's DRT can replace the per mentioned English alphabet eye charts to evaluates the correlation between illuminance level and students' Arabic handwriting performance. This method can be useful for schools that uses Arabic language as the main medium for teaching and learning. Noted that other factors such as WWR or WFR and the performance zone (2.5 m to 4.5 m away from the window) influenced the illuminance level and students' performance as well. Even though the current modified BAL eye chart can produce reliable results and prove of correlation between illuminance level and Arabic handwriting performance, the modified BAL eye chart and the methods used requires further improvement towards its adaptations to other field of studies.

References

1. Howlett O, Heschongand L, McHug J (2007) Scoping study for daylight metrics from luminance maps. J Illum Eng Soc 3(3):201–215. https://doi.org/10.1582/LEUKOS.2007.03.03.003
2. Alabdulkader B, Leat SJ (2017) A Standardized Arabic reading acuity chart: the Balsam Alabdulkader-Leat chart. Optom Vis Sci 94(8):807–816. https://doi.org/10.1097/OPX.0000000000001103
3. Samani SA, Samani SA (2012) The impact of indoor lighting on students' learning performance in learning environments: a knowledge internalization perspective. Int J Bus Soc Sci 3:127–136
4. Heerwagen J, Johnson JA, Brothers P, Little R, Rosenfeld A (1998) Energy effectiveness and the ecology of work: links to productivity and well-being. In: Proceedings of ACEEE summer study on energy efficiency in buildings, 1998. American Council for an Energy-Efficient Economy, Richland, WA (US)
5. DiLaura DL (2011) The lighting handbook: reference and application. lluminating Engineering Society of North America (IESNA)
6. Mataftsi A, Bourtoulamaiou A, Haidich A, Antoniadis A, Kilintzis V, Tsinopoulos IT, Dimitrakos S (2013) Development and validation of the greek version of the MNREAD acuity chart. Clin Exp Optom 96(1):25–31. https://doi.org/10.1111/j.1444-0938.2012.00799.x
7. Radner W (2016) Near vision examination in presbyopia patients: do we need good homologated near vision charts? Eye Vis 3(29). https://doi.org/10.1186/s40662-016-0061-7
8. Ferrier J, Horne J, Singleton C (2013) Factors affecting the speed of free writing. J Res Spec Educ Needs 13(1):66–78. https://doi.org/10.1111/1471-3802.12001
9. Barnett AL, Henderson SE, Scheib B, Schulz J (2009) Development and standardization of a new handwriting speed test: the detailed assessment of speed of handwriting. Br J Educ Psychol Monogr Ser II 6(21:137–157. http://hdl.handle.net/2299/8291
10. Richards L, Croft C (eds.), Larsen SC, Hammill DP (1989) Test of legible handwriting, the best of "set" assessment. New Zealand Council for Educational Research, Wellington, New Zealand
11. Rogers J, Case-Smith J (2002) Relationships between handwriting and keyboarding performance of sixth-grade students. Am J Occup Ther 56:34–39. https://doi.org/10.5014/ajot.56.1.34
12. Engel-Yeger B, Nagauker-Yanuv L, Rosenblum S (2009) Handwriting performance, self-reports, and perceived self efficacy among children with dysgraphia. Am J Occup Ther 63:182–192
13. Prunty MM, Barnett AL, Wilmut K, Plumb MS (2013) The impact of handwriting difficulties on compositional quality in children with developmental coordination disorder. Br J Occupat Therapy 79(10):591–597. https://doi.org/10.1177/0308022616650903
14. Preminger F, Weiss PL, Weintraub N (2004) Predicting occupational performance: handwriting versus keyboarding. Am J Occup Ther 58:193–201. https://doi.org/10.5014/ajot.58.2.193

15. Yazit RNSRM (2020) Window design for optimum classroom daylight in Islamic school. PhD thesis, Universiti Sains Islam Malaysia, Faculty of Engineering and Built Environment
16. Husini EM (2016) Occupant density and daylight illuminance level fluctuation for office building in Malaysia. PhD thesis, Universiti Teknologi Malaysia, Faculty of Built Environment

The Correlation Between Indoor Radon Concentration for Different Types of Building and Its Ages

Norhayati Abd Manap, Norelyza Hussein, Suhairul Hashim, and Zainura Zainon Noor

Abstract Radon is a naturally occurring gas that originated from the geology material. Most of the building materials like bricks, concrete blocks, aggregates and sand produce radon gas and it will exhale into the residential building. The high contamination of indoor radon gas in the residential building is very harmful to human health. Therefore, this study was conducted to investigate the indoor radon concentration in residential buildings as well as its relationship with building material and age of the building. The Radon Eye detector has been used to measure the indoor radon concentration. Based on the finding results, the indoor radon concentration of concrete type residence, 283 Bq/m^3 is higher than the wooden type of residence 14.13 Bq/m^3. However, few mitigations can be taken to reduce the indoor radon gas included to provide good ventilation system in the residence.

Keywords Radon · Indoor air pollution · Air quality · Building materials · Building ages

1 Introduction

Indoor air quality is very important to human because most people spend about 90% of time indoor either at home or in working area [1]. Thus, indoor air quality has a significant impact on human health. One of hazardous indoor air pollutants is radon. Radon can be defined as a radioactive gas that originated from geological materials which usually used in the building construction like aggregate, sand, and cement. The exhalation of radon gas from the building materials will accumulate in the building. If indoor radon gas been inhaled by human, its will cause the damage of respiratory system [2] and it had been agreed by Ahmad et al. [3]. World Health Organization (WHO) [4] and Internal Research on Cancer Canter (IRCC) had declared the radon gas as a carcinogenic gas for lung.

N. A. Manap (✉) · N. Hussein · S. Hashim · Z. Z. Noor
Universiti Teknologi Malaysia, Johor Bahru, Malaysia
e-mail: norhayati3@graduate.utm.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_10

The study should therefore be conducted to investigate the concentration of indoor radon in residentials buildings, especially its association with their age and type of building material. There is currently no clear law and regulation in Malaysia implemented by policy makers related to guidelines, requirements, or solutions to mitigate the risks of residential indoor radon concentration. This research was therefore carried out to identify the radon concentration in indoor residential buildings to help policy makers and industry solve the problem of indoor radon contamination in residential buildings.

Generally, this study is conducted to measure the indoor radon concentration for the different types of residence. There are three objectives of this research:

1. To measure the indoor radon concentration for different types of residential in Johor Bahru, Pahang, Negeri Sembilan, Kelantan and Putrajaya.
2. To investigate the correlation between indoor radon concentration and its building materials.
3. To investigate the correlation between indoor radon concentration and its ages.

2 Methodology

The indoor radon concentration measurement activity began from 17 August 2020 and was finished on 9 September 2020, taking approximately 22 days to complete. In the various types of residence, radon concentration measurement was performed, including single storey terrace, double storey terrace, multistorey, and residence on the village lot. The number of years of residency ranges from 2 to 30 years.

2.1 Indoor Radon Concentration Measurement by Using Radon Eye Detector

Radon Eye detector was used to measure the indoor radon.It is known as a user-friendly device because it is easy to operate. The detector is equipped with limit indicator (LED sign) which will show sign the indoor radon concentration exceeding the US EPA allowable limit, 148 Bq/m^3 as shown in Fig. 1.

2.2 Location of the Study

This research had carried out in 5 states in Malaysia inclusive Johor, Negeri Sembilan, Putrajaya, Pahang, and Kelantan. The Radon Eye detector has been used to measure the indoor radon.

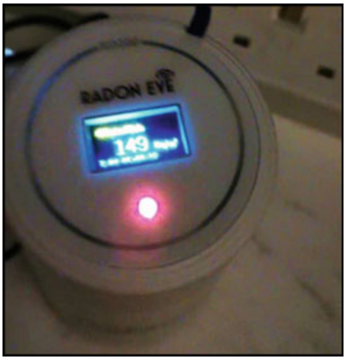


Fig. 1 LED blinking when indoor radon exceeding the allowable limits, 148 Bq/m^3

3 Results and Discussion

Measurement of indoor radon concentration was performed in 10 residential units in 5 Malaysian states. All these residentials were chosen in accordance with their types and ages. The Radon Eye detector measurement unit is in becquerel per cube meter (Bq/m^3).

3.1 Indoor Radon Concentration Measurement Data in the Different Types of Residential

The measured data for all types of residential has been shown in Table 1:

The highest value of indoor radon concentration is in the multistorey residential located at Putrajaya with 283 Bq/m^3. The type and characteristic of soil also play an important role to identify the level of radon gas concentration. Putrajaya was overlain on the Hawthorden Schist which located at the bottom of the rock layer followed by the sedimentary rocks of Kenny Hill formation which it consists of interbedded sandstone and shales. Then the upper layer of the rock is granite body [5]. According to a research by Deborah Tolulope Esan [6], the rock types of soil usually contain high natural radioactivity includes radon. Other than that, the second higher of indoor radon concentration is located at Kelantan and its concentration is 116.5 Bq/m^3. The major soil types in Kota Bharu Kelantan are mainly sand, gravel, silt and clay. Then, it is underlain by granite and metasedimentary rocks [7]. These types of soil contain high concentration of radon gas and they also contribute to the high concentration of indoor radon in that residence. These 2 levels exceeded the national average concentration reference level by WHO, 100 Bq/m^3 and it will increase the risk to get lung cancer [4]. The lowest value of indoor radon concentration is 14.13 Bq/m^3 and the type of residence is wooden village lot residence and located at Felda Sg Koyan 3, Pahang. The type of soil in Raub, Pahang mostly originated from silt loam soil

Table 1 Average indoor radon concentration for all types of residential

Item	Type of residential	Location	Residential ages (Years)	Level	Type of building material	Average indoor radon concentration (Bq/m^3)		Std. dev.
1	Single storey terrace residence	Taman Universiti, Johor	26	Ground floor	Concrete	31.38	+	17.88
2	Double storey terrace residence	Jalan Sejambak Taman Bukit Dahlia, Johor	10	Ground floor	Concrete	22.75	+	9.81
				First floor	Concrete	53.13	+	9.59
3	Double storey terrace residence	Jalan Semerbak Taman Bukit Dahlia, Johor	2	Ground floor	Concrete	22.75	+	9.81
				First floor	Concrete	40.00	+	5.89
4	Village lot residence	Felda Jengka 4, Pahang	10	Ground floor	Concrete	31.00	+	8.21
5	Village lot residence	Felda Palong 13, Negeri Sembilan	10	Ground floor	Concrete	33.50	+	11.47
6	Village lot residence	Felda Sg Koyan 1, Pahang	20	Ground floor	Concrete	40.00	+	6.12
7	Village lot residence (Wood)	Felda Sg Koyan 3, Pahang	30	Upper floor	Wooden	14.13	+	2.53
8	Multistorey residence	Apartment in Horizon Hills, Johor	6	Level 6	Concrete	27.25	+	6.08
9	Multistorey residence	Hotel in Putrajaya	7	Level 24	Concrete	283.00	+	18.51
10	Multistorey residence	Apartment in Kota Bharu, Kelantan	6	Level 9	Concrete	116.50	+	11.70

[8]. With reference to the previous study, the radon concentration in silt loam soil is less than sandy or rock soil.

3.2 The Correlation Between Indoor Radon Concentration with Its Building Materials

The hypothesis indicates that the indoor radon concentration in the concrete residence shall higher than the concentration in the wooden residence. The results of this study had indicated that the hypothesis is correct because the highest concentration of indoor radon gas had accumulated in the concrete multistorey building located at Putrajaya with an average concentration of 283 Bq/m^3. The high concentration in that building perhaps due to no natural air ventilation in the room because all windows and doors were closed. Therefore, the exhaled indoor radon from the building material was accumulated in the room and increase the concentration of indoor radon.

However, the lowest concentration of indoor radon in this study is 14.13 Bq/m^3 belongs to the Wooden Village Lot Residence located at Felda Sungai Koyan 3, Pahang. This residence was fully constructed by using wood. Based on the study carried out by Lee et al. [9], the wooden structure material does not exhale the radon gas and its lower concentration might be originates from surrounding soil.

3.3 The Correlation Between Indoor Radon Concentration with Ages of Residential Building

Based on the hypothesis, the indoor radon concentration of the older building supposedly higher than the new building. The results of this study had proved that the above hypothesis is correct. Table 1 shown that the highest indoor radon concentration is in the 10 years double storey residence with 53.13 Bq/m^3 compared to the 2 years residence which only 40 Bq/m^3. For multistorey resident (Concrete Type), the result had indicated that indoor radon concentration in Hotel at Putrajaya is 283 Bq/m^3 and its age is 7 years which is higher than the other two units of 6 years ages of multistorey residences and its concentrations are 116.5 Bq/m^3 for Apartment at Kelantan and 27.25 Bq/m^3 for Apartment at Johor Bahru. There is a big gap between the indoor radon concentration in a Hotel in Putrajaya and the other two multistorey residences. This is most probably because the Hotel in Putrajaya is not operated for the long-time duration due to the closure during Movement Control Order (MCO). Therefore, it causes the indoor radon gas accumulated in the room as well as increase the concentration. The lowest indoor radon concentration is 27.25 Bq/m^3 which located in the Apartment at Johor Bahru. Its lowest value most probability caused by the good ventilation system in that resident. Other than that, the concrete type village lot residence indicated that the highest concentration is 40 Bq/m^3 and the ages of residence is

20 years compared to the lowest concentration 31 Bq/m^3 and the ages of its building is 10 years. It is usually having some crack and it allows the radon gas emanating from the ground sip into the building. The structures of new building usually still in good condition compared to the older building.

3.4 Mitigation Measures

Providing good ventilation system is one of the strategies that can be used to reduce the concentration of indoor radon in the residential setting. The residence must have enough natural opening to prevent the accumulation of radon in the building.

4 Conclusion

The presence of radon gas in the building will cause a bad effect on human health. Nowadays, majority of building materials are made from soil and rock included bricks, sand, cement, and aggregate which will exhale radon gas into the residence. Based on this study, the indoor radon concentration in the residence made of concrete is higher than the residence made by wood. The other factor affecting the indoor radon concentration is the age of building because this study showed that the indoor radon concentration in old building is higher than new building. Therefore, few mitigations shall be taken to reduce the indoor radon. Further research needs to be carried out to assist the policy maker to implement the utilization of the low radon gas material in construction industry and incorporate this requirement in law and regulations.

Acknowledgements This work was supported/funded by the Ministry of Higher Education under Fundamental Research Grant Scheme (FRGS/1/2019/WAB05/UTM/02/7) and Universiti Teknologi Malaysia under UTMShine Signature Grant (Q.J130000.2451.07G91)

References

1. Dales R, Liu L, Wheeler AJ et al (2008) Quality of indoor residential air and health. Can Med Assoc J 179(2):147–152
2. Nonka GA, Dali TPA, Koua AA et al (2017) Dosimetric impact of indoor radon gas on the population from the commune of Yopougon, Abidjan, Cote d'Ivoire. J Radiat Res Appl Sci 10(4):295–300
3. Ahmad N, Khan IU, ur Rehman J et al (2017) An overview of radon concentration in Malaysia. J Radiat Res Appl Sci 10(4):327–330
4. World Health Organisation (2020) WHO calls for tighter standards on indoor radon [Internet]. https://www.who.int/phe/radiation/backgrounder_radon/en/
5. Ahba NA, Hussin A (2002) The occurrence and classification of hard rock body in Putrajaya and its implication to construction activities. War Geol 28(3):123–128

6. Esan DT, Sridhar MKC, Obed R et al (2020) Determination of residential soil gas radon risk indices over the lithological units of a Southwestern Nigeria University. Sci Rep 10(1):1–10
7. Shaari NA, Khan MMA, Bahar AMA et al (2016) Estimation of infiltration rate in major soil types of Kota Bharu, Kelantan, Malaysia. Bull Geol Soc Malaysia 62:7–11
8. Follett RF, Barber SA (2020) Properties of the available and the soluble molybdenum fractions in a Raub silt loam. Soil Sci Soc Am J 31(2):191–192
9. Lee JY, Choi GW, Kang SG (2018) Radon exhalation from five wood species. J Korean Wood Sci Technol 46(6):735–747

Developmental Stages of Eversley Childs Sanitarium—An Urban and Architectural Approach

Bela Lanyi

Abstract In the present pandemic, social distancing for health care calls for special attention. Eversley Childs Sanitarium and General Hospital (ECSGH), originally Eversley Child Sanitarium (ECS) in Metro Cebu/Philippines has been representing for decades a humane health care philosophy and built environment. In this study, the researcher inserts ECS in the typology of leprosy facilities and investigates its transition through time. He follows up the social-medical backgrounds of each spatial developmental phase. Comparing ECS with historical leprosy facilities, the researcher proves that from its foundation on, ECS has been following community-driven medical principles and realized corresponding architectural-urban features. The main finding consists in the resiliency of the Sanitarium's original design philosophy which is in position to give impulse for an incoming heritage conservation and urban rehabilitation. The researcher recommends to update the area to a modern hospital with a cluster of livable new subdivision designs in conformity with ECS' original dynamics.

Keywords Philippine architecture · Health-care architecture · Leprosy sanitarium · Urban sanitation · Heritage conservation

1 Introduction

ECS has been a successful leprosy facility for decades, despite frequent revisions of the disease's treatment. The researcher investigated it as a venue of continuously changing medical strategies which manifest themselves in adequately continuously changing architectural and urban forms. Although, fortunately, almost nothing of the original buildings had been demolished, they were being altered and reassessed through new buildings and an urban sprawl. In this resilient connection between medical strategies and design, the researcher recognizes a strong impulse for ECS'

B. Lanyi (✉)
University of San Carlos, Cebu City, Philippines
e-mail: blanyi@usc.edu.ph

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_11

incoming urban rehabilitation. The study's significance is its support for architectural and health-care consciousness in the Philippines.

2 Literature, Review of Sources

Early accommodations for lepers served the society's self-protection with little hope for healing. In the end of the nineteenth century, Hansen discovered the cause of leprosy, a bacillus—but he could not offer a medicine. This made the fear of infection stronger and caused so-called Segregation Laws. On the other hand, the call for the community's healing power also became heard. The study "The Dawn of Humane Leprosy Segregation: Transforming Leprosarium into Home" [1] distinguishes this community-driven approach from formal institutional approaches to leprosaria like the American National Sanitarium in Carville, USA [2]. Leprosy colony Culion (Philippines) was a first model realizations of principles approved at the Third Leprosy Conference in Strasbourg (1923). The social-political conditions of that time can be studied in Moran's book [3]. The following authors helped studying the predecessor institutions: Bailey [4], Robertson [5], Sakaino [6], The Leprosy Mission [7], and Chapman [8]. Interviews were made with stakeholders of ECS.

The leprosy sanatorium in Cebu, now called Eversley Childs Sanitarium and General Hospital (ECSGH), is located in Mandaue City (Cebu Province). The place is healthy: outside the city but not far. It was founded during the American colonial time by the Leonard Wood Foundation with Mr. Eversley Childs as donor, with involvement of Catholic male and female religious [9]. Construction began in May 1928 and was completed two years later on May 3, 1930. There were 52 concrete buildings, waterworks, sewage system, a telephone system, equipment and the like. It was occupied on May 26 with 540 patients transferred from the Carreta Treatment Center ("Cebu Skin Clinic)" [10]. ECS homepage indicates that originally inhabited area was Block I (32.2830 ha acquired in 1930), while in 1932, a work area, Block II, with 19.9575 ha, was added [9].

The urban planning of the area is unique. While it takes over urban planning of traditions of health-care facilities, it smartly adjusts itself to the local topography which contains a central plateau and several hill ridges. This kind of distribution of buildings is very much valuable as it breaks the buildings into small and uses the terrain's abilities.

"Eversley Childs Treatment Station was the first regional institution established purposely to make segregation and treatment of patients suffering from leprosy more attractive. This was a departure from the system of compulsory segregation of all bacterio-positive cases in Culion. It was later renamed ECS" [9]. ECS' area witnesses a community-oriented philosophy that, despite legal and habitual calls for separation and social distancing, saw healing as a community achievement.

3 Research Methodology

This study is a "case study research, a strategy in which a particular setting or circumstance is investigated holistically using a variety of data collection and analysis tactic" [11]. Thus ECS is viewed within the context of history (developmental stages), medical science (improving treatments), and sociology (formal and informal settlers). The research inserted ECS' core philosophy and its realization in the historical development of leprosy treatment. From the institutional and the community-driven approaches to Hansen's disease the research identified key principles of the community-driven approach and proved that these principles shaped ECS's architectural and urban design. Then the research mapped out the resilient continuation of ECS' core philosophy amidst changing medical technology and urban sprawl. In terms of limitations, this study covers only the original (1932) territory of ECS which needs an architectural-urban rehabilitation.

4 Key Principles of Historical Community-Driven Leprosaria

To identify key principles of historical community-driven leprosy settlements, the study correlates their *major spatial design features* with their *partial healing objectives.* The set of principles below, marked with letters from *A* to *I*, was extracted from Lim's paper (1) which contained but not explicitly listed them up. *Chapel and Convent buildings (A)* serve the patients' spiritual needs. They provide loving medical and personal care, counseling, and morale-building services. *Scenic building environment (B)* serves emotional relief. A major factor was to create *cottages instead of wards*, a *home rather than an institution (C).* "To establish a humane leprosarium, the arrangement of patient's houses should not be rigid or in massive scale. The whole leprosarium complex should be broken down into smaller forms and distributed on pleasant landscape," as observed by Lim and Lim [1, p. 5; 12] *Verandahs* provide fresh air. *Distinguished house rows separated genders and married couples (D)* to avoid children contagion. In fact, the only contrast between this leprosarium and a regular village was that male and female could not reside together [13, pp. 215–230]. *Workspaces for productive labor (E)* were provided in buildings and on the area. *Common facilities for an efficient community (F)* expressed a strive for self-support and self-governance of the patients. *School rooms (G)* expressed a sign of hope. *Various health-care buildings (H)* served a holistic care.

5 The Original Approach of ECS Was Community-Driven (1928–1932)

In this chapter, the researcher proves that the major principles of community-driven approach were applied here, despite the (at that time compulsory) social distancing. *Chapel and convent (A)* made the settlement resemble a monastery. Its center is Sacred Heart Chaplaincy (1932) [14]. For *scenic environment for emotional relief (B),* ECS was built on a hilly area but close to the sea and to a strong spring with potable water. *Cottages instead of wards—a home rather than an institution (C)* were built. This allowed a better identification of patients of the same cottage. The patients were empowered by the trust of a smaller community and less institutional control. "Each cottage housed 20 patients in a one-room house. There was no compartment. Five beds were placed on each sides, each with a bed-side table. The patients cooked" [15]. Bathhouses outside the cottages served hygiene.

Each ESC cottage had a *verandah for fresh air (D)*, cross-ventilation and community area. *Building rows for gender separation (E)*, a building law requirement of those times, was carefully realized in the urban design of the Sanitarium. The twenty two (22) male cottages were distributed on the tableland and partly on two mountain ridges. The eleven (11) female cottages were arranged on the other side of the playground plaza, in a plan forming letter "A". However, the community principle prevailed, despite strict separation, since the plaza serves not only a spatial separation but also a connection through common activities. *Workspaces for Productive Labor (F)* consisted in workshops and huge agricultural and fishery areas [15].

Common Facilities for Community-Driven Self-Support (G) were the administration and event buildings which expressed a democratic attitude of self-government for more than 1,000 patients and new contacts. An own patient police maintained border control and internal discipline. When after the 1980s, this order was challenged by locker medical rules and growing urban sprawl—inner fences had to be erected. Regularly, entertainment and sport events took place. *Teaching–learning (H)* provided in ECS was necessary since here born children were prevented from outside ducation due to the stigma of their parents' leprosy. *Holistic care (I)* provided well-equipped infirmary buildings and even a cottage for tuberculosis cases. The community had its own cemetery.

6 Further Developmental Stages

Updating the Sanitarium (1930–64) was the next developmental stage of the Sanitarium due to a new medical achievement in the 1950s. The introduction of Sulfones in the early 1950s changed the directions of sanitaria and patients' hopes. The Philippines, and this sanitarium in particular, was involved in medical research. Foreign scientists frequently arrived and spent significant time here. The growing Philippine population and the lack of efficient therapy led to a growing number of patients.

After WWII, ECS remained intact and was completed with a few new buildings for a growing number of patients with a peak in 1955 of 1,250 patients. A new a research building was built, with a farm for test animals.

After Lifting of the Separation Law (1964–1988), medical science confirmed the healing power of community and the human dignity which were always the convictions of ECS. A milestone here was the "Lifting the Separation Law" rule which instructed that "no persons afflicted with leprosy shall be confined in a leprosarium but be sent to skin clinics or physicians—except for some special cases" [16]. The number of patients decreased but there were also "healed" patients who relapsed. Thus some cottages were changed into daycare centers. Former hansenites still had to be accommodated who could not go back to their original place because the leprosy permanently changed their appearance, even if they were not any more contagious. Male and female were not any more separated—thus villages ("barrios") inside the Sanitarium came into existence but at that time, only for patients and their close relatives. A circumferential road was built to connect the villages which occupied "valleys" between cottage areas which were unused in the original design.

The Change to a Regular Hospital (1988–) is the recent trend after a new, finally very efficient and quick treatment (*Multiple Drug Therapy* or *Rifamicin*) made home treatment without infection possible. The successes of this multidrug therapy resulted in the Devolution Law (1991) which rationalized admission, discharged those who did not need hospitalization, and provided cash incentives for former patients who decided to leave the Sanitarium [17]. However, most of them did not want to leave because their appearance hindered them in job opportunities outside. Both the decreasing number of patients and the increasing medical expenses made the change to a regular hospital necessary. The Government' *Sanitarium Convertion Plan (1999)* foresaw here a general hospital. Thus in 2006, ECS was provided an allowance of 450 beds as a Sanitarium and 50 beds as a General Hospital. Today, only four (4) original cottages are occupied by hansenites who are negative patients with visible body damages [15].

Recent new buildings are the Outpatient Building and the Clinics Building (2008). At present, construction of a modern, multistory building is ongoing. While beautiful new buildings are being erected, the researcher observed how the original cottages under heritage protection are getting deteriorated. Due to decreasing discipline and urban sprawl, outside illegal settlers moved in (2000–today). Most of the unused original cottages were turned over to Sanitarium employees [10, 15]. For protection in a chaotic situation, the Hospital Area and the Custody Care Area had to be fenced [15]. Only one local researcher uses the underused Research Building. As an unfortunate recent development, landtitle claims arose abusing inaccuracies in the land acquisitions' documentation more than 80 years ago. Although presidential decrees twice ordered that associations of inhabitants be protected with land titles but 400 families still live in insecure legal conditions [18–20].

7 Findings, Conclusions

The Sanitarium's original design sensitively mirrors the professional philosophy behind it. Treatment strategies and hopes for healing underwent several changes—and the Sanitarium was always able to physical facilities. Thus in chronology, its spatial development corresponds to changes in leprosy healing. ECS is a very dynamic and sensitive example of health-care architecture where old buildings can adapt to new situations and accept additional new buildings in a flexible and organic cooperation of building generations. In fact, its heritage conservation is necessary not only for cultural awareness but also for health care consciousness. The researcher's feeling is that the building complex will undergo a radical change through its accepted new role as a General Hospital.

References

1. Lim JJ, Lim YL (2013) The dawn of humane leprosy segregation: transforming leprosarium into home. Department of Architecture, Faculty of built Environment, Universiti Teknologi Malaysia, Skudai, Johor, p 4
2. Martin B (1963) Miracle at Carville. Image Books
3. Moran MT (2007) Colonizing leprosy (2007) imperialism and the politics of public health in the United States. University of North Carloina, Chapel Hill, USA
4. Bailey W. The lepers of our Indian Empire (1890–91) a visit to them in 1890–91. Darien Press
5. Robertson J (1964) The leprosy asylum in India: 1886–1947. J Hist Med All Sci 474–517
6. Sakaino K (2007) Research on the transition of residential environment and facility configuration of leprosy sanatorium (in Japanese). Dissertation, Kyoto University, Kyoto, Japan
7. The Leprosy Mission (1974) This spreading tree: the story of the Leprosy Mission in the second half of its hundred-years' ministry. The Leprosy Mission
8. Chapman RF (1982) Leonard Wood and leprosy in the Philippines: the Culion Leper Colony, 1921–1927. Ronald Fettes, Chapman
9. Eversley Childs Sanitarium and Hospital (2021) [Online]. https://ecs.doh.gov.ph/13-about-us. Accessed 6 June 2021
10. Javier SCFr (2021) Interviewee, Eversley Childs Sanitarium. [Interview]. 14 May 2021
11. Groat LN, Wang D (2013) Architectural research methods. Wiley, Hoboken 2013:18
12. The Best Type of Wards (1920) In: Conference of leper asylum superintendents and others on the leper problem in India, Calcutta
13. Kakar S (1996) Leprosy in British India, 1886–1947: colonial politics and missionary medicine. Med Hist 215–220
14. Bacaltos EFr (2021) Interviewee, Eversley Childs Sanitarium. [Interview]. 14 February 2021
15. Sabuero N (2021) Interviewee, Eversley Childs Sanitarium Museum. [Interview]. 15 May 2021
16. RA No. 4073
17. Devolution Law, RA No. 7160
18. Eversley Sanitarium Dwellers Get Lots for Socialized Housing, Cebu Daily News, 2009
19. Presidental Proclamation No. 1772 of 2009 (2009) Manila, 2009
20. Zerna PM, Zerna DF. Interviewees, Eversley Childs Sanitarium. [Interview]. 12 March 2021

Impact of the 4.0 Industrial Revolution on the Construction Industry in Malaysia

Gunalaan Vasudevan and Wong Wei Ming

Abstract This paper discusses the impact of the 4.0 Industrial Revolution on the Malaysian construction industry, which has been evolving since the 1980s. This research seeks to investigate and understand the increasing awareness for a comprehensive change in the social needs in the modern construction industry. One hundred respondents completed the questionnaire for this study and the results were analyzed and tabulated using the SPSS system. Most respondents agreed or strongly agreed that they look forward to Malaysia adopting the industry 4.0 technologies in the near future. Most respondents have a positive mindset and provided positive feedback. A strategic construction knowledge in the application of Industry 4.0 technologies can ensure a better future and benefit the construction industry in Malaysia. Presently, the impact of industry 4.0 on the Malaysian construction industry is still in its early stage relative to other countries. Proper utilisation of industry 4.0 technologies will take the Malaysian construction industry to the next level.

Keywords 4.0 Industrial Revolution · Construction industry · Strategic construction

1 Introduction

The term Fourth Industrial Revolution was coined by Klaus Schwab, who is a former professor and the founder of the World Economic Forum. Technologies such as artificial intelligence, autonomous vehicles and the Internet of things are increasingly being infused and adopted in daily life. These technologies are even used in our bodies, such as voice-activated virtual assistants, facial identity recognition and health care sensor. In other words, modern technologies are increasingly merging with human life, and the technologies are currently transforming and evolving at a faster pace than the previous Industrial Revolutions. As a conclude for shape shaping the future technologies, the Fourth Industrial Revolution is making a way to changes ours

G. Vasudevan (✉) · W. W. Ming
Faculty of Built Environment, Department of Construction Management, Tunku Abdul Rahman University College Malaysia, Kuala Lumpur, Malaysia
e-mail: gunalaanv@tarc.edu.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_12

way of life and it impacting in every of the business in Malaysia as it is happening and changing without even a notice [1]. Associated with this flexibility, Industry 4.0 aims at overcoming contemporary challenges, such as intensifying global competition, volatile markets and demands, required customization, as well as decreasing innovation and product life cycles. Industry 4.0 serves as a useful and targeted approach to deal with these challenging requirements [2]. This process shows that Artificial Intelligence can operate by itself and co-function with humans to produce a customer-oriented product that continuously improves itself. The machine has the ability to collect data and analyse the data in a split second. Moreover, it has becoming in a way that they can introducing optimization, cognition, and customization by itself in the business industry.

2 Problem Statement

The Fourth Industrial Revolution could increase sales, revenues, and profit, reduce expenditure and introduce cutting edge technologies. Despite this, employment remains the most special aspect of the Fourth Industrial Revolution. An average employee would want to know if there will be a creation of new jobs; if the traditional industrial worker would be able to adapt to the new working environment; and if the changes would result in them losing their jobs. Even though the Fourth Industrial Revolution offers the most advanced technologies in manufacturing, the use of machines in the industry may replace the traditional way of working. The most challenging aspect in the Industry 4.0 technology is IT (Information Technology) security risk. Storing all data in the computer means they are exposed to data security problems such as a breach of the security system that leaks data to the public. The threat of cybercrime must always be given the top priority because it affects the nation and not just several individuals [3].

3 Research Methodology

The purpose of this information data is to investigating how is suppose that our chosen respondents where we had chosen from the area, we wanted to research and randomly selected 50 respondents and observe their answer of the question of Impact of Fourth Industrial Revolution in Malaysia's Construction Industry. The questionnaire was distributed to respondents in Klang Valley.

3.1 Part A (Demographic Information)

The questions in Part A gather information on the respondent's name and age, occupation, organisation, prior expertise and experiences with Industry 4.0 technology. This part will also involve the respondent's company or firm operate their company with their own method and opinion on Industry 4.0.

3.2 Part B (Respondent's Response)

The questions in Part B gather the respondent's responses and opinions on the modern construction industry being forced to abandon the traditional construction industry. The questions gather the respondent's opinion on the traditional construction industry before the adoption of Industry 4.0 and the impact of its adoption on the industry.

3.3 Part C (Respondent's Vision)

The questions in Part C are concerned with increase of consciousness of comprehensive of changing the social needs in construction learning. This section seeks to understand the respondent's preference based on their past and current e-learning experiences, the challenges in adopting Industry 4.0 in the construction industry, the vision of the future of the construction industry, and the advantages and disadvantages of Industry 4.0.

3.4 Data Analysis

The gathered data was analysed using the SPSS software. The software performs statistical analysis using learning algorithms, open or end source of extension, and integrate the data into the application.

4 Result and Discussion

4.1 Experience with Industry 4.0

Table 1 shows the frequency table for the experience with Industry 4.0 in the construction industry. More than half of the respondents, 52%, chose Maybe as the response, and 23% indicated that they do not have experience in Industry 4.0. The remaining

Table 1 Experience with Industry 4.0

	Frequency	Percent	Valid percent	Cumulative percent
Yes	25	25.0	25.0	25.0
No	23	23.0	23.0	48.0
Maybe	52	52.0	52.0	100.0
Total	100	100.0	100.0	

25% of the respondents have experience applying Industry 4.0 in the construction industry.

4.2 Awareness of the Changing Social Needs in the Modern Construction Industry

Figure 1 shows that the highest mean of 4.09 is for the question, "Which method of producing a design drawing do you prefer, hand drawing the building design or using BIM to produce the building design? Do you prefer the method because of its efficiency and advantages?", indicating that most respondents agreed with the statement and most respondent have pick on agree. The second-highest mean of 4.01 is concerning the awareness for a comprehensive of changing the social needs in the construction industry. "If Malaysia has implying technology of industry 4.0, and do you think you can able to work with the technology?" and "Do you look forward to Malaysia adopting the industry 4.0 technology in the near future?" Most respondents has chosen more tend towards agreeing with the opinion. Moreover, as for the third highest Mean is 3.94 where is it the question "Should people start to look more into the future construction industry with Industry 4.0?" as most respondents also tend to agree than disagree. Following as the fourth highest Mean is 3.91 which indicate of "If working beside with modern technology, do you think it will bring more benefit than less benefit to the construction industry?" most of the respondents also chose

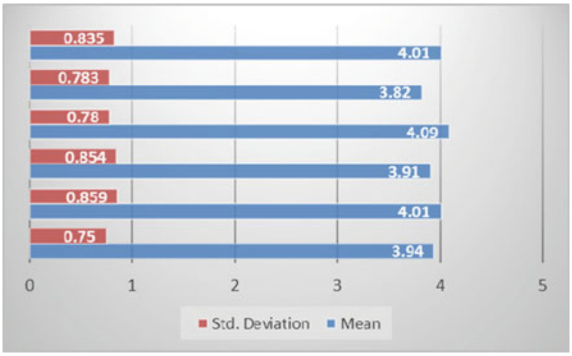


Fig. 1 Awareness of the changing social needs in the modern construction industry

towards more agree than disagree and neutral. Last but not least for, least amount of Mean which is 3.82, represent of "Do you think technology industry 4.0 brings people unite as one and gather people working together?" while even though is least Mean among them but it is also the most respondents has chosen agree on.

4.3 Identify the Modern Business Industry That Is Forced to Abandon the Traditional Business Industry

The descriptive statistics in Table 2 shows that the question "Do you think that the 4.0 Industrial Revolution has an impact on the Malaysian construction industry?" has the highest mean of 3.93, which means that most respondents agreed with the Yes the statement with the second-highest mean of 3.86 is "Do you think economic, organization, politic and even social will become more challenging if implying industry 4.0 technology in construction industry?" Moreover, as for the third and fourth is the factors has the Mean,3.86 about respondent choose agree on "Do you think economic, organization, politic and even social will become more challenging if implying industry 4.0 technology in construction industry?" and Fourth Mean is present by 3.74 which mostly respondent will chooses agree on the factor Malaysia's Government will support industry revolution 4.0 in the construction industry?". List going to the Mean is 3.70 represent to the factors of "If all of the traditional construction industry will be fully replaced with industry revolution 4.0, is it acceptable for you?" of most respondent had chosen agree on and Mean is 3.20 which represent the factors of "Do you think those who still using traditional method will out of job the response to the question "Do you prefer using traditional construction method over

Table 2 Descriptive statistics for identifying the modern business industry forced to abandon the traditional business industry

	N	Mean	Std. deviation
Do you agree with completely replacing the traditional construction industry with the 4.0 Industrial Revolution?	100	3.70	0.732
Do you think that the 4.0 Industrial Revolution has an impact on the Malaysian construction industry?	100	3.93	0.756
Do you think that the Malaysian Government supports the 4.0 Industrial Revolution in the construction industry?	100	3.74	0.883
Do you prefer using the traditional construction method over the modern construction method?	100	3.18	0.845
Do you think that utilizing industry 4.0 technology in modern construction would incur higher costs than the traditional construction method?	100	3.87	0.787
Do you think economic, organization, politic and even social will become more challenging if implying industry 4.0 technology in construction industry?	100	3.86	0.817

Table 3 Descriptive Statistics for whether the revolution resulted in greater disparity in the modern construction industry

	N	Mean	Std. deviation
Do you think the increased use of industry 4.0 technologies will increase the society's anxiety with the construction industry?	100	3.27	1.014
Do you think it will cause more obvious on Low skilled/Low pay and High skilled/High pay in the future construction industry if utilizing industry 4.0?	100	3.63	0.800
Do you think human worker will want to work together with technology industry 4.0?	100	3.80	0.752
Do you think the workers see technology industry 4.0 as a threat to their work/job?	100	3.13	1.186
Do you think people can put their trusting in technology Industry 4.0 and allow them to carry the burden of the work?	100	3.82	0.809
Do you think employer should allow their worker to take academic purpose for better efficiency to operate technology industry 4.0?	100	4.12	0.671

the modern construction method?" has the lowest mean of 3.18. Most respondents have no preference and will abide by the decision made by their organisations.

4.4 *Examine the Revolution Lead to Greater Dissimilarity in Modern Construction Industry*

Table 3 shows that the statement "Do you think employer should allow their worker to take academic purpose for better efficiency to operate technology industry 4.0?" has the highest mean of 4.12, indicating that most respondents not agreed with the question. The second-highest mean of 3.82 is for the question "Do you think people can put their trusting in technology Industry 4.0 and allow them to carry the burden of the work?" indicating that a higher number of respondents agreed with the question relative to those who disagreed or are neutral. The 3.80 mean for the statement "Do you think human worker will want to work together with technology industry 4.0?" indicates that most respondents are willing to work using industry 4.0 technologies. The question "Do you think it will cause more obvious on Low skilled/Low pay and High skilled/High pay in the future construction industry if utilizing industry 4.0?" has a mean of 3.63, which shows that most respondents either agreed with the question or were neutral regarding whether Industry 4.0 will completely replace and not replaced them. Most respondent either agreed with the question or are neutral concerning the question "Do you think the rise of industry 4.0 technology will increase the society to more worry about construction industry?"; this statement has a mean of 3.27. Finally, the question "Do you think people see industry 4.0 technology as a threat to their work/job?" has a mean of 3.13, indicating that most respondents are neutral relative to those who agreed or disagreed. They believed that Industry 4.0 would not necessary fully replaced work job or fully replaced the work job.

5 Conclusions

In conclusion, Industry 4.0 or the 4.0 Industrial Revolution has an impact on the Malaysian construction industry [4]. Although Malaysia is still in the early phase of the 4.0 Industrial Revolution relative to other countries, its construction industry will achieve a higher level that would bring prosperity and glory to Malaysia. It is based on economic, social, political, and organization challenge on construction industry with how respondents is looking regarding modern construction industry is slowly replaced traditional construction industry [5]. The respondents of this study agreed that the modern construction industry should replace the traditional construction industry. like project the executives, arranging and configuration just as the offsite assembling and supply of building materials with utilizing industry 4.0 can be easily execute efficiency and less cost required. Most of the respondents look forward to adopting Industry 4.0 since this could meet the requirement of how the social needs regarding in efficient and quality in future construction industry and such as interoperability is the way of communication of information the data to finalize the report like measurement and coordination in construction field with more emphasis in priority and better condition of the data and enable to access and comprehensive the data [6]. Industry 4.0 enhances the overall of the efficiency construction industry.

Future research could investigate the data on the impact of the Fourth Industrial Revolution on Malaysia's construction industry may not be accurate. and each of construction worker's opinion might be varies and also different. Allowing to be part of actual experiencing in Industry 4.0 impact Malaysia's construction firm to understand more about the research topic. Modern construction industry force to replaced traditional construction industry, awareness of comprehensive of social needs in construction industry and Industry 4.0 escalate social tension in construction industry [7].

References

1. Chen B (2017) Smart factory of Industry 4.0: key technologies, application case, and challenges
2. Dahlan MS (2017) Industry 4.0 and it effects toward industry
3. Dallasega P (2018) Industry 4.0 as an enabler of proximity for construction supply chains: a systematic literature review. Computer in Industry
4. Maskuriy R (2019) Industry 4.0 for the construction industry—how. MDPI
5. Mohammed BS (2018) Industry Revolution IR 4.0: future opportunities and challenges in construction industry. MATEC Web Conf

6. Oesterreich TD (2016) Understanding the implications of digitisation and automation in the context of Industry 4.0: a triangulation approach and elements of a research agenda for the construction industry. Computers in Industry
7. Zervoudi VK (2019) Fourth Industrial Revolution: opportunities, challenges, and proposed policies. Article, pp 11

The Challenges and Impacts of COVID-19 on the Construction Industry in Malaysia

Gunalaan Vasudevan and Yap Chai Yuen

Abstract The COVID-19 pandemic brings with it serious challenges that have a huge impact on the construction industry. Malaysia was placed under lockdown during the pandemic and a Movement Control Order (MCO) was enforced on 18 March 2020 to prevent the spread of COVID-19. This research seeks to determine the challenges and impacts of COVID-19 and the measures taken by the Government on the Malaysian construction industry. The literature review provides the theoretical background for the study and establishes, enhances, and consolidates the knowledge base for this study. A questionnaire survey using Google form was used to collect the data. One hundred questionnaires were distributed to gather the data. This survey was carried out in Klang Valley, Kuala Lumpur. This study used the SPSS software to analyze the collected data employing frequency analysis, descriptive analysis, and chart builder. The findings of this research contribute to the body of knowledge on the challenges and impacts of COVID-19 and the measures taken by the Government on the construction industry in Malaysia.

Keywords COVID-19 · Construction industry · Impacts · Challenges · Government measures

1 Introduction

Coronavirus disease (COVID-19) is a new disease that appeared in China and was transmitted to humans from animal species. In humans, COVID-19 can cause an illness that ranges from the common cold to moderate respiratory illness. The rapid spread of COVID-19 in Malaysia brings forth many challenges that impacted the construction industry and economy [1].

The Federal Government imposed a nationwide Movement Control Order (MCO) on 18 March 2020, which was then extended to 9 June 2020 to curb the COVID-19 pandemic. During the Movement Control Order, only essential services such

G. Vasudevan (✉) · Y. C. Yuen
Faculty of Built Environment, Department of Construction Management, Tunku Abdul Rahman University College Malaysia, Kuala Lumpur, Malaysia
e-mail: gunalaanv@tarc.edu.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_13

as banking and finance, health care, energy, transportation, e-commerce, and radio communication were allowed to operate [2]. Construction works were not included in the essential services and therefore were not allowed to continue. No new construction projects are allowed until the end of the MCO. The Ministry of Public Works enforced the Movement Control Order across the board except for the essential services and critical work that do not cause harm and pose danger to the public, environment, and workers [3].

The Covid-19 outbreak in Malaysia caused the construction sector to come to a temporary halt and 6.3% have become the lowest point and largest contraction on the record as compared with the previous period. Construction activities declined in the first quarter of 2020. Any subsequent extension and implementation of a Movement Control Order (MCO) would dampen Malaysia's economic activities due to the suspension of the operations by non-essential service providers.

2 Problem Statement

The COVID-19 pandemic brings with it a wide range of challenges to the Malaysian construction industry and has a significant adverse impact on the industry. It is estimated that the Malaysian economy incurred a loss of RM2.4 billion each day during the Movement Control Order because most businesses and industries could not start so as to export. According to Prime Minister Tan Sir Muhyiddin Yassin, the Movement Control Order resulted in Malaysia incurring a loss of RM63 billion, and extending the Movement Control Order for another month would cause an additional loss of RM35 billion, bringing the total losses to an estimated RM98 billion throughout the lockdown period [4, 5].

About 17,000 construction companies were affected by the COVID-19 pandemic. According to statistics from the Construction Industry Development Industry, the construction companies in Malaysia hire the highest workforce of 850,000 construction workers [6]. On 4 May 2020, the Government enforced the Conditional Motion Control Order (CMCO) that allowed the construction industry to operate on the condition they comply with the Government's Standard Operating Procedure (SOP).

Most building materials, including steel, aluminum, tiles, and architecture finishes, are imported from COVID-19 embattled countries such as China, Europe, and Indonesia because of their low price [7]. If COVID-19 continues to spread across the world, there might be supply chain bottlenecks that cause a delay in the shipment of the raw materials and equipment for all current projects. Construction companies have to face the challenge of assessing how they will complete all ongoing projects while complying with the Standard Operation Procedure (SOP). One of the challenges that developers have to deal with is manpower due to the strict requirement for physical distancing requirement on the construction sites.

3 Methodology

Research methodology is a system of procedures, techniques, and models for obtaining the results for a research problem. It is the most common element in research that considers the methods employed to achieve the aims and objectives of the research. The methodology adopted for this research comprises several processes, including research strategy, research approach such as a questionnaire survey, selecting the sample and determining the sample size, data collection, and data analysis using SPSS statistics software. This research discusses the quantitative methods employed for collecting and analyzing the data to achieve the research aims and objectives. The data were gathered through a literature review, questionnaire survey, and SPSS descriptive and frequency analysis [8].

4 Result and Discussion

Research methodology is a system of procedures, techniques, and models for obtaining the results for a research problem. It is the most common element in research that considers the methods employed to achieve the aims and objectives of the research. The methodology adopted for this research comprises several processes, including research strategy, research approach such as a questionnaire survey, selecting the sample and determining the sample size, data collection, and data analysis using SPSS statistics software. This research discusses the quantitative methods employed for collecting and analyzing the data to achieve the research aims and objectives. The data were gathered through a literature review, questionnaire survey, and SPSS descriptive and frequency analysis [8].

4.1 Government Measures to Control Covid-19 in Malaysia

Table 1 showed the frequency table for the measures taken by the Government to Control the COVID-19 pandemic in Malaysia. Fifty-four (67.5%) of the respondents agreed that the Government managed to control the spread of COVID-19 in Malaysia, while 26 (32.5%) disagreed. For example, the respondents believed that an effective

Table 1 Frequency table for the measures taken by the government to control the Covid-19 pandemic in Malaysia

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Yes	54	67.5	67.5	67.5
	No	26	32.5	32.5	100.0
	Total	80	100.0	100.0	

way to control the pandemic in the Malaysian construction industry is by improving the living condition and accommodation for the foreign workers and carrying out inspections at the construction sites. Any construction that fails to comply with the standard operating procedure must be closed immediately.

4.2 Disruption in the Supply Chain of Building Materials Due to COVID-19

For Table 2 shows that most respondents agreed with the statement that the prices of materials for producing steel imported from China have increased considerably and this resulted in a higher steel price; this statement has a mean value of 4.0875. The mean value for the second statement, which measures the respondent's agreement with whether the construction materials and finishes are stuck in the warehouses and at the ports during the restriction period, is 4.0750.

The Movement Control Order has resulted in the materials were stuck at the supplier's warehouses and port, and this caused an increase in the price of building materials. According to [9], the prohibition to transport non-essential goods, including construction materials, during the first phase of the Movement Control Order resulted in 70% of import containers being stuck at the port, including 50,000 20-foot equivalent units for the automotive and constriction industry stuck at the port.

The respondents agreed with the third statement that there was reduced cement production because cement plants were not allowed to operate during the Movement Control Order; the mean value for this statement is 4.0250. According to the Cement

Table 2 Descriptive statistics for the disruption in the supply chain of the building materials due to COVID-19

	N	Minimum	Maximum	Mean	Std. deviation
There was a disruption in the supply chain of construction materials and finishes because the materials were stuck at the supplier's warehouses and port during the movement control order	80	1.00	5.00	4.0750	0.97792
The price of raw materials imported from China to produce steel increased considerably and resulted in a higher steel price	80	1.00	5.00	4.0875	0.91671
Reduced cement production because the cement plants were not allowed to operate during the movement control order	80	1.00	5.00	4.0250	0.88554
Valid N (listwise)	80				

Note 1-Strongly disagree; 2-Disagree; 3-Neutral; 4-Agree; 5-Strongly agree and Concrete Association of Malaysia, the cement industry provides 100,000 jobs and service contracts to small and medium construction companies, such as contractors, suppliers, and developers. The cement industry was not allowed to operate during the phase 1 and 2 of the Movement Control Order, resulting in massive losses to the construction industry and late completion of projects because cement is one of the critical raw materials in the construction industry.

4.3 Delay in Construction Progress and Project Completion

Figure 1 shows that the mean for the first statement is 4.0750, which means that the respondents agreed they were affected by the limitation of 50% of the workforce on construction sites. The respondents agreed with the second statement concerning the lengthy period to test and inspect heavy equipment on the sites because they were idle during the Movement Control Order (mean value of 4.0). The third and fourth statements have a mean value of 3.9875 and 3.9375, indicating that the respondents agreed with the statement that the registration process to operate a construction site is time-consuming and the number of government officers to carry out inspection, particularly on the heavy machinery, is limited. The 3.9125 mean for the fifth statement shows that the respondents agreed they were unable to obtain permits or a

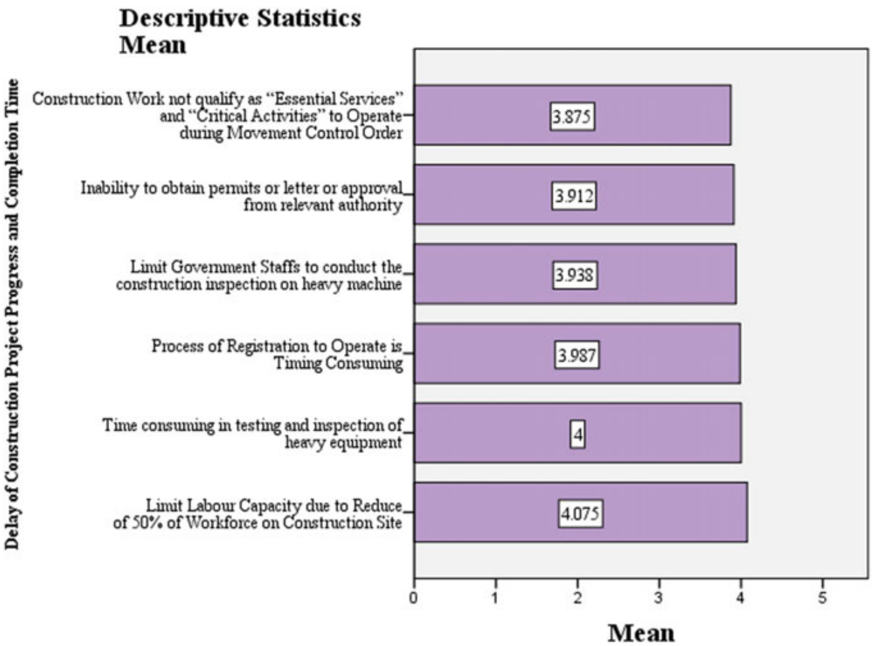


Fig. 1 Delay in construction progress and project completion

Table 3 Inspection of the construction sites in Malaysia

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Strongly disagree	3	3.8	3.8	3.8
	Disagree	3	3.8	3.8	7.5
	Neutral	6	7.5	7.5	15.0
	Agree	40	50.0	50.0	65.0
	Strongly agree	28	35.0	35.0	100.0
	Total	80	100.0	100.0	

letter of approval to operate from the relevant authority. The 3.8750 mean for the last statement indicates that the respondents agreed construction works are not essential services and critical activities during the Movement Control Order.

This not only affects the quality of labor but also the overall labor performance due to the limited number of workers allowed on the construction sites. Limiting the number of workers at the construction sites to 50% significantly reduced the labor productivity and capacity, and resulted in late completion of the projects.

4.4 Inspection of the Construction Sites in Malaysia

References Table 3 shows that forty (50%) respondents agreed with the inspection of the construction sites across the county by CIDB. Twenty-eight (36.5%) respondents strongly agreed with the statement, six (10%) were neutral, three (3.8%) strongly disagreed, and three (3.8%) disagreed.

5 Conclusions and Recommendation

There is a dearth of literature relevant to this research due to the limited research on COVID-19 in Malaysia. The limited literature review is one weakness of this research because it does not accurately represent the challenges, impacts, and government measures in dealing with COVID-19 in the construction industry. Another limitation of this research is the results of the findings do not reflect the general opinion of respondents because of their lack of in-depth knowledge on COVID-19. Due to time constraints, this questionnaire survey was conducted only in Klang Valley, Kuala Lumpur, and this could affect the accuracy of the data. The small sample size of 80 respondents may also affect the accuracy of this study.

This research sought to identify the challenges, impacts, and government measures taken to control the COVID-19 on the Malaysian construction industry. The results of this research are useful to the parties in the construction industry, including the employers, developers and consultants, and future researchers investigating the

COVID-19 challenges, impacts, and government measures for dealing with the pandemic. This area of research can help various parties in the construction industry understand the challenges and impacts of the pandemic and the measures taken by the Government to control the pandemic. The construction industry should be concerned with the challenges and impacts of COVID-19 to ensure the continuity of future projects. The Government could use the findings of the research to help the construction industry deal with the challenges and impacts of the pandemic.

References

1. Trade F (2020) CORONA VIRUS—the situation in Malaysia | Flanders Trade. [online] Flandersinvestmentandtrade.com
2. Thomasphilip.com.my (2020) Is COVID-19 or the movement control order ("MCO") a force majeure event in construction contract? | Thomas Philip advocates and solicitors. Kuala Lumpur, Malaysia
3. Zicolaw.com (2020) COVID-19: issues faced by developers under the housing development (control and licensing) Act 1966 | ZICO Law
4. NST Online (2020) MCO: 'Reducing construction workforce will affect projects' | New Straits Times
5. NST Online (2020) 19,077 contractors applied but only 1,856 approved to operate new straits times
6. Malaymail.com (2020) With 78Pc of Covid-19 cases now from foreign workers, Dr Noor Hisham calls for more attention on their poor living conditions | Malay Mail
7. The Edge Markets (2020) C&CA lauds MITI's quick decision for cement plant ops to resume. [online] https://www.theedgemarkets.com/article/cca-lauds-mitis-quick-decision-cement-plant-ops-resume. Accessed 4 March 2021
8. Calstatela.edu (2016) IBM SPSS Statistics 23. [online] https://www.calstatela.edu/sites/default/files/groups/Information%20Technology%20Services/training/pdf/spss23p1.pdf. Accessed 18 Feb 2021
9. The Malaysian Reserve (2020) Local manufacturers hit by low supply of raw materials from China

Application of Steel Framework for Multi-storey Modular House Modules: A Review

Mohamad Azil Muzammil Bin Baharudin and Mohd Hafizal Mohd Isa

Abstract In developing a vertical modular house module, framework is the most crucial element in the construction. Framework act as the support system for the capsule to attach to the main mother structure. Thus, the main structural system needed to be durable and resistant. The structural system is based on all elements' type-design practice: steel columns, beams (crossbeam), floorings, and curtain wall panels. The use of separate frame system elements (beams, columns, floorings, wall panels) that are produced offsite and assembled on-site, as well as the use of 3D elements (block containers) with necessary internal engineering facilities, can be understood as two main directions in the construction of modular buildings. The light steel frame is one of the frame structures used for the construction of modular house modules. Based on the characteristics and features, it is very suitable for construction. Apart from that, modular house modules need a very efficient system to transport them from place to place. Thus, the management of the modules needs to be light and easy to transfer. The structure system that supports the module (mother structure) needs to be strong and afford to support the modules' load. High-strength steel is a review based on its characteristics and performance to support the framework's study to support the housing modules. The study employs qualitative methods and draws on previously collected data on a variety of steel framework and modular housing. Thus, the data tabulated will help the study to improve the mechanism created especially regarding the vertical system of modular construction in term of the support, structure and things related to the construction. The application of steel frameworks will aid modular construction industries in developing an improved and more efficient system of multi-story modular housing.

Keywords Modular architecture · Steel frame structure · Framework · Steel

M. A. M. B. Baharudin (✉) · M. H. M. Isa
School of Housing, Building and Planning, Universiti Sains Malaysia, 11800 USM Penang, Malaysia

M. H. M. Isa
e-mail: hafizal@usm.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_14

1 Introduction

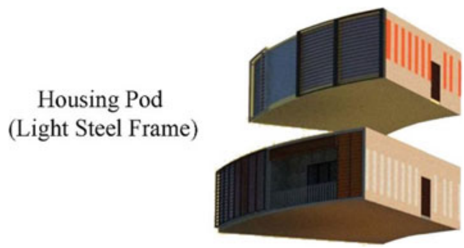
In some countries conventional methods of construction using cast in place structural elements and brick walls remain widely used because of the relatively low labour cost. However, because these construction methods are inefficient, economic growth has been stifled in the construction industry, and they are losing financial advantage as labour costs rise [1]. In Malaysia's Industrialized Building Systems (IBS), the Modular Construction System (MCS) and the Volumetric Modules Construction System (VMC) were classified as innovative methods [2]. It was determined that it was necessary to promote a solution that would assist the construction industry in increasing productivity and quality. Malaysia adopted IBS in response to concerns about skilled craftspeople, expedited completion, cost, and transportation [3].

Modular construction is a construction method where construction modules are manufactured off-site. Modular constructions incorporate a variety of structural systems and construction materials into a single structure [4]. Modular housing is the industry's most recent innovation. Prefabricated room-sized volumetric units are manufactured in a factory and installed on-site as load-bearing building blocks in modular construction [5]. In most cases, the modular discrete units form an autonomous structure. They are usually built in the factory and then fully equipped with floors, lighting, plumbing and heating [6].

Referring to Fig. 1, it is a housing module pod. The housing pod was constructed with the external light steel frame. The pod system is using the plug and play system which the pod will be attached to the main core structure (referring to Fig. 2) and the core structure r0emains as the supportive skeleton while the pod can be plug in and out. The main structural system is the most important element in designing the modular house modules in terms of supporting elements, as well as a system of module installation to the main structure system. The system can be also considered to be the hybrid system. Hybrids referring to Fig. 3 usually combine panel and modular prefabrication systems to construct a whole building [28] is the combination of the off-site prefab modules and on-site build steel structure system or also known as the plug in and out system.

The main structural system must be durable and resistant to support each of the housing modules installed and attached to it. Steel is today the structural material most frequently used for buildings and bridges because of its higher anti-seismic properties, environmental protection, rapid construction, high usage of space, new

Fig. 1 Housing pod



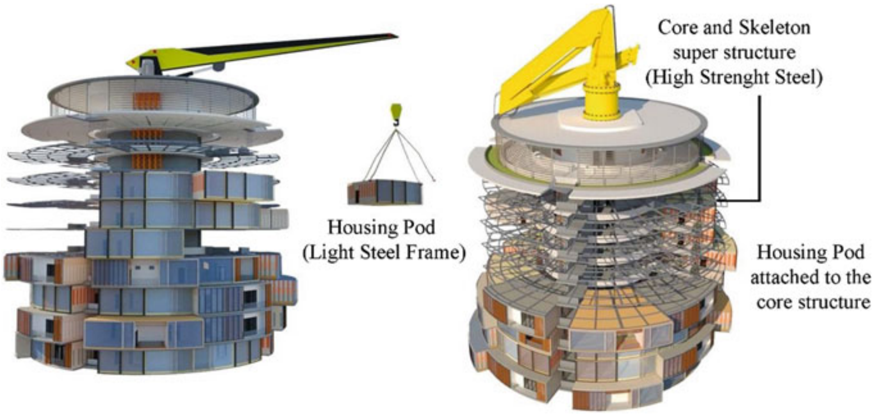


Fig. 2 Core structure

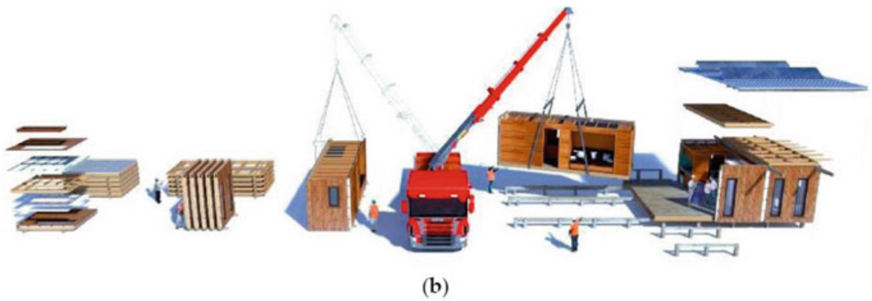


Fig. 3 Installation procedure

pictures and many other advantages. The steel structure is today the most used structure for buildings and bridges because of its superior anti-seismic properties, protection of the environment, fast construction, high use of space, innovative images and numerous other advantages [12]. They are recyclable, have a high structural efficiency, are highly adaptable in terms of design and manufacturing, and are quick to construct. Durability is a term that refers to the ability of a structure to perform over time [9]. To avoid deflections in the design, tension and compression are preferred instead of bending in the structure design [13]. Apart from that, based on the housing demand today, which become the catalyst idea of creating the vertical module house. The steel structure study will also examine the benefits of steel framing, such as the increased speed of on-site construction enabled by prefabrication of the wall panels and their ease of assembly on-site [7].

2 Research Methodology

The paper is aimed to review the application of the external frame structure for modular housing modules construction in order to develop the best selection of the structures for the modular housing modules. The study is carried out using qualitative methods, with parameter data collected based on previous research on a selection of steel framework and modular housing. The data gathered will be analysed based on the literature review to achieve the best selection of steel structure for multi-storey modular design. The study's findings will be examined in terms of the type of steel structure used, its durability and resistance, cost and its relationship to the construction.

3 Steel Frame Structure

Steel is one of the most widely used building materials on a global scale. Steel's inherent strength, toughness, and high ductility make it an ideal material for seismic design [12].

3.1 Light Steel Framework

Light Steel Framing (LSF) is a technique for supporting the building's floors, roof, and walls with a "skeleton frame" of vertical steel columns and horizontal I-beams arranged in a rectangular grid. It is a way to build quickly while also maintaining a cleaner construction environment and reducing waste materials, all of which directly impact the final budget [14]. The benefits of higher production quality and a simpler, more reliable, much more consolidated and fast connection system give light-weight steel frames a significant advantage over other structures [10]. The advantages of light steel framing are accelerated construction on the premises because of the prefabrication and the easy assembly of wall panels. This provides the subsequent businesses with a dry work environment, allowing the brickworks cover and the roof tilting to complete the critical path [11] (Fig. 4 and Tables 1 and 2).

3.1.1 Application of Light Steel Frame in the Construction

See Table 3.

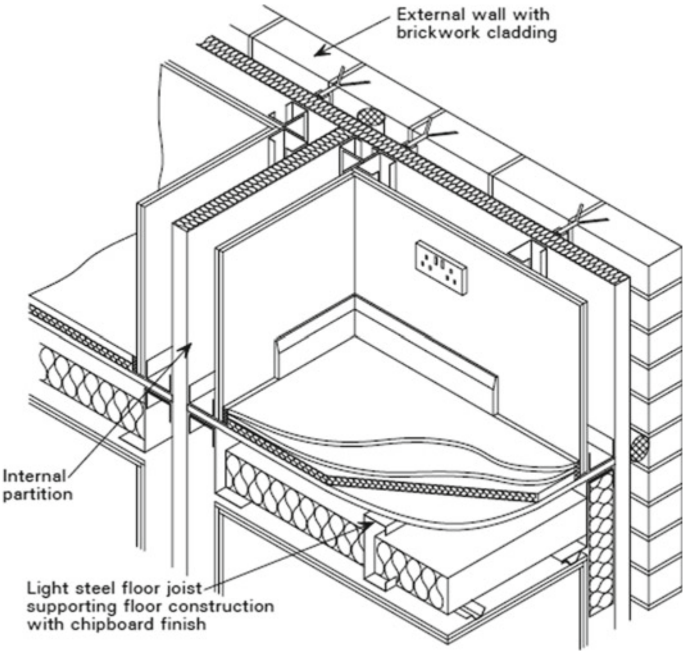


Fig. 4 Sectional perspective of light steel frame

Table 1 Light steel framing features

Floor depth	– 250 to 300 mm joists made of light steel – Lattice joists, 350 to 500 mm
Span	The distance between load-bearing walls should be between 3 and 6 m
Weight	0.6 to 1.0 kN/m2
Height suitability	2 to 6 storeys
Fire resistance	30 to 60 min for the outer layer of plasterboard
Other features	– Multiple layers of facing board serve as acoustic insulation – External walls are braced for stability

Table 2 There are three basic forms of light steel construction

Type 1	Components are made of light steel and assembled on-site
Type 2	Panels or sub-frames that are prefabricated in a factory and assembled on site to form a complete building structure
Type 3	In the factory, volumetric production of the entire room with internal finishes and services

Table 3 LSF application

Author	Description	Finding
Salman Mashhadifarahani (2015)	Light steel frames (LSF) have a significant advantage over other structures due to the benefits of higher factory production quality and a more simple, more reliable, much more consolidated, and rapid connection system [10]	Due to the light weight of LSF structures, lateral loads applied to them have a negligible effect, preventing future problems [10]
Amarildo V. Moreira, JR. (2015)	Different methods can have a variety of effects on the construction process, including the length of time it takes to complete, the final cost, and the building's quality [14]	Light Steel Framing is a technique for supporting the building's floors, roof, and walls with a "skeleton frame" of vertical steel columns and horizontal I-beams arranged in a rectangular grid. It is a method of constructing quickly while also preserving a clean construction environment and minimising waste materials, all of which have a direct effect on the final budget [14]
Wenwei Yang, Qili Yang (2017)	In comparison to a traditional brick structure, the light steel structure makes extensive use of lightweight steel as the primary bearing component, resulting in a significantly lighter structure [16]	The light steel structure's strength and seismic performance are superior to that of traditional brick structures because steel's strength and stiffness are greater than those of traditional brick structures [16]
R. M. Lawson, S. O. Popo-Ola, A. Way, T. Heatley, R. Pedreschi (2010)	Additionally, these building components offer the following advantages: reduced weight with high mechanical strength; large-scale prefabrication of substructures and subsequent site assembly, allowing for faster assembly; increased quality control; no dimensional variations due to moisture; architectural flexibility; and low cost [7]	The advantages of light steel framing include the reduced time required for on-site construction due to the prefabrication of wall panels and their ease of assembly. This creates a dry working environment for the subsequent trades, allowing for the completion of the brickwork cladding and roof tiling off the critical path [7]

(continued)

Table 3 (continued)

Author	Description	Finding
Cláudio Martins, Paulo Santos, Luís Simões da Silva (2014)	The advantages of light steel framing include on-site construction speed, which is achieved through the prefabrication of wall panels and their simple assembly [17]	The primary advantages and disadvantages of the LSF construction system were reviewed, with a strong emphasis on sustainability. These specifications are critical during the design stage to minimise operational energy consumption, increase energy efficiency, and achieve the sustainability label

3.2 *High Strength Steel*

The advantages of high-strength steel structures are mechanical performance, cost, and sustainability. Steels with a nominal capacity of 460 MPa or more are classified as steels of the highest strength. Strength, solderability and adequately ductility required for the traditional plastic designs or performance-based designs in civil engineering application. The proper application of HSSs in structural engineering benefits mechanical performance, cost and long-term viability. High-strength steels have several advantages, including increased safety due to higher strength in the elastic state, better economy due to smaller member sizes and structural weights, as well as the corresponding welding work, and, most importantly, more environmental, and ecological friendliness due to the use of fewer steels, welding, and coating materials. [13]

3.2.1 Application of High Strength Steel in the Construction

See Table 4.

4 Factors Affecting Steel Framework

4.1 *Steel Framework Durability and Resistance*

The design of new and existing structures for long-term durability is critical for the built environment's long-term development. The steel framework is used in a variety of ways in the construction industry. Steel is a combination of carbon and iron in which the most universally useful and versatile structural building material currently

Table 4 HSS application

Author	Description	Finding
Huiyong Ban, Gan Shi (2017)	High-strength steel (HSS) structures offer numerous advantages in terms of mechanical performance, economy, and sustainability [18]	With appropriate design considerations, the use of HSSs in frame structures may significantly improve their loading capacities, and their ductility and energy dissipation capacity may also be acceptable for seismic design requirements [18]
Fu Lei et al (2018)	High strength steel is a steel that has a good balance of strength and tenacity, which also means that it is a low-alloy steel that has good overall mechanical properties after tempering [12]	The widespread use of Grade Q345 high performance steel in high-rise buildings, combined with the success of Grade Q460 high strength and performance steel, has demonstrated to the entire steel structure industry the superiority and potential of high strength and performance steel [12]
Huiyong Ban, Mark A Bradford (2013)	Because the majority of the steel segment is tensile when HS steel is used on composite beams, the potential benefits of the high strength of those steel beams can be maximised. The compressive region can buckle and the strength is determined primarily by the steel elastic modulus when using pure steel beams that are bent [26]	HS steel is used in place of low-strength steel. Mild steel can be used to reduce member size, resulting in a structure with a lower self-weight and thus smaller foundations; it can also be used to reduce welding and coating materials, lowering construction costs; and it can be used to reduce the structure's weight, resulting in smaller foundations. resulting in more environmentally friendly design [26]

in use and well-known for providing a structure that no other material can match. Steel possesses a strength and durability unmatched by wood or concrete. Steel is a malleable, weldable, and ductile metal. Steel possesses exceptional tensile and compressive strengths, as well as the ability to withstand wear and tear [8].

Modular Steel Building connections are structurally significant because they significantly impact structural stability and durability. The proposed connection is horizontally and vertically separated. The vertical connection is formed by partially welding the lower and upper modular columns. The horizontal connection is formed by field-bolting the shop-welded angles to the floor beams [12].

4.2 Degradation of Steel Frame

In response to the classification of corrosivity according to standards, an application of degradation models was developed [23]. The models were developed for a variety of materials, taking into account the effects of four environmental variables: wetness time, sulphur dioxide, salinity, and temperature. The degradation model takes the following shape (Table 5):

$$y = A \cdot t^{B}\left(\frac{TOW}{C}\right)^{D} \cdot \left(1 + \frac{SO_2}{E}\right)^{F}\left(1 + \frac{Cl}{G}\right)^{H} e^{J(T+T_0)}$$

y = corrosion loss (μm); t = exposure time (years); TOW = time-of-wetness (h/year); SO_2 = sulfur dioxide concentration (μg/m^3); Cl is chloride deposition rate (mg/m^2/day); T = air temperature (°C); A, B, C, D, E, F, G, H, J, and T_0 = empirical coefficients.

Figure 5 depicts the degradation curves for zinc and carbon steel for the selected model (Table 3). Environmental variables have been analysed using values corresponding to the EN 12,500 corrosiveness classes (2000)—Corrosion protection for metallic materials. Probability of corrosion in an atmospheric environment- Corrosivity classification, determination, and estimation of atmospheric environments.

Table 5 Results based on the calculation from the formula

Material	Equation coefficients									
	A	B	C	D	E	F	G	H	I	J
Carbon steel	13.4	0.98	3800	0.46	25	0.62	50	0.34	0.016	20
Zinc	0.16	0.36	3800	0.24	25	0.82	50	0.44	0.05	20

Source Dean and Reiser (2002)

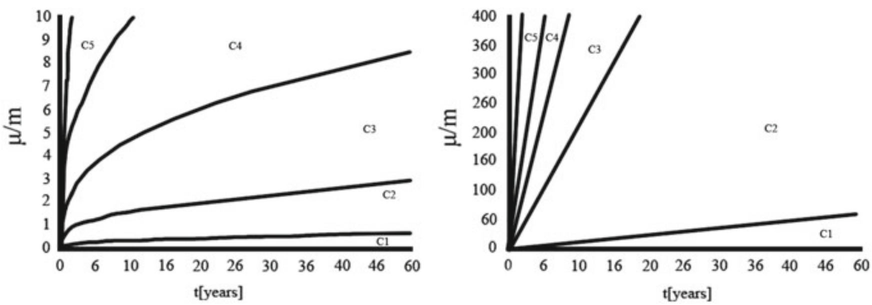


Fig. 5 Zinc thickness loss as a function of time (**a**) and carbon steel (**b**) with varying degrees of corrosiveness classes (**c**), according to selected degradation models

4.3 High Steel Frame Fire Resistance

In higher elevation buildings, steel structures have been used extensively due to their strength and seismic performance in ambient design. In contrast, at high temperatures steel material characteristics deteriorate significantly. Framed structures must maintain stability for a specified period in order to guarantee safety of occupants during an accidental fire [29]. HSS is a newly developed class of structural steel that combines high strength, ductility, toughness and superior performance (efficiency greater than 460 N/mm2). It is produced by micro alloys and mechanically controlled thermal rolling (TMCR) [28]. Many studies on the effects of fire on the steel frame were conducted (Table 6).

Yiwen Wu et al. developed a technique for determining the mechanical properties of materials at elevated temperatures by employing a constant material, Q550 HSS. Static tests (loading at a constant temperature) are used in which the temperature is maintained throughout the test and the load is increased at a constant rate until the specimen is damaged.

Table 6 HSS fire resistance

Author	Studies
Bailey et al. (1996)	The effects of fire spread on the behaviour of two-dimensional frames were investigated, and it was discovered that progressive fire spread increased the residual displacements of beams when compared to simultaneous burning across the same range of compartments [30]
Röben et al. (2015)	the behaviour of a multi-story composite frame when it is exposed to avertically propagating fire between three floors. It was demonstrated that the inter-floor time delay had a significant effect on the global behaviour, and that the axial forces generated by thermal expansion in individual floors may induce cyclic loading on the column, which is not normally considered in structural fire design but may be critical in determining structural behaviour [31]
Rackauskaite and El-Rimawi (2015)	the behaviour of a three-story, three-bay symmetrical steel frame when subjected to six distinct localised fire scenarios. It was demonstrated thatfire compartmentation was necessary in unprotected steel structures not only to ensure people's safety during a fire, but also to improve a building's ability to achieve longer fire survival times [33]
Rezvani et al. (2016)	The structural response of a seismically designed steel moment-resisting frame subjected to travelling fire was investigated, and the analysis revealed that the size of the fire had a significant effect on the total collapse time of the frame [34]

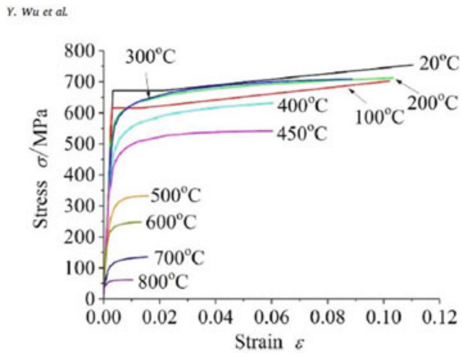


Fig. 6 Curves of stress–strain for Q550 HSS at various temperatures each colour represent the tested temperature

As illustrated in Fig. 5, the elevated temperature steady test can be used to determine the stress–strain curves of Q550 HSS at various temperatures. From Fig. 5, the following conclusions can be drawn. When the temperature is lower than 450 degrees Celsius, the difference in mechanical properties is negligible, and ductility is excellent. When the temperature of Q550 HSS is increased to 500 degrees Celsius, the yield strength, ultimate tensile strength, and ultimate tensile strain all decrease significantly, indicating that the mechanical properties degrade abruptly at this temperature. When heated above 500 degrees Celsius, HSS's mechanical properties and ductility rapidly deteriorate (Fig. 6).

5 Conclusion

The structure is a critical element in developing the modular house module, first and foremost as a support system for the modular house module. When the module house is connected to the main mother structure, the main structure system acts as a skeleton, securing the module house in place. Additionally, research is conducted to ascertain the appropriate steel structure specifications for use in the construction of the housing modular modules. The chosen steel, which is a light steel frame, has numerous advantages in the construction industry, including cost savings and compatibility with modular structures. The light steel frame can also be used for the modules' components due to its light weight and ease of transportation, as well as for assembling the modules' components during construction. Thus, productivity and time management are enhanced, which contributes to the modular construction's overall efficiency. The more efficient the module is constructed, the more benefits the public will gain from housing development. Following that, the use of high-strength steel as the primary core structure system results in increased safety due to increased elastic strength, increased economy due to smaller member sizes and structural weights, and other benefits for vertical modular module house construction. The central core component will serve as the mother structure for all housing modules that will be connected to it. The core structure will remain in place to support any housing module system developed for attachment to the mother core structure. HSS offers numerous advantages, as the frame structures may significantly improve loading capacities. The ductility and energy dissipation capacity may also meet seismic design requirements with appropriate design considerations and the fire resistance. The greater the structure selected, the more secure and efficient the structure will be.

Acknowledgements The authors would like to thank Architecture Programme, School of Housing, Building and Planning, Universiti Sains Malaysia for the financial support through fulfilment of dissertation submission.

References

1. Construction Industry Development Board (1992) Raising Singapore's construction retrieved January 2018. https://www.bca.gov.sg/publications/BuildabilitySeries/others/rscp_intr2.PDF
2. Aziz S, Abdullah MR (2015) Modular construction system in Malaysia: issues for research in sustaining an affordable home project
3. Azman M, Ahamad M, Wan Hussin W (2012) Comparative study on prefabrication construction process. Int Survey Res J 45–58. http://www.rism.org.my/ISMDoc/ISrJ/Vol-2.1/Full-2.1.pdf#page=45
4. Lacey AW, Chen W, Hao H, Bi K (2018) Structural response of modular buildings—an overview. J Build Eng 16:45–56. https://doi.org/10.1016/j.jobe.2017.12.008
5. Lawson P, Byfield M, Popo-Ola S, Grubb P (2008) Robustness of light steel frames and modular construction. Proc Inst Civ Eng Struct Build 161(1):3–16
6. Annan CD, Youssef MA, El-Naggar MH (2009) Effect of directlywelded stringer-to-beam connections on the analysis and design of modular steel building floors. Adv Struct Eng 12(3):373–383
7. Lawson RM, Popo-Ola SO, Way A, Heatley T, Pedreschi R (2010) Durability of light steel framing in residential applications. Proc Inst Civil Eng—Constr Mater 163(2):109–121. https://doi.org/10.1680/coma.2010.163.2.109
8. Sharma V, Kumar R, Singh H, Ahmad W, Pratap Y (2017) A review study on uses of steel in construction. Int Res J Eng Technol (IRJET) 4(4)
9. Saba D (2013) Investigating the durability of structures (Unpublished doctoral dissertation, 2013). McGill University, Montréal
10. Mashhadifarahani S (2015) Light weight steel frames versus Common building structures—structural performance evaluation. Am Sci Res J Eng Technol Sci 12, 1st ser., 222–229
11. Lawson RM, Ogden RG, Rackham JW (2004) Light steel framing. In: Steel in multi-storey residential buildings. Steel Construction Institute, Ascot, p 36
12. Fu L, Xu G, Yan Y, Yang J, Xie J (2018) The application and research progress of high strength and high-performance steel in building structure. IOP Conf Series: Mater Sci Eng 392:022008. https://doi.org/10.1088/1757-899x/392/2/02200
13. Coelho AM, Bijlaard F (2010) High strength steel in buildings and civil engineering structures: design of connections. Adv Struct Eng 13(3):413–429. https://doi.org/10.1260/1369-4332.13.3.413
14. Moreira VA (2015) Design analysis of structures for residential light steel framing systems. Int J Eng Res Technol (IJERT) 4(08). ISSN: 2278-0181
15. Generalova E, Generalov V, Kuznetsova A (2016) Modular buildings in modern construction. Proc Eng 153:167–172. https://doi.org/10.1016/j.proeng.2016.08.098
16. Yang W, Yang Q (2017) Study on the dynamic characteristics of light steel residential structural system. Engineering 09(06):591–598. https://doi.org/10.4236/eng.2017.96037

17. Santos P, Martins C, Simões da Silva L (2014) Thermal performance of lightweight steel-framed construction systems. Metallurg Res Technol 111(6):329–338. https://doi.org/10.1051/metal/2014035
18. Ban H, Shi G (2017) A review of research on high-strength steel structures. Proc Inst Civ Eng. https://doi.org/10.1680/jstbu.16.00197
20. Raoul J, Günther HP (2005) Use and application of high-performance steels for steel structures. IABSEAIPC-IVBH, Zürich, Switzerland
21. Li G, Wang Y, Chen S (2015) The art of application of high- strength steel structures for buildings in seismic zones. 11(4), 492–506. https://doi.org/10.18057/ijasc.2015.11.4.6
22. Annan CD, Youssef MA, El Naggar MH (2009) Seismic vulnerability assessment of modular steel buildings. J Earthq Eng 13(8):1065–1088
23. Lucrezia C, Portioli F, Landolfo R (2007) Durability design of metal structures based on lifetime safety factor method. In: Portugal SB 2007—sustainable construction, materials and practices: challenge of the industry for the New Millennium, pp 522–529
24. Klinesmith DE, McCuen R, Albrecht P (2007) Effect of environmental condition on corrosion rate. J Mater Civil Eng
25. Dean S, Reiser DB (2002) Analysis of long term atmospheric corrosion results from ISO CORRAG Program. ASTM, West Conshohocken
26. Hou YY, Zhang L (2004) Light steel residential structural system and its application. Shanxi Arch 30:29–30
27. Ban H, Bradford M (2013) Ductility of composite beams constructed with high-strength steel sections
28. Boafo F, Kim J, Kim J (2016) Performance of modular prefabricated architecture: case study-based review and future pathways. Sustainability 8(6):558. https://doi.org/10.3390/su8060558
29. Wu Y, Fan S, He B, Li C, Zhou H (2021) Experimental study and numerical simulation analysis of the fire resistance of high-strength steel columns with rectangular sections under axial compression. Fire Saf J 121:103266. https://doi.org/10.1016/j.firesaf.2020.103266
30. Ren, W. (2020). Behaviour of steel frames exposed to different fire spread scenarios. Int J Steel Struct 20(2):636–654. https://doi.org/10.1007/s13296-020-00311-x
31. Bailey CG, Burgess IW, Plank RJ (1996) Analyses of the effects of cooling and fire spread on steel-framed buildings. Fire Saf J 26(4):273–293
32. Röben C, Gillie M, Torero J (2010) Structural behaviour during vertically travelling fires. J Constr Steel Res 66(2):191–197
33. Rackauskaite E, El-Rimawi J (2015) A study on the effect of compartment fires on the behaviour of multi-storey steel framed structures. Fire Technol 51(4):867–886
34. Rezvani FH, Behnam B, Ronagh HR et al (2016) Robustness assessment of a generic steel fire-protected moment-resisting frame under travelling fire. Eur J Environ Civ Eng 22(1):64–81

A Sustainable Facade Treatment Through Self Cleaning Coating Agents: A Review

Mohamed Farhan Mohamed Noor and Mohd Hafizal Mohd Isa

Abstract Building façades play an essential role in building aesthetics and in shielding the structural system and contents from defects and deterioration due to exposure to a climate such as air pollution: The impact of air pollution on building facades can be defined as "discolouration, material degradation, and structural collapse." Abrasion, deposition and removal, direct chemical attack, indirect chemical attack, and decay are ways atmospheric contaminants deteriorate. This paper aims to investigate the type of coatings through self-cleaning agents for various types of building materials on building façades. Application of self-cleaning material, rather than repainting the entire building elevation, is becoming more practical to preserve clean facades for more extended periods. In particular, their presence eliminates indirect costs associated with repair activities over the house's life, providing quick and cost-effective access to the envelope surfaces. Furthermore, their existence reduces indirect costs related with maintenance operations throughout the life of the building by allowing for fast and cost-effective access to the exterior surfaces throughout construction.

Keywords Façade material · Deterioration · Cleaning process · Self-cleaning material · Façade treatment

1 Introduction

Façades; the first aesthetical feature of a building that distinguishes one building from another, have to fulfil the fundamental aspects like defence against fire and burglary, climatic impact, and environmental pollution. The development of facades has made it more practical, providing designers with the ability to produce high-performance solutions, which are visually pleasing and exciting for both internal and external and It is necessary to keep facade materials in a generally clean condition

M. F. M. Noor · M. H. M. Isa (✉)
School of Housing, Building and Planning, Universiti Sains Malaysia, 11800 USM Penang, Malaysia
e-mail: hafizal@usm.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_15

throughout time in order to ensure that the proper functioning of the envelope components is preserved [1]. Research shows that high density architecture has attracted a lot of attention regarding the effect of outdoor pollutants and globally especially in big cities. Moreover, having bad air quality is one of the most significant factors contributing to deterioration of building façades in most high-density urban contexts. A viable alternative for mitigating the effect of this deterioration is to incorporate a self-cleaning substance into the paints used on the facades of the particular contaminated buildings. Cleaning processes in these situations will be greatly simplified by the use of effective self-cleaning coatings, which are designed to take advantage of the combination chemical-physical behaviour of treated surfaces [2–6]. Rather than repainting the whole building repeatedly, it is becoming more practical to use self-cleaning materials to maintain cleaner facades over a more extended period [7]. Self-treatment coatings are increasingly becoming an integral part of the global strategy for bacterial pathogen protection. This paper would discuss the application of coatings to the self-cleaning treatment of building façades. Examining the latest generation of release-based coatings, emphasising the threats and uncertainties they create. Recent methods for controlling self-treatment and release of façade materials, imparting multi-functionality, and enhancing the long-term durability of building materials/façade finishes are illuminated in particular (Fig. 1).

A case study was conducted on the facades of many buildings in Cairo, Egypt and Beirut, Lebanon to examine the outer characteristics of the buildings. The facades of the buildings show trace of pollution and marks of stain. These instances are prevalent in a large number of buildings in these areas. Due to their flexibility on the substrate and the ability to preserve the original aesthetical look of such buildings with almost no effort and meagre cost, self-cleaning materials have found wide acceptance in building, especially for building preservation [8].

Another example is Talaat Harb Square, Cairo's central squares downtown. Due to air pollutants and pollen, Egypt faces significant façades destruction. The surface would be clean as the coating decomposes the chemical compounds on the surface. A component of the inorganic pollutants can remain on the surface after the molecules decompose, easily washed down by rain or other cleaning methods [9]. This square is considered an important and historic downtown centre of Cairo, with distinctive

Fig. 1 Example of exterior stained façade in Cairo, Egypt

(a) Before year 2007 (b) Year 2007 (c) Year 2014 (d) Year 2015

Fig. 2 Example of an exterior limestone cladding coated with a self-cleaning coating that resists algae growth (**c**) and (**d**) [9]

architecture surrounding and identifying its central position. Trying to fix the issue of erosion, the Egyptian government paints façades every few years. The government's primary goal is to retain a better urban look for this critical square. Unfortunately, it returns after a short period. Figure 2 shows the same buildings in 2007 to 2015. Therefore, self-cleaning agents is one of the key solutions in reducing cost for building maintenance as well as to preserve the building facades especially for fragile and exquisite building materials and features.

2 Types of Coatings

2.1 Paint

Paints serving defensive or decorative functions and their need for our goods as well as buildings remain as critical as in the past. Developing waterborne structures focused on polymer dispersions practically revolutionised traditional internal and external used paints. It's no surprise that there's much interest in nanostructured paints with suspended nanoparticles or nanotubes that are applied as liquids and then hardened on the materials' surface [10]. Today, nano paints come in many forms and have been developed with many different needs in mind. Typical objectives include improved scratch and abrasion resistance, hardness, glossiness, and colour steadfastness.

However, as shown in Fig. 3, finishes are frequently low-quality finishes, resulting in unplanned maintenance and extra costs. The new regulatory and scientific study focused on metal surfaces. Studying the regularities of structure-forming and coating properties on porous substrates, and developing guidelines to improve quality, would enhance the quality of protective and decorative coatings and ensure maintenance-free life. Coatings used for building facades, performing aesthetic preventive roles should have a high-quality look, i.e. should be defect-free (inclusions, stains, shark-skin, strokes and scratches, waviness). Passive coatings can detect bacteria from adhering to surfaces and destroy bacteria as they contact them. Surface roughness, wettability, and conductivity are both physical and chemical properties of the coating that have a significant impact on bacterial activity [11].

Fig. 3 Example powder coating for metallic trends for façade

2.1.1 Example of Paints Products

(i) **Epoxy paints**

Much of epoxy paints are operating as the two-component framework (2K) and used for many applications, much of it for painting; concrete, steel frame, and wooden grounds as a primer and finish often coating metal surfaces, fuel pipes and tanks. One of the important coating missions is coating pipelines and tanks for water and gasoline.

(ii) **Polyurethane paints**

As epoxy, its function relies typically on the 2K system with high wash-ability weathering and chemical resistance, making it ideal for applying steel, wooden, and concrete surfaces. As currently described, polyurethane is graded based on the polyol used in its manufacture, which impacts the properties of PU. Still, it is commonly known for its abrasion resistance, durability, strength, chemical resistance, and weather resistance [12].

(iii) **Aluminium Paints**

It's a metallic paint used for defence purposes, the base material in aluminium paint is aluminium powder. Aluminium paint is used to coat woodwork and metal surfaces. This paint is recommended for its weather resistance and water resistance. It is extremely heat resistant as well as corrosive resistant. it relies on aluminium paste as a pigment, which makes it corrosion resistance

(iv) **Varnish**

It's a colourless paint used for protection and disappearing the primed surface underneath it and often has a yellowish tint. Historically, natural resin solutions, which are secretions of plants, were used to create the first varnishes. It has been stated that the amines occurring in the structure of solvent-based varnishes become yellow over time due to the effects of oxidation; however, these substances that produce yellowing have not been used in the manufacturing process of water-based varnishes [13]. Varnishes are used to preserve wooden surfaces, paintings, and a variety of other ornamental items from the elements. Varnish preserves and improves the look of hardwood floors as well as wood panelling and trim in the interior of buildings and furniture. It was found that there is a significant connection between overall change in wood colour and resistant characteristics after thermal treatment [14].

2.2 Self Repelling Paints/Coatings

Nanotechnology is a relatively new field in materials science, though it has grown significantly in nature, it is concerned with the boundary between atoms and molecules and the macro universe, where the properties are essentially determined by the fundamental behaviour of atoms [15]. If nanotechnology can be implemented creatively, it resulted in drastic increase in material efficiency and new technologies in the building industry. According to modern research, the lotus leaf utilises nanotechnology to produce a self-cleaning, non-wetting, super-water-repellent, or superhydrophobic [16, 17] (Fig. 4).

The lotus leaf's self-cleaning potential is its unique surface structure. A lotus leaf's nanostructure consists of different cone-like protrusions [11, 19–21]. As a result, the lotus leaf powerfully repels water that brings soil off the leaf, enabling the lotus to stay clean despite rising in turbid water [22]. This is commonly recognised as "lotus impact," mimicking various substrates utilising certain newly created coating materials (Fig. 5).

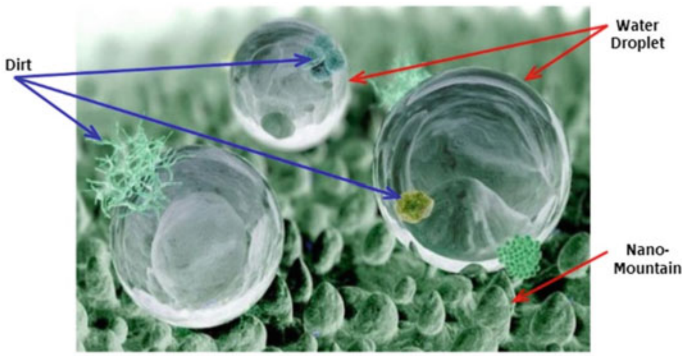


Fig. 4 Water drops suspended on nanostructured lotus leaf [18]

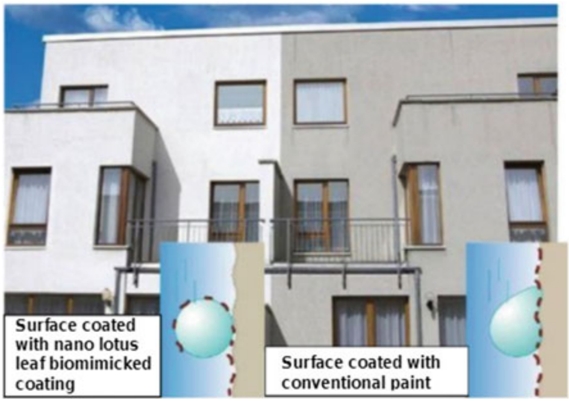


Fig. 5 Comparison of conventional and nano lotus leaf bio mimicked coating (adapted from European Consumers Choice 2017)

2.3 Photocatalyst Coating

Photocatalysts are materials that, under sunlight, it decomposes hazardous compounds such as titanium oxide (TiO_2). It is mainly used as a photocatalyst. TiO_2 stage anatase has the most significant photocatalytic effect among polymorphs. Photocatalytic coatings, using a coating that produces reactive radical species with a solid antimicrobial range, give an alternate way of surface disinfection [23].

Conventionally, in the end of the façade assembly process or on present façade surfaces, photocatalytic coatings in anti-bacterial coating (paints, plasters or spray-clear coatings) demonstrated suitable air purification and quick durability [24–27]. One of the most successful photocatalytic approach used to treat various organic oxide compounds, including dyes and phenol. According to [28] (2009), these reactive organisms behave as antimicrobial surfaces: these compounds are generally known as light-activated antimicrobials (LAAAs). The oxidation of organic materials involves complex processes depending on radical hydroxyl details, based on the photodegradation mechanism of organic compounds using TiO_2. This carries generate free hydroxyl radicals that may interact with organic compounds in secondary reactions (Fig. 6).

2.4 Anti Bacterial Coating

Antimicrobial coatings utilise chemicals to hinder pathogen growth by cell membrane perturbation. In layman's terms, an antimicrobial coating is a surface application of a chemical agent that can prevent bacterial infection micro-organisms. Besides increasing surface durability, appearance, corrosion resistance, etc., these coatings often guard against harmful disease-causing microbes. There are several ways to strengthen anti-bacterial and antimicrobial surfaces using nano products. One

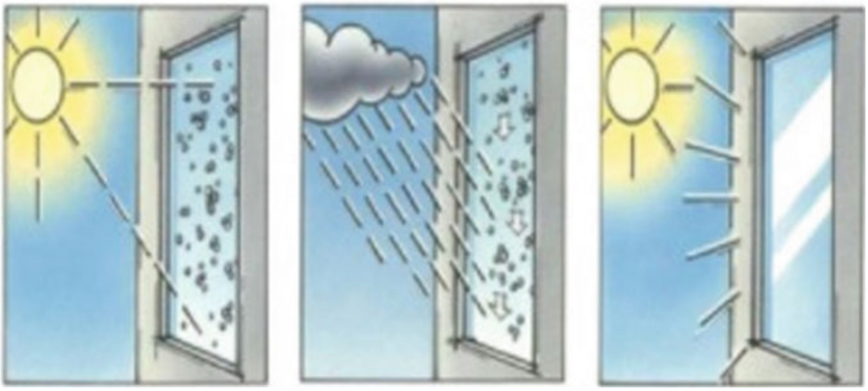


Fig. 6 The basics of how photocatalysis surfaces execute [29]

approach uses copper or silver nanoparticles trapped in another matrix, such as coatings on certain raw materials or directly integrated into bare material surfaces. This technique takes advantage of copper's antimicrobial properties long-established, but this has been significantly improved, thanks to the far wider surface area of nanoparticles. The upper layer achieves hydrophobic function, significantly reducing surface tension and molecular attraction. The lower layer ensures the surface coating speed. It cannot reverse this layer. Once added into cracks, it cannot be extracted. Unlike standard coating schemes, Nano-based anti-graffiti coatings are permanent and stay in effect long after removing writing from walls.

3 Analytical Study to Distinguishing the Application of Nano-coating for Building Components

(i) Floor

It may be used as floor finishing material to manufacture water-repellent flooring for improved service life. Water involves certain flooring materials' corrosion processes. Water repellence reduces water infiltration into flooring materials and thereby increases floor system life span with higher durability.

(ii) Wall Concrete Brick

Nano lotus leaf biomimicked coating may be added to the exterior walls or façades of buildings, minimising humidity due to water sorption and obtaining a dust-free, self-cleaning wall surface.

Fig. 7 The most relevant metrics and sustainability requirements arising from the use of nano coatings in architectural facades in line with the comparative empirical analysis

(iii) Glass

Water droplets roll off quickly with soil, and nano lotus leaf biomimicked coating would not absorb dust due to its strong water repellence. Buildings painted with a bio mimicked nano lotus leaf coating substance can self-clean through rain and remain dry due to the lotus effect. As water droplets slip down, they hold the dust particles as they do on the wall, keeping the windows self-cleaned.

(iv) Drainage System

This one-of-a-kind coating often resists the building surface development of fungus, mildew, and algae. It may be added from outside windows for self-cleaning. Nano lotus leaf bio mimicked coating may be added as a water-repelling coating on pavements for fast drainage, enabling them to dry quickly throughout the rainy season, thereby contributing to safe driving and increased durability.

(v) Pavement

For similar purposes, it may also be used for safe walking on the sidewalk; but, it must be assured that the friction property of the concrete surface is not compromised by the presence of bio mimicked nano-lotus leaf coating. Nano lotus bio mimicked coating may be used on the building's roof to accelerate the drainage of snow-melt water or rainwater, thereby reducing algae or bacterial growth and thereby (Figs. 7; Table 1).

4 Conclusion

In the standards and benchmarks of the sustainability of architectural facades, there have a few points that can be focused on these issues:-

- self-cleaning coatings represent a durable coating over the existence of the structure, minimize maintenance costs and prolong building lifespan.
- The self-cleaning coating often represents the interior air quality and allows for unrestricted design versatility.
- Easy-to-clean coatings increase the reliability of coating materials' performance and service of the building.

- Application on Nano paint coatings could provide a long-term anti-graffiti solution for a building within this uses of Nano paint coatings improve the quality of life and could act as a more sustainable building materials which can work in different climatic conditions and weather.

Table 1 Analytical study distinguishing the application of various nano paint coatings used in the architecture façade to make them sustainable

Properties	• **Anti Bacterial Coating** To incorporate copper or silver nanoparticles onto another material, such as coatings in various necessary materials or directly mixed with surfaces of essential material. Such a strategy favours bacteria but has already been documented • **Self Repelling Paints** The lotus surface produced from the nanotechnology sector is a hydrophobic surface that works on removing and separating water from surface areas • **Photocatalysis** Hydrophilic surfaces working on destroying particles of dust and dirt and making them loose on surfaces [27]
Advantages	• **Anti-bacterial coating** Since ions prevent cell division, weaken cell membranes and walls, and contain the transference of enzymes from the feeding substrate, bacteria have a slight possibility of surviving. Hence, by utilising this process, bacterial elimination can be achieved indefinitely without chemical materials. Silver nanoparticles minimise the need for chemical detergents and the amount of time it takes to scrub [12] • **Self Repelling Paints** The use of the Lotus Effect remains for a long time, as facades are still practical after five years. Cleanly and a drop in maintenance requirements, the merits of these surfaces are mainly reflected • **Photocatalysis** In coating, organic contamination on the surface is decomposed, making the surface clean. Once the particles decompose, a portion of inorganic pollutants may be quickly cleaned off the ground using rain or washing methods
Disadvantages	• **Anti-bacterial coating** There are many defined favourites of types, concentrations and shapes, as well as the distribution of the volume of nanoparticles to microbes for high potency; it is nevertheless important to note that all microbes with similar composition are not affected; more studies on the types of microbe activities that can breathe are required • **Self Repelling Paints** Limited drops of water nearly often result in the formation of water droplets in the formation of drywalls or areas, leaving the surface dusty rather than clean. The composition of these materials cannot survive solid mechanical corrosion • **Photocatalysis** Self-cleaning surfaces by photocatalysis usually are more efficient in the open air than in enclosed spaces if the required requirements are met, including ultraviolet light, oxygen, and air humidity. It is suggested that it be used only on the building's exterior facades and not inside

(continued)

Table 1 (continued)

Usage	• **Anti-bacterial** Support maintenance strategies related to healthcare situations. It is using silver nanoparticle technology in buildings that are exposed to microbes and fungi regularly • **Self Repelling Paints** To make the most use of self-cleaning facades, thus reducing maintenance costs. Also, coating roof tiles in a house that is only washed regularly [30] • **Photocatalysis** Coating granite and marble walls to prevent the adhesion of dust and dirt

Acknowledgements The authors would like to thank the Department of Architecture, School of Housing, Building and Planning, Universiti Sains Malaysia, for the financial support through the Research University Grant.

References

1. Rigone P (2011) Le facciate continue - La manutenzione dell'involucro edilizio vetrato. MaggioliEditore, Sant'Arcangelo di Romagna (RN), Italy
2. Diamanti MV, Del Curto B, Ormellese M, Pedeferri MP (2013) Photocatalytic and self-cleaning activity of coloured mortars containing TiO_2. Constr Build Mater 46:167–174
3. Watanabe T, Nakajima A, Wang R, Minabe M, Koizumi S, Fujishima A, Hashimoto K (1999) Photocatalytic activity and photoinduced hydrophilicity of titanium dioxide-coated glass. Thin Solid Films 351:260–263
4. Parkin IP, Palgrave RG (2005) Self-cleaning coatings. J Mater Chem 15:1689–1695
5. Yang YH, Han YS, Choy JH (2006) TiO_2 thin-films on polymer substrates and their photocatalytic activity. Thin Solid Films 495:266–271
6. Nishimoto S, Bhushan B (2013) Bioinspired self-cleaning surfaces with strong hydrophobicity, superoleophobicity, and super-hydrophilicity. RSC Adv 3:671–690
7. Rao NV, Rajasekhar M, Rao GC (2014) Detrimental effect of air pollution, corrosion on building materials and historical structures. Am J Eng Res 3(3):359–364
8. Quagliarini E, Bondioli F, Goffredo GB, Cordoni C, Munaf'o P (2012) Self-cleaning and de-polluting stone surfaces: TiO_2 nanoparticles for limestone. Constr Build Mater 37:51
9. Lumley R, Morton A (2006) Nanoengineering of metallic materials. In: Hannink RHJ, Hill AJ (eds) Nanostructure control of materials, 1st edn, Chap 9. Woodhead Publishing Ltd., pp 219–247
10. Carpio E, Zúñiga P, Ponce S, Solis J, Rodriguez J, Estrada W (2005) Photocatalytic degradation of phenol using TiO_2 nanocrystals supported activated carbon. J Mol Catal A: Chem 228:293–298
11. Li J, Zhou L, Yang N, Gao C, Zheng Y (2017) Robust superhydrophobic coatings with micro and nano-composite morphology. RSC Adv 7(70):44234–44423
12. Harper CA, Petrie EM (2003) Plastics materials and processes a concise encyclopedia. Wiley, New Jersey
13. Johnson R (1997) Waterborne coatings, an overview of waterborne coatings: a formulator's perspective. J Coat Technol 69:117–121
14. Bekhta P, Niemz P (2003) Effect of high temperature on the change in color, dimensional stability and mechanical properties of spruce wood. Holzforschung 57:539–546
15. Ashby M, Ferreira P, Schodek D (2009) Nanomaterials, nanotechnologies and design: an introduction for engineers and architects. Elsevier Science Ltd., Massachusetts

16. Mozumder MS, Zhang H, Zhu J (2011) Mimicking lotus leaf: development of micro-nanostructured biomimetic superhydrophobic polymeric surfaces by ultrafine powder coating technology. Macromol Mater Eng 296(10):929–936
17. Neinhuis C, Barthlott W (1997) Characterisation and distribution of water-repellent, self-cleaning plant surface. Ann Botany 79(6):667–677
18. Rame-Hart (2015) Is your super hydrophobic surface the real deal, or is it a fake? And what is pseudo super hydrophobicity anyway? Rame-Hart Instrument Co Newsletter, October 2015
19. Cheng Y-T, Rodak DE, Wong CA, Hayden CA (2006) Effects of micro- and nano-structures on the self-cleaning behaviour of lotus leaves. Nanotechnology 17(5):1359–1362
20. Stratakis E, Zorba V, Barberoglou M, Spanakis E, Rhizopoulou S, Pzanetakis P, Anastasiadis S, Fotakis C (2009) Laser structuring of water-repellent biomimetic surfaces. SPIE Newsroom, 19 January 2009, 3 pp
21. Yamamoto M, Nishikawa N, Mayama H, Nonomura Y, Yokojima S, Nakamura S, Uchida K (2015) Theoretical explanation of the lotus effect: superhydrophobic property changes by removal of nanostructures from the surface of a lotus leaf. Langmuir 31(26):7355–7363
22. Robbins J (2011) Engineers ask nature for design advice. New York Times, December 11
23. Wilson M (2003) Light-activated antimicrobial coating for the continuous disinfection of surfaces. Infect Control Hosp Epidemiol 24(10):782–784
24. Laufs S, Burgeth G, Duttlinger W, Kurtenbach R, Maban M, Thomas C, Wiesen P, Kleffmann J (2010) Conversion of nitrogen oxides on commercial photocatalytic dispersion paints. Atmos Environ 44:2341–2349
25. Aguia C, Angelo J, Madeira LM, Mendes A (2010) Influence of photocatalytic paint components on the photoactivity of P25 towards no abatement. Catal Today 151(1–2):77–83
26. Maggos T, Bartzis JG, Liakou M, Gobin C (2007) Photocatalytic degradation of NOx gases using TiO_2-containing paint: a real-scale study. J Hazard Mater 146:668–673
27. Salthammer T, Fuhrmann F (2007) Photocatalytic surface reactions on indoor wall paint. Environ Sci Technol 41:6573–6578
28. Page K et al (2009) Antimicrobial surfaces and their potential in reducing the role of the inanimate environment in the incidence of hospital-acquired infection. J Mater Chem 19:3819–2831
29. Wang R, Hashimoto K, Fujishima A, Chikuni M, Kojima E, Kitamura A, Shimohigoshi M, Watanabe T (1998) Adv Mater 10:13
30. Cheng Y-T (2005) Is the lotus leaf superhydrophobic? Appl Phys Lett 86(14):Paper No. 144101

Investigation of Direct Sunlight in Existing Classroom Design in Indonesia: Case Study of Lhokseumawe

Atthaillah, Rizki A. Mangkuto, and Mochamad Donny Koerniawan

Abstract Investigations of direct sunlight inside school classrooms in Indonesia are currently missing. This study therefore investigates the availability of direct sunlight inside several state elementary school classrooms in Banda Sakti region of Lhokseumawe, Indonesia. Daylight in the location is abundantly available, thus, there is a risk of excessive daylight inside the classroom that may disrupt the student performance. A computational simulation was carried out to assess direct sunlight availability inside the space by utilizing the annual sunlight exposure ($ASE_{1000,250}$) metric. Results show that 43.42% of the observed school classrooms suffer from excessive direct sunlight inside the classroom. Two orientation groups (F and I) were examined to evaluate the sensitivity of input variables within this study. It is found that corridor shading depth, corridor shading elevation, and window-to-wall ratio (WWR) have moderate influence on the sunlight availability inside the existing classrooms in Lhokseumawe.

Keywords Annual sunlight exposure · Classroom · School · Daylight · Sensitivity analysis

Atthaillah (✉)
Engineering Physics Doctorate Program, Faculty of Industrial Technology Institut Teknologi Bandung, Jl. Ganesha 10, Labtek VI, Bandung 40132, Indonesia
e-mail: atthaillah@unimal.ac.id

Architecture Program, Faculty of Engineering, Universitas Malikussaleh, Jl. Cot Teungku Nie, Aceh Utara 24355, Indonesia

R. A. Mangkuto
Building Physics Research Group, Faculty of Industrial Technology, Institut Teknologi Bandung, Jl. Ganesha 10, Labtek VI, Bandung 40132, Indonesia

M. D. Koerniawan
Building Technology Research Group, School of Architecture, Planning, and Policy Development, Institut Teknologi Bandung, Jl. Ganesha 10, Labtek VI, Bandung 40132, Indonesia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_16

1 Introduction

Daylighting is a significant indicator for a good performance design in a building in terms of energy-saving [1–3] and user performance [4–7]. However, daylighting also has its disadvantages, particularly when the quantity is too little or too much. Therefore, good daylighting management is required to obtain its optimum benefit, particularly in the tropical region where daylighting is abundantly available, such as Lhokseumawe, Indonesia. Lhokseumawe is one of the Indonesian coastal-tropical cities which is located slightly at the north of equator (5°10′0″ N, 97°8′0″ E, 2 ~ 24 m above sea level). In such locations, the risk of excessive daylight inside a space can be disrupting for the users, particularly for sensitive users such as elementary school children.

There is no proper regulation for good daylighting design for school classrooms in Indonesia. Most of the school classroom designs are based on the Decree of the Ministry of Education, which focus only on the physical features of the classrooms [8]. The only daylighting design criteria still in use is a static metric of daylight factor (DF) [9]. However, the DF is insensitive to geographical locations, and cannot represent the annual and direct sunlight contribution inside a space. Therefore, this study proposes an annual daylight metric, which is called annual sunlight exposure (ASE), that can be used as a criterion to assess the availability of direct sunlight inside school classrooms.

This research therefore aims to investigate the contribution of the direct sunlight inside existing elementary school classrooms in Banda Sakti region of Lhokseumawe, Indonesia. The most sensitive design variables that influence the availability of sunlight inside the school classrooms are observed. The finding from this research is beneficial for the design of elementary classrooms with similar characteristics elsewhere in the tropical region, to avoid excessive direct sunlight exposure.

2 Methods

This research employed a computational method for the simulation purpose using the Ladybug tool (LB) to investigate annual direct sunlight contributions inside the existing classroom design. The classrooms were obtained from 22 state elementary schools (SDN), consist of 256 classrooms, in the Banda Sakti region of Lhokseumawe, Indonesia. To obtain the data, a physical measurement was conducted. The data consisted of sizes for the room, shading, distance to an adjacent building, corridors, glazing, opening position, and elevation. Those data are mainly collected for the digital modelling of the existing classroom design. Figure 1 depicts some examples of the digital representation for the school objects.

From the physical data measurement, some input variables considered influential to the daylight distribution inside the classroom were identified. Those variables were window elevation (X_1), window to wall ratio (WWR, X_2), distance to adjacent

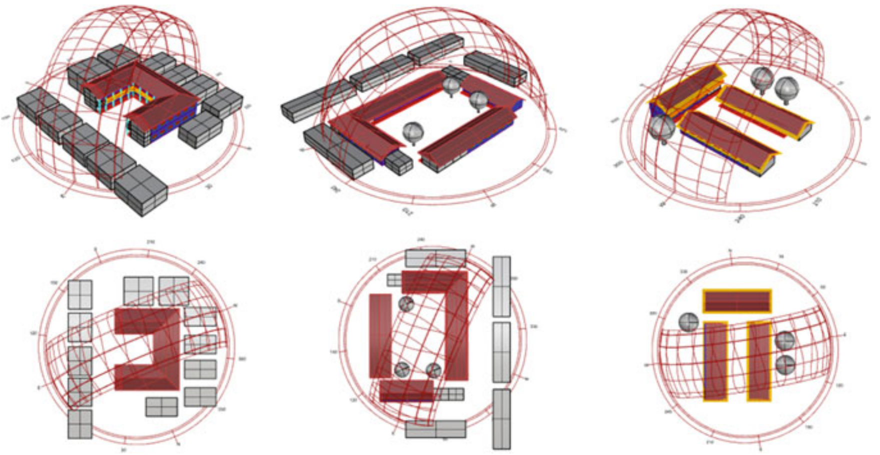


Fig. 1 Digital modeling samples of existing schools being surveyed, perspective views (top row) and top views (bottom row). The objects were SDN 8, 9 and 10 Banda Sakti, Lhokseumawe (left to right)

buildings (X_3), corridor shading depth (X_4), corridor shading elevation (X_5), back shading depth (X_6), and back shading elevation (X_7). Also, all the school objects were categorized by their orientations and WWRs which resulted in 76 unique groups of classrooms. The corridor side was utilized as a reference for the classroom orientation. For instance, if the corridor side of a classroom faces East, it means the classroom orientation is 0° and so on. Also, it was based on the counter-clockwise rule for the orientation degrees increment (Fig. 2).

For the digital modeling, this study utilized Rhinoceros (RH) and a visual programming interface called Grasshopper (GH) [10, 11]. All the school classrooms were modeled without thicknesses for their walls. The model without thickness was created since the earlier study had proved a relatively small impact for the result of annual daylight simulation using climate-based metrics [12]. All the school objects were modeled in RH and were imported into GH for the simulation purpose.

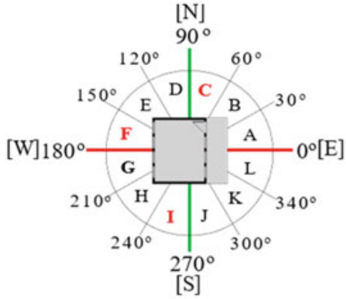


Fig. 2 Orientation in the range of 30 degrees span for each group. The graph shows a sample classroom orientated to the 0° (East/group A)

Next, once imported to GH, the objects were connected to the LB algorithm for calculating Annual Sunlight Exposure ($ASE_{1000,250}$), which is defined as the percentage of sensors receiving direct sunlight hours inside a space that equal or exceed 1000 lx for 250 h ($n_{SE1000lx \geq 250\,h}$) divided by the total number of sensors (n_{total}) annually [13]. Mathematically, $ASE_{1000,250}$ can be explained in Eq. (1).

$$ASE_{1000,\,250} = \frac{n_{sE1000lx \geq 250h}}{n_{total}} \times 100\% \tag{1}$$

Based on the document of Leadership in Energy Efficient Design version 4 (LEED v4), originally the threshold must not exceed 10%, however, in 2017 the threshold was updated to 20% [14]. However, since the 20% threshold required some more efforts to improve the performance toward $ASE_{1000,250}$, the 10% threshold was more appropriate to be employed for an existing space design as intended within this study. Furthermore, $ASE_{1000,250}$ was calculated only the contribution of the direct sunlight, meaning that it omitted the surface reflection inside the space. In order to calculate $ASE_{1000,250}$ accurately, the sun position must be assumed to be in the reallocation in the sky throughout the year [15]. By using the LB algorithm, the calculation for such a case was made possible. Firstly, the *EnergyPlus* (*E*+) weather file (.epw) for Lhokseumawe was used and extracted for its direct normal and diffuse horizontal illuminance data by using the *Ladybug_hourly* surface solar component. All data were organized to be employed as the input in *Ladybug_SunPath*. The analysis period was set for the full year from 09:00 to 17:00, assuming 0.6 for the glass transmittance, while the interior room surfaces were considered black. Simulation was run using *Ladybug_Sunlight Hours Analysis*, and the $ASE_{1000,250}$ was calculated from the output of the component.

3 Data Analysis

For the data analysis, the 76 school objects were group based on the orientation ranges. The ranges were label as A to L as explained in Fig. 2. The orientation group that had more than 10 (ten) school objects was further analysed for its correlation. From the data, it was obtained that only orientation group C (60° to 90°), F (150° to 180°), and I (240° to 270°) meet the criterion (highlighted in bold-red).

Furthermore, the Spearman Rank (r_s) was utilized for the correlation analysis. If the correlation is more than 0.70 then it had a strong correlation while in the range of 0.50 to 0.69, it has moderate correlation, otherwise, it was a weak and very weak category. This category was labelled based on absolute r_s ($|r_s|$). From the strong and moderate correlation criteria, the sensitivity analysis was conducted.

The sensitivity analysis utilized was the standardized regression coefficient (SRC). The SRC can be observed to standardize input (X_1–X_7) and output ($ASE_{1000,250} = Y$) variables by using a multi-linear regression model. The normalization was performed since the input and output variables vary in their units. Therefore, all variables were equally weighted. The normalized input or output was differentiated by adding accent on input or output variables label (X_1'–X_7' and Y'). The SRC value ranges from −1.0 to 1.0, where −1.0 or 1.0 represent the most sensitive variable, while the negative and positive signs indicated the trend. A negative SRC value means that the higher the value of an input, the lower the output value. In addition, SRC in this study was categorized as low (SRC = ±0.00 to 0.33), moderate (SRC = ±0.34 to 0.66) and high (SRC = ±0.67 to 1.00).

4 Result

The simulation shows that 33 school objects (43.42%) are above the 10% threshold (red line in Fig. 3) and 10 objects (7.6%) above the 20% threshold (red dash-line in Fig. 3). This condition shows that in existing classrooms, some have suffered from excessive daylight leading to the potential for perceptual discomfort and overheating during the study time.

Meanwhile, from orientation group C that consists of 11 objects, 4 exceed the 10% threshold (red bar in Fig. 4 top graph). In group F, it is shown that the orientation group which has more problematic classroom objects, 10 out of 15 objects (red bar in Fig. 4 middle histogram). Lastly, in group I, which consists of 20 objects, only 5 exceed the 10% threshold (Fig. 4, bottom graph). The result from Fig. 4 is further evaluated for its correlation.

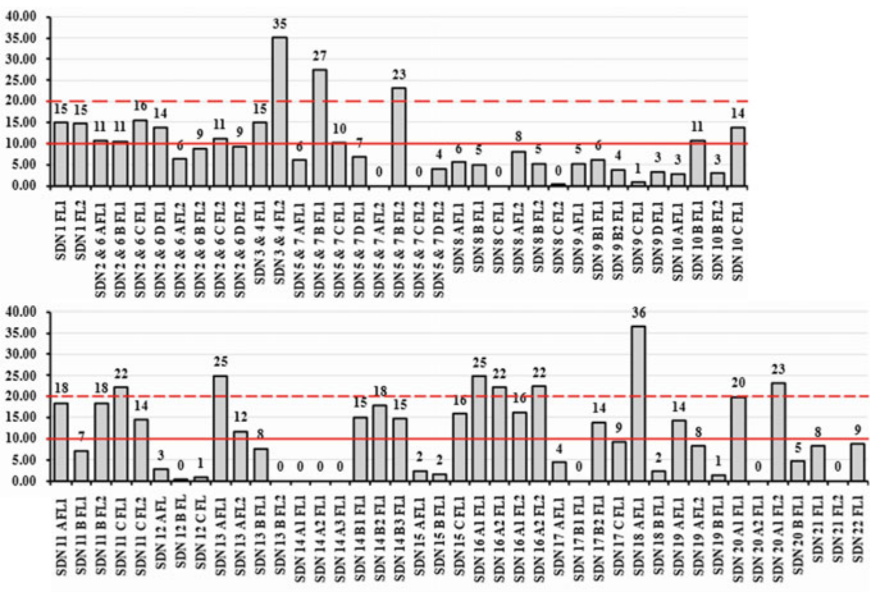


Fig. 3 $ASE_{1000,250}$ simulation result for all 76 school objects

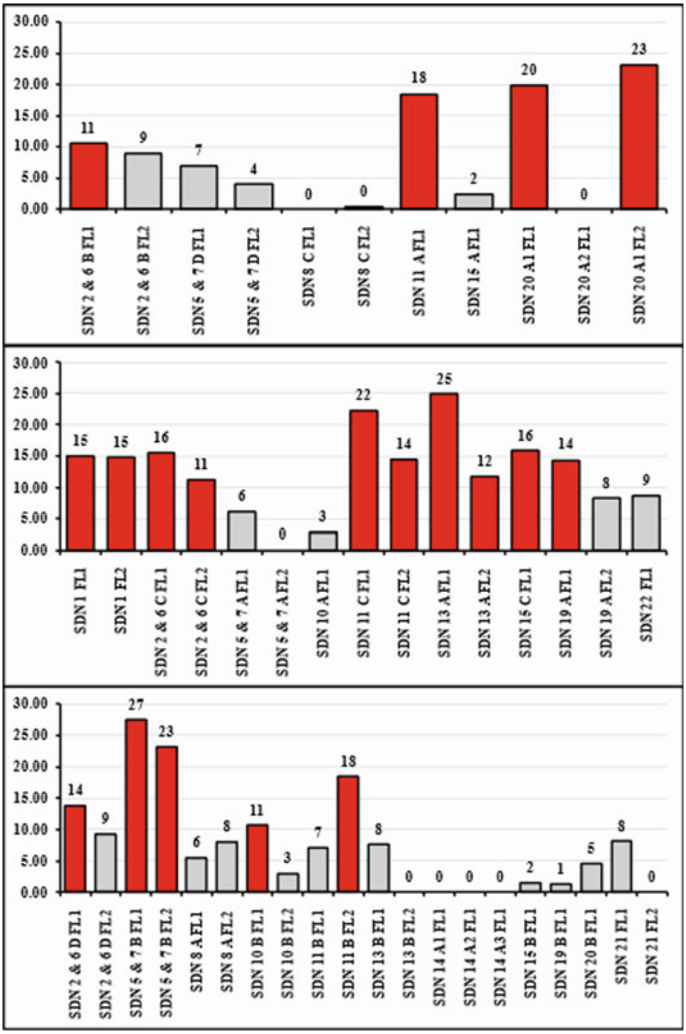


Fig. 4 $ASE_{1000,250}$ result per orientation group that has more than 10 objects at orientation group C (top), F (middle), and I (bottom)

From the correlation analysis, it is found that there are two variables at orientation group C that are moderately correlated, which are X_1 (glazing elevation) and X_2 (WWR) (bold in Table 1). Table 1 reveals that X_2 (WWR) has a p-value $= 0.12$, which means the correlation is considered insignificant. Similarly, when conducts for sensitivity analysis the model suggests statistically insignificant which is indicated by the p-value $= 0.21$, which is larger than 0.05. Therefore, from this orientation group, none of the variables being observed is sensitive.

Table 1 Correlation between input variables ($X_1 - X_7$) with the output variable ($ASE_{1000,250}$) at orientation group C

Variables	X_1	X_2	X_3	X_4	X_5	X_6	X_7
r_s	**−0.68**	**0.49**	0.35	0.19	−0.42	−0.32	−0.12
N	11.00	11.00	11.00	11.00	11.00	11.00	11.00
T Statistic	2.79	1.71	1.11	0.58	1.39	1.03	0.35
DF	9.00	9.00	9.00	9.00	9.00	9.00	9.00
p-value	**0.02**	**0.12**	0.30	0.58	0.20	0.33	0.73
$\lvert r_s \rvert$	0.68	0.49	0.35	0.19	0.42	0.32	0.12
Correlation	**Moderate**	**Moderate**	Weak	Very Weak	Weak	Weak	Very Weak

At orientation group F, only one strong input correlation is called X_4 (corridor shading depth) and one for moderate which is X_3 (distance to adjacent building). Table 2 shows the r_s value for the relevant variables in bold. At this orientation group, sensitivity analysis is performed for these two input variables, which reveals only X_4 (corridor shading depth) as the moderately influential input variable (Fig. 5, left histogram), in a negative trend (SRC = −0.64). It means that at this orientation group, when the corridor shading depth is increased, the $ASE_{1000,250}$ value is decreased. Furthermore, at orientation group F, X_3 (distance to adjacent building) is not sensitive for the direct sunlight.

Table 2 Correlation between input variables (X_1-X_7) with the output variable ($ASE_{1000,250}$) at orientation group F

Variables	X_1	X_2	X_3	X_4	X_5	X_6	X_7
r_s	−0.07	0.04	**−0.61**	**−0.75**	0.08	−0.01	0.13
N	15.00	15.00	15.00	15.00	15.00	15.00	15.00
T Statistic	0.24	0.13	2.77	4.08	0.29	0.04	0.47
DF	13.00	13.00	13.00	13.00	13.00	13.00	13.00
p-value	0.82	0.90	**0.02**	**0.00**	0.77	0.97	0.65
$\lvert r_s \rvert$	0.07	0.04	0.61	0.75	0.08	0.01	0.13
Correlation	Very Weak	Very Weak	**Moderate**	**Strong**	Very Weak	Very Weak	Very Weak

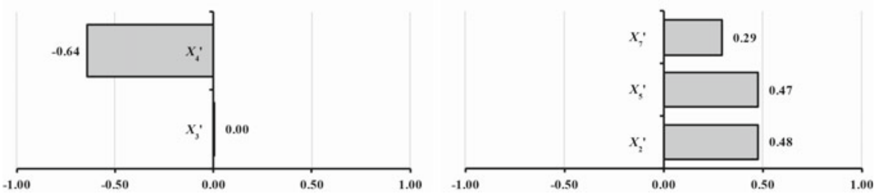


Fig. 5 SRC values for orientation group F (left) and I (right)

Next, at orientation group I, there is one strong correlated input variable which is X_7 (back shading elevation). Also, within this group, there are two moderately influential input variables, which are X_2 (WWR) and X_5 (corridor shading elevation). Figure 5 (right graph) shows the sensitivity result for orientation group I. Input variables with moderate correlation are found to also have moderate influence with positive trends (SRC = 0.48 for X_2*'* and SRC = 0.47 for X_5*'*).

5 Discussion

Based on existing classrooms for the state elementary schools design in Lhokseumawe, Indonesia, this study has revealed two orientation groups that can be evaluated in terms of sensitivity regarding direct sunlight inside the classroom. The first orientation group is F, which suggests that the corridor depth shading can be used to mitigate the excessive sunlight exposure inside the classroom. As explained earlier, the greater the depth of the corridor shading, the lesser the $ASE_{1000,250}$ value. At this orientation group, the windows are located slightly off the West (corridor side of the classroom) and East (back of the classroom) orientations. The SRC = −0.64 indicates that the influence of the corridor shading depth is moderate with respect to $ASE_{1000,250}$.

The second orientation group is I, which indicates that two input variables moderately influence the $ASE_{1000,250}$. Those variables are WWR (SRC = 0.48) and corridor shading elevation (SRC = 0.47). Meanwhile, back shading elevation is the weakest sensitive input variable (SRC = 0.29). In this orientation group, both classroom's windows are slightly off the North and South orientations. In this group the trend is positive, which means when the corridor shading elevation and WWR are increased, the $ASE_{1000,250}$ is likely to improve as well. Therefore, careful attention is expected when designing WWR and back shading elevation. In this orientation group, a larger window design in combination with a higher back shading elevation may contribute to more excessive direct sunlight inside the classroom (Table 3).

Table 3 Correlation between input variables (X_1–X_7) with the output variable ($ASE_{1000,250}$) at orientation group I

Variables	X_1	X_2	X_3	X_4	X_5	X_6	X_7
r_s	−0.05	**0.51**	−0.29	0.28	**0.65**	0.12	**0.76**
N	20.00	20.00	20.00	20.00	20.00	20.00	20.00
T Statistic	0.21	2.49	1.28	1.23	3.60	0.52	4.99
DF	18.00	18.00	18.00	18.00	18.00	18.00	18.00
p-value	0.84	**0.02**	0.22	0.24	**0.00**	0.61	**0.00**
$\lvert r_s \rvert$	0.05	0.51	0.29	0.28	0.65	0.12	0.76
Correlation	Very Weak	**Moderate**	Very Weak	Very Weak	**Moderate**	Very Weak	**Strong**

6 Conclusion

From this study, it is found that excessive sunlight occur in 43.42% of the investigated state elementary school classrooms in the Banda Sakti Region of Lhokseumawe, Indonesia. Moreover, it is found that there are two orientations (F and I) at which the impact of different input variables can be observed with respect to the availability of direct sunlight inside the classrooms. At orientation group F, the corridor shading depth design may hold a vital role to reduce excessive sunlight. Meanwhile, at orientation group I, two input variables, which are WWR and corridor shading elevation, shall be carefully designed to guarantee good daylighting distribution without excessive direct sunlight. At both orientation groups, various design features shall be properly considered to achieve optimum indoor daylight performance inside the classroom.

Acknowledgements This research is supported by the Ministry of Research and Technology/National Institute of Research and Innovation of the Republic of Indonesia, through the PDD 2021 Research Program, under the contract number 2/E1/KP.PTNBH/2021. We appreciate Chris Mackey of Ladybug Tools for providing the foundation of the algorithm for calculating ASE using only LB components. We also would like to express our gratitude to students of the Architecture Program, Universitas Malikussaleh, Indonesia for their contribution during the field measurement. Those students were Muhammad Dastur, Ridho Fernand, Muhammad Andi Arief, Safirannur and Maulana Habib Simatupang.

References

1. Lechner N (2007) Heating, cooling, lighting: Strategi Desain untuk Arsitektur 2nd ed. PT Raja Grafindo Persada, Jakarta
2. Anderson K (2014) Design energy simulation for architects. Routledge, New York, p 249
3. Idrus I, Ramli Rahim M, Hamzah B, Jamala N (2019) Daylight intensity analysis of secondary school buildings for environmental development. In: IOP Conference Series: Earth and Environmental Science 382. IC21ADRI-USN 2018
4. Boubekri M (2008) Daylighting, architecture, and health: building design strategies. Elsevier, Oxford
5. Boubekri M, Lee J, Bub K, Curry K (2020) Impact of daylight exposure on sleep time and quality of elementary school children. Eur J Teach Educ 2(2):10–17
6. Heschong L, Wright R, Okura S (2000) Daylighting and productivity: elementary school studies. In: Efficiency and sustainability, Washington
7. Bahdad AAS, Fadzil SFS, Taib N (2020) Optimization of daylight performance based on controllable light-shelf parameters using genetic algorithms in the tropical climate of Malaysia. J Daylight 7(1):122–136
8. Kementerian Pendidikan Nasional RI (2007) Peraturan Menteri Pendidikan Nasional No 27 Tahun 2007 Standar Sarana dan Prasarana Untuk Sekolah Dasar/Madrasah Ibtidaiyah (SD/MI), Sekolah Menengah Pertama/Madrasah Tsanawiyah (SMP/MTS), Dan Sekolah Menengah Atas/Madrasah Aliyah (SMA/MA). Menteri Pendidikan Nasional
9. Badan Standardisasi Nasional (BSN) (2001) SNI 03-2396: Tata Cara Perancangan Sistem Pencahayaan Alami

10. McNeel R, Rhinoceros A (2019) NURBS [Internet]. [cited 2019 Nov 28]. https://www.rhino3d.com/nurbs
11. Rutten D. Evolutionary Principles applied to Problem Solving - Grasshopper [Internet]. 2010 [cited 2020 Jan 19]. https://www.grasshopper3d.com/profiles/blogs/evolutionary-principles
12. Mangkuto RA, Fela RF, Utami SS (2019) Effect of façade thickness on daylight performance in a reference office building. In: Proceeding of building simulation 2019 [Internet]. The 16th conference of international building simulation association, Rome. https://doi.org/10.26868/25222708.2019.210503
13. USGBC (2013) LEED reference guide for building design and construction, LEED v4. Washington DC
14. USGBC (2017) 100002149 | U.S. Green Building Council [Internet]. https://www.usgbc.org/leedaddenda/100002149
15. Subramaniam S, Mistrick RG (2017) A more accurate approach for calculating illuminance with daylight coefficients. In: The IES annual conference 2017. Portland, Oregon, USA

Turning Challenge into Advantage: UNIMAS Experience in Conducting Architecture Design Studio During COVID-19 Pandemic

Dona Rose Amer Koesmeri, Julaihi Wahid, Bambang Karsono, and Atta Idrawani Zaini

Abstract The Malaysian Movement Control Order (MCO) had forced teaching and learning (T&L) of architecture design studio course to be conducted remotely, as a response to the COVID-19 pandemic outbreak in early 2020. In maintaining the quality of the education, the Universiti Malaysia Sarawak (UNIMAS) architecture programme tried to turn the challenge into advantages through experiential and immersive blended learning. This paper presents a case study with some data validations of experience through mixed method approach. Apart from using UNIMAS experience as the main framework, observation on students' performance and a survey was also conducted to reflect students' perceptions of their experience. The results of the experience were obtained by measuring students' achievement. The stages of the design process in the course were designed systematically in such a way that they are transferable and scalable as necessary, potentially to be adapted by any architecture design studio courses.

Keywords Architecture pedagogy · Architecture education · Architecture design studio · Distance learning · Blended learning · COVID pandemic

1 Introduction

Architecture design studio courses are the core of architecture education [1]. The term 'studio' refers to two things. Firstly, it serves as a student-centred educational pedagogy of learning based on projects (project-based learning), which is a course developed for students to gain the necessary knowledge and skills required of an architect by analysing and responding to authentic, engaging, and real-world complex issues. Secondly, the design studio is also referring to the venue to conduct design learning, monitored by sufficient qualified lecturers set by the Board of Architects Malaysia (LAM). The Council of Architectural Accreditation and Education of Malaysia (MAPS) under LAM has issued a Special Note #4 stated that the longer

D. R. Amer Koesmeri (✉) · J. Wahid · B. Karsono · A. I. Zaini
Faculty of Built Environment, Department of Architecture, Universiti Malaysia Sarawak (UNIMAS), Kota Samarahan, Malaysia
e-mail: akdona@unimas.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_17

design studios' T&L to take place in a non F2F learning environment, the more it might jeopardize the quality of the design studio learning. This paper presents UNIMAS experience in conducting their architecture design studio course during its Semester 2–2019/2020 academic session, when the COVID-19 pandemic was in its initial outbreak and during the strictest MCO restriction ever imposed. The case study is then supported by the data in validating the experience's effectiveness, in answering the objectives as follows:

1. Will online learning be able to support T&L with the absence of educational facilities and equipment during the MCO?
2. How exactly will online learning be conducted to achieve a conducive learning environment while maintaining the quality of the architecture education?

1.1 Hypothesis

Exploratory learning is of exploring environments and virtual experiences with tutorials and peer-based support which acknowledges the cognitive process that helps students to use their imagination and creativity to compose output from interactions. This is a complex process and occurs at different levels of understanding. Hence, learning can be supported through different media and interactions, rather than solely on textual engagements. The main hypothesis of this study is expressed as: If students are immersed in the learning activities, they tend to be more engaged in the entire learning process.

1.2 Exploratory and Blended Learning

de Freitas and Neumann [2] describes 'exploratory learning' as learning through exploring environments, which may be real, virtual or a combination of both settings with peer and tutorial supports. This approach of T&L emphasises more on students' involvement and encourages learners to examine discussions in discovering relationships between prior knowledge and unfamiliar concepts. It is a student-centred pedagogy that encourages students to think creatively, experience different concepts and learn how to reflect on what they learned. The requirement of one-to-one interactions between lecturer and students is central to this [2]. On the other hand, blended learning, or the integration of F2F and online instruction [3], is known to have the potential to enhance effectiveness of learning [4]. Compared to F2F learning, studies have found that blended learning improves student success and satisfaction [5], as well as the sense of community among the students [6]. Within the pandemic constraint, immersive blended learning in architecture design courses through exploratory learning was adopted, where an environment is created for learning to take place in a more experiential way by integrating a range of different tools, applications and communications despite it was done remotely online.

2 Research Methods

The research used mixed method where both qualitative and quantitative analyses were used. The case study is based on the implementation of Architecture Design Studio 6 which was conducted in semester 2–2019/2020. Other than literature review, observation is made on students' ongoing responded behaviour. A survey was also conducted to gather feedbacks on the students' perception on the initiatives. The results of the initiatives were obtained by measuring students' achievement.

2.1 Studio Teaching and Learning Challenges

Manual of Accreditation for Architecture Programme [1] interprets design studio course activities may involve lectures, precedent studies, talks, student-led discussions, 'desk crits' (project critiques on a one-to-one basis) and 'critique sessions' (presentation of project for purpose of sharing learning experience) within the studio environment. There are also portfolio review, exhibitions, presentations and assessments, as well as off-studio activities (such as site visits, study tour etc.). Whatever instructional models applied, the focus would be the attainment of standards which should be adequate with regards to design, technical, professional, knowledge and skills required by MAPS.

2.2 Case Study—UNIMAS Design Studio T&L Approaches During MCO

The visual perception of representations is a complex internal information-processing task which is subject to the type of representation [7]. The objectives of visual perception and spatial cognition are to identify, recognize, estimate and provide meaning to objects and spaces with which the human being is engaged [8]. The followings are some stages in the design process conducted in the course during the ephemeral phases.

(a) **Site Analysis**

The visits to sites, land or council office and meeting the client are real-world experience that provides opportunities towards an experiential learning process. Drone technology was used during the site study to reinforce hands-on experience practice to ensure the deep learning, technical knowledge and skill enhancement.

(b) **Collaborative Learning (Group works and Student-led Discussions)**

Collaborative oriented education is a learning method where students share their knowledge and experiences and develop them by discussion and collaboration [9].

(c) Lectures and Talks

Lectures act as a complement to a problem-based learning course such as design studio course [10]. This form of lecture is organized to support meaningful learning and to give an opportunity for the students to interact with the speakers, actively process the content of the lectures and open new discussions via a joint studio lecture as an integrated online talk series which is named AD+ (Architecture + Design Talk).

(d) 'Desk Critiques' and Tutorials

The following outlines the comparison between conventional desk crit and online desk crit both (non-conventional) with blended learning approach (Table 1).

(e) Interim Assessments and Final Presentations

Interim assessments and final presentations are the stage where the students present their design proposal through drawings, scaled building models and animations. This is an interactive environment that allows exchange of knowledge and ideas among individuals.

Table 1 Comparison of different desk crit method

	Conventional desk crit	Non-conventional desk crit
Mode	• Physical F2F • Synchronously	• Online F2F • Synchronously
Venue	Takes place at a desk	Takes place online
Tools	May employ a drafting board, pens, and papers where the students present their drawings and concepts one-on-one	Conducted using computers on a video conferencing platform. Available to the students were file transfer feature, text-based chat, digital audio, digital video, a shared whiteboard drawing application, and application sharing of AutoCAD, SketchUp, PowerPoint and other programs
Annotation	Lecturer comments and gives feedbacks directly on the student's papers	Lecturer comments and gives feedbacks directly on the student's digital drawings, by using touch-screen technology or Wacom
Record-keeping	Crit session activities are normally not recorded	Sessions are recorded and can be made available for all students to refer to asynchronously
Sequence of activities	Follow the working model of activity sequence	Follow the working model of activity sequence
Interaction	Direct lecturer-student dialogue, with visible expression and body language during presentation	Direct lecturer-student dialogue but limited to merely camera view. Invisible expression and body language, moreover if camera is turned off during presentation

2.3 *Students' Perception*

A survey has been conducted to gather feedbacks from all eight (8) students of BEA3218 Architecture Design Studio 6. The students were asked to rank their view about the teaching and learning delivery on a six-point Likert scale. The data is presented in Table 2.

3 Discussion

Basically, the initiative provides a meaningful learning experience in aspects of cognitive, psychomotor and affective.

i. **Cognitive Aspect**

Several studies proved design studio learning as a high-level cognitive ability and underscored the link between the cognitive process and the concept of aesthetics in design [11, 12].

ii. **Psychomotor**

The activities were based on free-hand, technical drawings, some skills on the usage of various tools, applications and other media which can be categorized within psychomotor domain, in the margins of contemporary architectural education [13].

iii. **Affective**

Affective domain in architecture design studio learning represents emotional aspect of behaviour which can be seen throughout the whole design process. Students educated in an immersive learning environment can be more engaged in the learning process within this creative environment. The learning blends interaction, collaboration, and the enhanced integration of tools and technology. The setting provides activity-based instruction and student-led participation, which significantly improve attention and develop active interest in the development of the design.

4 Conclusions

At the end of the course, the assessment result was all Course Learning Outcomes achieved by the students. Although the studies are still considered underway, we may offer some tentative conclusions. Even though the students preferred to have physical face-to-face teaching and learning, it was found that they were able to adapt to the online design process. As design studio learning requires a high-level cognitive ability, students were able to internalize design concepts and develop their own ideas. The knowledge enables student to analyse and respond to authentic, real-world complex issues and problems. The stages in the design process in the course

Table 2 Respondents views on their use of eLEAP (web-based learning management system (LMS)) and video conferencing

	% of responses					
	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
When many activities were restricted due to MCO, our studio implemented blended learning setting that utilises face-to-face and one-to-one learning by making use of several interaction platforms such as eLEAP, live video conferencing, and other social networking media			11.1	11.1	11.1	66
The above activities were effective and efficient. I was able to achieve the learning objective even though activities were conducted online	11.1		22.2	44.4	22.2	
Blended learning technique offers the benefits of online learning that allows remote delivery	11.1			44.4	22.2	22.2
eLEAP was useful for my study during the MCO	11.1	22.2	22.2	22.2	22.2	22.2
eLEAP as an interaction platform was useful/easy to communicate with		11.1	11.1	55.6	11.1	11.1
The discussion forums on eLEAP were good because one had to write everything down and it was easy to follow the discussions		11.1		22.2	55.6	11.1
eLEAP is a good platform to place all teaching and learning materials			11.1	11.1	33.3	44.4

(continued)

Table 2 (continued)

	% of responses					
	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
eLEAP provides easy access and is user-friendly			11.1		55.6	33.3
eLEAP is a good platform to submit assignments/projects				11.1	22.2	66.7
Video conferencing sessions were enjoyable	11.1			22.2	44.4	22.2
Video conferencing was a more efficient medium for group discussions than the eLEAP discussion forums		11.1			33.3	55.6
I prefer live video conferencing than discussion on eLEAP. Because it is more appropriate for direct interaction through real-time sharing				11.1	22.2	66.7
Video conferencing sessions were good because I was able to get immediate feedback				22.2	11.1	66.7
From the implementation of blended learning, the architecture design studio course was able to adapt to the new normal without compromising the quality of the learning outcomes through immersive learning by integrating a range of different tools, applications and communication media			11.1	22.2	44.4	22.2

(continued)

Table 2 (continued)

	% of responses					
	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
Physical face-to-face teaching is more effective for developing a design project						100

were designed systematically in such a way that they are transferable and scalable as necessary, to be adapted by any architecture design studio courses.

References

1. Manual of Accreditation for Architecture Programme (MAAP, 2013)
2. de Freitas S, Neumann T (2009) The use of 'exploratory learning' for supporting immersive learning in virtual environments. Comput Educ 52:343–352. https://doi.org/10.1016/j.compedu.2008.09.010
3. Graham CR (2013) Emerging practice and research in blended learning. In: Moore MG (ed) Handbook of distance education, 3rd edn. Routledge, New York, pp 333–350
4. Garrison DR, Kanuka H (2004) Blended learning: uncovering its transformative potential in higher education. Internet Higher Educ 7:95–105
5. Dziuban C, Hartman J, Cavanagh T, Moskal P (2011) Blended courses as drivers of institutional transformation. In: Kitchenham A (ed) Blended learning across disciplines: models for implementation. IGI Global, Hershey, pp 17–37
6. Rovai AP, Jordan HM (2004) Blended learning and sense of community: a comparative analysis with traditional and fully online graduate courses. Int Rev Res Open Dist Learn 5(2):1–13
7. Marr D (1983) Vision: a computational investigation into the human representation and processing of visual information. W. H. Freeman, New York. 0716715678
8. Gifford R (2002) Environmental psychology: principles and practice. Optimal Books, Colville. 0968854303
9. Garrison D, Vaughan N (2008) Blended learning in higher education: framework, principles, and guidelines. Jossey-Bass, San Francisco, p 7
10. Fyrenius A, Bergdahl B, Silén C (2005) Lectures in problem-based learning–why, when and how? An example of interactive lecturing that stimulates meaningful learning. Med Teach 27(1):61–65. https://doi.org/10.1080/01421590400016365
11. Oxman R (1996) Cognition and design. Des Stud 17(4):337–340
12. Nguyen TA, Zeng Y (2012) Clustering designers' mental activities based on EEG power. Tools and methods of competitive engineering. Karlsruhe
13. Savic M, Kashef M (2013) Learning outcomes in affective domain within contemporary architectural curricula. Int J Technol Des Educ 23:987–1004. https://doi.org/10.1007/s10798-013-9238-8

Factors of Obsolescence Affecting Adaptively Reused Shophouses in the Core Zone of Melaka, Malaysia

Nor Syahila Ab Rashid and Tim Heath

Abstract Fast economic growth and restructuring has resulted in a large number of obsolete buildings in large cities. Many of these buildings represent different eras and building typologies. Some, such as the distinctive shophouses of Southeast Asia, are important heritage legacies. The desire to undertake research related to the obsolescence of shophouses arises from the abandonment and demolition of many of these unique urban assets. Consequently, the aim of this paper is to examine the dimensions of obsolescence in adaptively reused shophouses in the Core Zone of Melaka. This research uses qualitative method through semi-structured interviews to gather information from three case study buildings. These three case study buildings were made up of shophouses which were converted into boutique hotels. NVivo software was employed to assist analysis for the collected data. The research findings indicate that functional and social obsolescence are the most dominant factors influencing all of the case study buildings. Further research is required to find the best formulas for revitalising and converting obsolete shophouses in this area for suitable uses, as this can inform policy and the success of the adaptive reuse of shophouses in the future.

Keywords Building obsolescence · Adaptive reuse · Traditional shophouses · Melaka world heritage site · Core zone of Melaka

1 Introduction

Rapid economic development and restructuring mean that there are more old and obsolete buildings in large cities, as reported by Tan et al. [17]. Uncertainty about the future of an area can cause gradual deterioration of old-fashioned buildings and

N. S. A. Rashid (✉)
Faculty of Engineering and Built Environment, Department of Architecture, Universiti Sains Islam Malaysia (USIM), Bandar Baru Nilai, 71800 Nilai, Negeri Sembilan, Malaysia
e-mail: norsyahila@usim.edu.my

T. Heath
Faculty of Engineering, Department of Architecture and Built Environment, University of Nottingham, University Park, Nottingham NG7 2RD, UK

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_18

infrastructure. These factors can cause values and prices in the declining district to fall further and property to be similarly devalued [5].

Tiesdell et al. [20], Carmona et al. [2], Thomsen and van der Flier [19] and Pinder et al. [14] have expressed similar views that, in practice, obsolescence is commonly regarded as the decreasing performance of buildings due to rising expectations. The impact of building obsolescence can be classified into correctable, meaning cost-efficient to rectify, and non-correctable, meaning not cost-efficient to rectify, at least at the current time [2, 4].

Obsolescence is a condition that often justifies demolition [19]. Recent research by Zawawi and Abdullah [23] has shown that the threat of obsolescence requires shophouse owners in Kuala Lumpur, Malaysia to determine the scope of redevelopment. It could be adaptive reuse, rehabilitation, facade conservation or total redevelopment. Total redevelopment is intended to remove low-quality buildings, and this means demolition. On the other hand, adaptive reuse should be considered as a sustainable option.

The Core Zone of Melaka consists of two major areas: the St. Paul's Hill Civic Zone and the Historic Residential and Commercial Zones (see Fig. 1). Most traditional shophouses are located in the Historic Residential and Commercial Zones. These shophouses were mainly subject to the Malay, Southern Chinese and European (Dutch and British) influences. The combination of these historic features characterises this architectural typology as a unique tangible heritage and this can be seen in their urban and street context, and their styles and characteristics that make a significant contribution to the inscription of Melaka as a UNESCO World Heritage Site in 2008.

In relation to that, there is a need for a comprehensive study concerning the impact of obsolescence on shophouses in the Core Zone of Melaka at the present time. Problems related to these shophouses arising from natural causes, modernisation, legislation, gentrification, lack of funds, ownership and conflict of interest, attitudes and perceptions, upgrading and conservation, and heritage tourism, as revealed by Ismail and Shamsuddin [7] may be categorised as obsolescence. It should be pointed out that Ismail and Shamsuddin focused fully on demolished shophouses rather than on converted shophouses. However, nowadays, demolition is no longer permitted on shophouses in this area.

In the Conservation Management Plan (CMP) and the Special Area Plan (SAP) for the Melaka World Heritage Site, shophouses in the Core Zone of Melaka are classified under Category II [13]. Category II buildings have two options either to continue with existing uses or to adapt for new uses. However, preserving shophouses for their original use might not necessarily be appropriate as the nature of uses can change over time. Therefore, adaptive reuse is suggested to extend the service of such buildings and to avoid obsolescence being used as a justification for demolition.

Consequently, this study examines the factors of obsolescence in adaptively reused shophouses in the Core Zone of Melaka, in which through this objective, the most significant factors affecting all of the case study buildings are discovered and reviewed. This could be a stepping stone for further research on the adaptive reuse

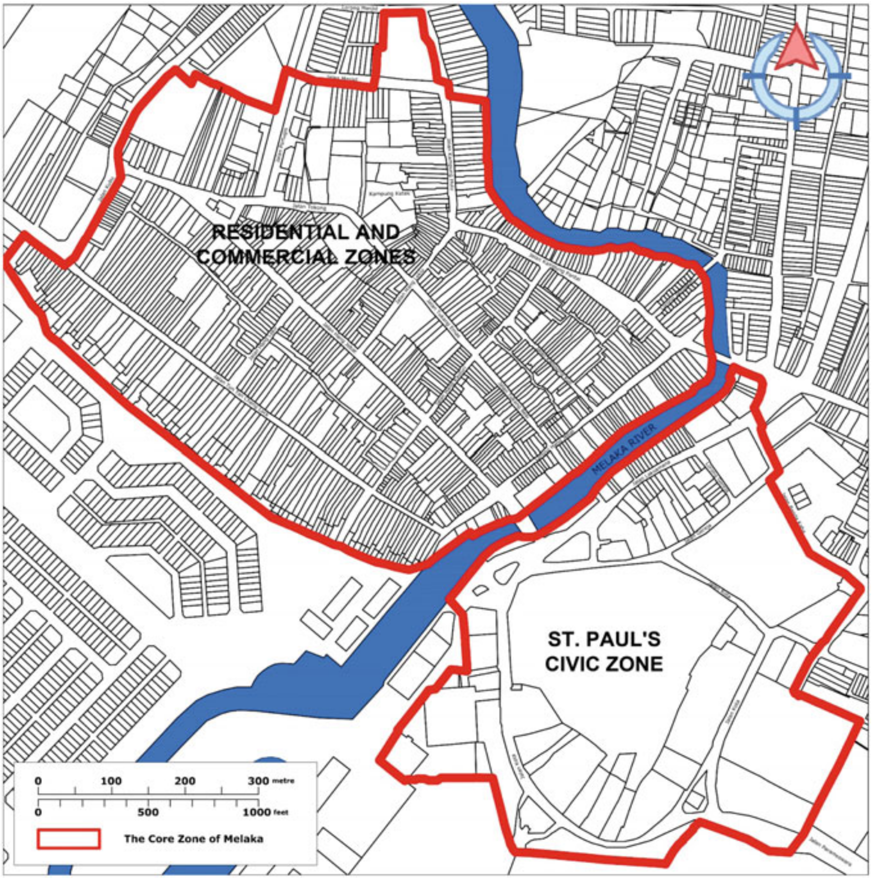


Fig. 1 The Core Zone (Property Zone) of Melaka consists of two major areas: the St. Paul's Hill Civic Zone and the Historic Residential and Commercial Zones

practices of obsolete shophouses in this area. Their survival is crucial to maintaining the continuous inscription of Melaka on the UNESCO World Heritage List.

2 Methods

This research is entirely qualitative in nature. It has been carried out through a detailed case study approach of three adaptively reused shophouses in the Core Zone of Melaka. The on-site survey conducted by Rashid [16] clarified that 31% of shophouses in this area have experienced adaptive reuse practices. This is a relatively significant percentage, in which greater number of adaptive reuse projects indicates greater number of obsolete shophouses. The most popular adaptive reuse option for these shophouses is to boutique hotels and as such this typology was selected for this study. The three adaptively reused shophouses are as follows: the Fomecs Boutique Hotel (Fomecs Hotel), the Jonker Boutique Hotel (Jonker Hotel) and the Timez Modern Heritage Hotel (Timez Hotel).

An interviewing technique was employed as the primary data collection mechanism with nine interviewees who are associated with the conversion process of the case study buildings. These interviewees were as follows: the hoteliers as the building owners, the architects in charge as the professional experts, and the hotel managers or supervisors as the specialist users. However, much of the information has been retrieved from the architects in charge. This is because the architect is the leader of consultant team [21], who can see the possibilities and the difficulties in reusing the building [18]. The data collected were analysed using NVivo software to enable the development of key themes across different cases (cross-case) along with content analysis that had been selected as the primary means of data analysis.

3 Results and Discussion

Eight factors of obsolescence, namely: physical, functional, technological, economic, environmental, locational, social and legal, have been identified in Fomecs Hotel, Jonker Hotel and Timez Hotel for cross-case comparison (see Table 1). These forms of obsolescence were experienced by these case study buildings before their conversions into hotel-type accommodation. It should be noted here that the factor(s) with the highest frequency is defined as the factor(s) that affects all of the case study buildings. Explanations of each factor are outlined in detail after Table 1.

3.1 Physical Obsolescence

The vacancy and abandonment of Timez Hotel for several years prior to its conversion into a boutique hotel had led to its physical deterioration. According to Wilkinson et al. [22], physical obsolescence can be defined as an increased deterioration as a consequence of inadequate maintenance and repair routines. This is in line with Feilden (as cited in [7]), in which human action causes the greatest damage. This may reduce the capability of the building to meet both user expectations and performance requirements.

The physical structure of Timez Hotel was in a dilapidated condition with a collapsed roof at the back and poor-quality materials for some elements. As indicated by Bartlett and Howard [1], heritage buildings that were poorly built in the past will not outlive their expected life. Good quality materials, especially for the walls and the roof are important to make the building solid and able to keep out the weather [8].

Table 1 Cross-comparisons on factors of obsolescence affecting the case study buildings

Factor	Obsolescence	Case study building		
		Fomecs Hotel	Jonker Hotel	Timez Hotel
Physical	Dilapidation			✓
	Physical deterioration			✓
	Poor quality materials			✓
Functional	Inadequate building function	✓		✓
	Inadequate spatial capacity	✓	✓	✓
	Inappropriate building layout			✓
Technological	Changes in building services		✓	✓
	Limitation of facilities			✓
Economic	Drop in demand	✓	✓	
	Low rental income levels	✓		
	Uneconomical building function	✓		
Environmental	Improper waste management		✓	✓
	Improper water supply system		✓	
	Poor indoor air quality			✓
	Road congestion	✓		
Locational	Changes in economic activities	✓	✓	
Social	Changes in taste and style	✓	✓	✓
	Human migration	✓	✓	✓
	Lack of significant values		✓	✓
Legal	Changes in legislation			✓
	Existence of flammable materials			✓

3.2 Functional Obsolescence

The previous uses of Fomecs Hotel and Timez Hotel as a warehouse, factory, shop and residence were no longer relevant for current needs as a consequence of inadequate building function.

The small and narrow structure of these buildings had prompted the need for larger spatial capacity to provide more warehouse space in Fomecs Hotel, and additional living space for the residents of Timez Hotel. This fact is supported by the architect in charge of Jonker Hotel who suggested that the conversion of the upper floor of shophouses in the Core Zone of Melaka from living quarters into storage is because of the growing sales volume and a wide range of goods.

There was also an insufficient number of kitchens, toilets and showers in Timez Hotel because of limited spatial capacity, and all of the residents had to share these facilities. Apart from that, the previous building layout of Timez Hotel was inappropriate for modern needs as it consisted of a deep inside corridor and windowless rooms for natural ventilation and lighting. Cheong [3] and Wilkinson et al. [22] agreed that a building may be deemed to be functionally outdated because of its ineffective and inflexible layout.

3.3 Technological Obsolescence

The dependence of the residents of Jonker Hotel and Timez Hotel upon wells for water supply for washing and drinking, and the bucket system for waste disposal, had become the main issues before the public services were installed.

Many residents had their own wells, which were commonly located in the kitchen at the back of these buildings. Up to recent times, there was still a need to source a water supply. During the vacancy and abandonment of Timez Hotel for several years prior to its conversion, there were no electrical and water supply even though the systems were there. However, these building services were already outdated.

Cheong [3] pointed out that, when several electrical and mechanical services are no longer technologically appropriate concerning performance, there may be efforts to improve efficiency through technological innovation. This technological change can sometimes make older buildings unsuitable for modern production processes [4]. As recommended by Wilkinson et al. [22], the need for this technology to be upgraded or changed will have an impact on the obsolescence of older buildings. There are occasions when expensive retrofitting will make an upgrade less attractive.

The number of facilities such as the kitchen, toilets and showers in Timez Hotel was limited. The limited shared facilities had become inadequate for the needs of the residents.

3.4 Economic Obsolescence

Traditional trades in Fomecs Hotel and Jonker Hotel, for instance as a shop, factory and coffee shop, had seen a drop in demand, as these activities were considered to be old-fashioned and no longer relevant. Moreover, the migration of residents out of the Core Zone of Melaka also made these activities no longer profitable since the activities were based on the demands of the residents.

Rental rates for the previous uses of Fomecs Hotel as a shop and warehouse were low and unprofitable. This situation contributed to an uneconomical building function in Fomecs Hotel because these uses did not make much profit for the building owner. As emphasised by Langston [9] and Wilkinson et al. [22], failure to generate a consistent operating revenue can lead to the building being economically outdated. Since there is no funding available for maintaining privately-owned heritage buildings such as shophouses, the tendency towards conserving them will largely depend on the potential profits [7]. Otherwise, they will be left in a dilapidated state or they will be demolished in favour of new more profitable buildings.

3.5 Environmental Obsolescence

The reliance of the residents of Jonker Hotel and Timez Hotel upon improper waste management involving manual collection for the disposal of wastewater, and having a refuse chamber chute for the disposal of garbage and rubbish, could have negatively affected their health and the environment. Indeed, shophouses can be more seriously threatened by pollution from inadequate waste disposal than from tourism in itself [7].

The dependence of the residents of Jonker Hotel upon an unsafe drinking water supply system from wells could have exposed them to diseases related to untreated water. In addition, the previous building layout of Timez Hotel included a deep inside corridor and windowless rooms resulting in the absence of natural ventilation. This led to poor indoor air quality. As stated by Rani [15], indoor air quality has a significant impact on human comfort, health and productivity.

The status of the Core Zone of Melaka as a tourist attraction, especially after the inscription of Melaka as a UNESCO World Heritage Site, resulted in road congestion, making many residents decided to move out of this area because of parking problems. The nuisance arising from crowded traffic and tourists could encourage the residents to leave. As a consequence, the original function of shophouses as living quarters on the upper floor(s) would start to decline. A more worrying development is that this architectural typology could undergo demolition as a result of these environmental factors [7].

3.6 Locational Obsolescence

Since the Core Zone of Melaka became a tourist attraction, the previous economic activities of shophouses in this area related to commercial, import/export, agriculture and industry changed to tourist related activities.

This situation occurred because the traditional trades were considered to be uneconomical, old-fashioned and no longer relevant, as people no longer bought their daily needs at the shop, processed their food traditionally and had their coffee in the traditional coffee shop. Tourism became the main generator of profits, therefore, in this situation the shophouses might become locationally outdated if their original function was to continue. A study by Carmona et al. [2] revealed that a location can suffer depreciation when it is considered by the users to be less fashionable and attractive.

3.7 Social Obsolescence

Lifestyle trends in this area in terms of living, shopping and dining have also changed. People no longer wanted to live with their extended family in the place where they worked and ran their business. They no longer bought their daily needs in the shop or had their coffee in the traditional coffee shop. The traditional trades, which were part of the original function of shophouses, are now considered to be old-fashioned and no longer relevant. As highlighted by Langston [10], fashion and style changes in society can contribute to the demand for building renovation or replacement even though new materials and technologies have been already installed.

This situation was compounded by the displacement of the residents of all of the case study buildings for various reasons such as parking problems and property divestment. The migration of residents out of this area meant that traditional trades were no longer profitable because these activities were based on the needs of the residents.

In addition, the design of Jonker Hotel and Timez Hotel was simple and did not have much in the way of architectural and historical values that needed to be preserved. The styles of these shophouses were a mixture of a few styles, and the absence of significant values meant that some elements had to be changed or demolished. This is due to the fact that the image or style of a building can promote market interest and raise property values or rental income streams [22]. However, it is important to appreciate shophouses as many of them provide the setting for public buildings, especially in Melaka. Any apparent lack of appreciation of this architectural typology could result in negative social pressures [6].

3.8 Legal Obsolescence

As is often the case with other heritage buildings, Timez Hotel was constructed according to an outdated building code where there was less consideration of fire risks or of the requirements for fire safety. This building code is believed to have been part of the 1822 Jackson Plan that was originally enacted in Singapore by Sir Stamford Raffles. It was soon adapted in Melaka [12], and it contained recommendations to build houses with masonry and to use roof tiles in order to reduce fire risk.

What is of greater concern is the fact that some parts of Timez Hotel were built using flammable materials such as dried timber that present specific concerns associated with fire safety, leading to a dangerous building. As indicated by Tiesdell et al. [20] and Langston et al. [11], amended fire or occupational health and safety regulations, as well as modern building ordinances, may cause legal obsolescence. This form of obsolescence occurs when the building fails to achieve certain minimum standards of functionality determined by a public agency [2, 20], in this case by the Melaka Historic City Council (MBMB).

4 Conclusions

The traditional shophouses within the Core of Melaka are an important tangible heritage that reflects Western colonialism in Malaysia. These historic buildings in turn provided an opportunity for Chinese immigrants to establish their settlements in this country, resulting in a hybrid fusion of Malay, Southern Chinese and European styles. As the dominant heritage building typology of the old core of the city, their survival is crucial to ensure the continuous inscription of Melaka as a UNESCO World Heritage Site. However, a significant number of these shophouses were obsolete primarily as a result of functional and social factors.

Over time, the small and narrow structure of these buildings with limited facilities had driven the need for larger spatial capacity for increased production and extended family accommodation. At about the same time, lifestyle trends in terms of living, shopping and dining have changed, leading to the original function being seen as old-fashioned and no longer relevant. The migration of residents from the Core Zone of Melaka because of parking problems and property divestment, also made the traditional trades of the shophouses no longer profitable.

Meanwhile, obsolescence has greatly influenced Timez Hotel, and that Fomecs Hotel is the least likely building to be in this situation. This could be the result of vacancy and abandonment of Timez Hotel for several years prior to its conversion. Fomecs Hotel and Jonker Hotel were constantly refurbished over time, which could potentially minimise the impact of obsolescence. In addition, all forms of obsolescence were experienced by at least two case study buildings except for physical and legal obsolescence. This suggests that physical and legal matters are not the main factors influencing the obsolescence of adaptively reused shophouses in the Core Zone of Melaka.

It has therefore become necessary to identify contemporary functions for these shophouses through adaptive reuse, which in this case into boutique hotels to keep them in active use and minimise obsolescence issues.

Acknowledgements The authors would like to thank the Ministry of Higher Education Malaysia (MOHE) and the Universiti Sains Islam Malaysia (USIM) for providing financial support through the SLAI Scholarship [number KPT(BS) 810904045266].

References

1. Bartlett E, Howard N (2000) Informing the decision makers on the cost and value of green building. Build Res Inf 28(5–6):315–324. https://doi.org/10.1080/096132100418474
2. Carmona M, Heath T, Oc T, Tiesdell S (2010) Public places—urban spaces: the dimensions of urban design. Elsevier Ltd., Oxford, England
3. Cheong ES (2010) A study of building obsolescence in standard design terrace houses in Perak. Unpublished advanced diploma dissertation. Kolej Tunku Abdul Rahman, Perak, Malaysia
4. Douglas J (2006) Building adaptation, 2nd edn. Elsevier Ltd., Oxford, England

5. Heath TP (2002) Re-populating city centres: the role of post-War office to residential conversions. Doctoral dissertation, University of Nottingham, United Kingdom. http://eprints.nottingham.ac.uk/id/eprint/13301
6. Heritage of Malaysia Trust (2004) Buletin warisan. Heritage of Malaysia Trust, Kuala Lumpur, Malaysia
7. Ismail WHW, Shamsuddin S (2005) The old shophouses as part of Malaysian urban heritage: the current dilemma. Paper presented at the 8th international conference of the Asian Planning Schools Association, Penang, Malaysia
8. Kalman H (1991) Adapting existing buildings as museums. In: Lord GD, Lord B (eds) The manual of museum planning. HMSO, London, England, pp 305–314
9. Langston C (2011) Estimating the useful life of buildings. Paper presented at the 36th Australasian University Building Educators Association Conference, Queensland, Australia
10. Langston CA (2011) Life-cost approach to building evaluation. Routledge, Oxon, England
11. Langston C, Wong FKW, Hui ECM, Shen LY (2008) Strategic assessment of building adaptive reuse opportunities in Hong Kong. Build Environ 43:1709–1718. https://doi.org/10.1016/j.buildenv.2007.10.017
12. Lee WH (2016) The history of Melaka's urban morphology. https://doi.org/10.13140/RG.2.1.1719.3367
13. Melaka JPBD (State Town and Country Planning Department) (2011) Conservation management plan and special area plan for Melaka. Melaka JPBD, Melaka, Malaysia
14. Pinder J, Austin S, Schmidt R III, Gibb A (2012) Form, function and the economics of change. In: Finch E (ed) Facilities change management. Blackwell Publishing Ltd., West Sussex, England, pp 26–41
15. Rani P (2015) The impact of adaptive reusing heritage building as assessed by the indoor air quality case study: UNESCO World Heritage Site Penang. Procedia Soc Behav Sci 179:297–307. https://doi.org/10.1016/j.sbspro.2015.02.433
16. Rashid NSA (2020) The adaptive reuse of obsolete shophouses in the Core Zone of Melaka, Malaysia as boutique hotels. Doctoral dissertation, University of Nottingham, United Kingdom
17. Tan Y, Shen L, Langston C (2014) A fuzzy approach for adaptive reuse selection of industrial buildings in Hong Kong. Int J Strateg Prop Manag 18(1):66–76. https://doi.org/10.3846/1648715X.2013.864718
18. Thompson EK (ed) (1977) Recycling buildings: renovations, remodelings, restorations, and reuses. McGraw-Hill Inc., New York, NY
19. Thomsen A, van der Flier K (2011) Obsolescence and the end of life phase of buildings. Paper presented at the management and innovation for a sustainable built environment 2011, Amsterdam, The Netherlands
20. Tiesdell S, Oc T, Heath T (1996) Revitalizing historic urban quarters. Architectural Press, Oxford, England
21. Wasserman B, Sullivan P, Palermo G (2000) Ethics and the practice of architecture. Wiley, New York, NY
22. Wilkinson SJ, Remøy H, Langston C (2014) Sustainable building adaptation: innovations in decision-making. Wiley, West Sussex, England
23. Zawawi NAWA, Abdullah A (2011) Evaluating stakeholders preferences: reconciling heritage and sustainability. WIT Trans Ecol Environ 150:675–686. https://doi.org/10.2495/SDP110561

Performance Comparison on Water Demand Methods Applied at Pengkalan Gawi, Kenyir Lake, Malaysia

Nor Najwa Irina Binti Mohd Azlan, Shuhairy Norhisham, Marlinda Abdul Malek, Nur Syafiqah Mohd Shkuri, Maslina Zolkepli, L. W. Ean, and Ani Munirah Mohamad

Abstract Every day, demand and supply of water resources rises along with the urbanisation, population, and technological advancement. The situation has brought up the needs to explore water demand of an area for the water authority to supply enough water to the people. The objective of the research is to compare the performance of Micro-Component Analysis (MCA) and National Water Service Commission (SPAN) Guideline with actual water demand implied at Pengkalan Gawi, Kenyir Lake, Terengganu, Malaysia. Actual water consumption and forecasted water consumption (MCA and SPAN Guidelines) are used to evaluate the performance accuracy. The method used to compare the performance of the models is statistical analysis of Mean Absolute Deviation (MAD), Mean Square Error (MSE) and Root Mean Square Error (RMSE). As a result, MCA produced statistical indices of MAD, MSE and RMSE of 28.32, 2165.89 and 46.54, respectively. Meanwhile, SPAN Guidelines resulted with 58.42, 17,128.23 and 130.87 of MAD, MSE and RMSE. The study conclude that MCA has better accuracy with lower value of statistical indices compared to the other model and eventually assist the water authorities in

N. N. I. B. M. Azlan · S. Norhisham (✉) · M. A. Malek
Department of Civil Engineering, College of Engineering, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia
e-mail: shuhairy@uniten.edu.my

S. Norhisham · N. S. M. Shkuri
Institute of Energy Infrastructures (IEI), Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

N. S. M. Shkuri
College of Energy Economics & Social Sciences, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

M. Zolkepli
Faculty of Computer Science and Information Technology, Universiti Putra Malaysia, UPM Serdang, 43400 Seri Kembangan, Selangor, Malaysia

L. W. Ean
Institute of Sustainable Energy, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

A. M. Mohamad
School of Law and Centre for Testing, Measurement and Appraisal (CeTMA), Universiti Utara Malaysia, 06010 Bukit Kayu Hitam, Kedah, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_19

constructing sensible water plans for the area of same geographical state using the respective technique.

Keywords Micro-component analysis · National Water Service Commission (SPAN) guideline · Performance accuracy · Statistical analysis

1 Introduction

In the globalisation era, population density in the world increases invasively and reflects to high demand of water resources for their daily necessities. Criticised and detailed management of water demand is required to overcome the obstacle to ensure the well-being of people's life. The essential requirement on water supply and demand framework is a strong emphasis on the applicability of forecasting methods [1]. Apart from that, the right choice of water demand forecasting serves as an assurance to the design and management of present and future water supply systems [2]. There are many water demand methods available globally, such as Time-Series Model [3], multiple regression analysis [4], and Artificial Neural Network (ANN) [5]. Shirkoohi et al. [6] predicted water demand at Quebec, Canada by comparing ANN model, Autoregressive Integrated Moving Average (ARIMA) model and pattern-based model. The result showed highest accuracy of ANN model compared to the other two models. Similar application of this study where several forecasting methods are being compared individually.

The estimation method of water demand is chosen based on their applicability and compatibility towards the available data and parameter from the targeted study area. As for this study, the methods applied are Micro-Component Analysis (MCA) and National Water Service Commission (SPAN) Guideline. Latest study by Abu-Bakar et al. [7] reviewed application of MCA to improve household water-use pattern at England and reduce per capita consumption. Exploration of MCA is continued by Knox [8] to differentiate indoor and outdoor water demand in Western Cape and Gauteng with variety of data considered. Currently, the study of MCA in water demand management increases each day [9–13].

National Water Service Commission (SPAN) Guidelines is another method being compared in this study. The method is chosen parallel to Malaysia's water requisite as the study area located at Malaysia. The guideline applied from the SPAN Guideline is Uniform Technical Guidelines (UTG) Water Reticulation and Plumbing. One of the recent studies adopting UTG from SPAN Guidelines is by Lim et al. [14] where water demand of each premises at Regional Operation Center (ROC) Melaka, Malaysia is estimated using the guideline. The guideline also can be used to find the correct depth of underground water pipe from the ground surface assisted together with Ground Penetrating Radar (GPR) analysis [15]. UTG from SPAN Guideline has been applied to few other studies [16] and report [17] specifically for location of study area in Malaysia.

Investigation on performance accuracy of water forecasting methods is expanding globally each day. The performance of each water demand techniques is being analysed either between two or three techniques. A study by Shirkoohi et al. [6] predicted that hybrid model (Artificial Neural Network (ANN)-Genetic Algorithm (GA)) produced the most accurate result of 15 min forecasted water demand compared to the other two model ARIMA and pattern-based. Another research on performance accuracy between two methods of short-term water demand techniques namely hybrid method (Self-Organising Maps (SOM)-Regression Tree (RT)) with time-series method (Seasonal Autoregressive Integrated Moving Average (SARIMA)) and the study found that hybrid of SOM-RT produced highest accuracy than time series method of SARIMA. The performance accuracy of any methods can be discovered with enough water consumption data accompanied with the number of variables focuses on the respective study [18].

This paper presents performance accuracy of water demand estimation models by statistical indexes. The performance of each estimation method varies as it requires different parameters. The results collect from statistical analysis for MCA and SPAN Guidelines will conclude with the most accurate estimation method for Pengkalan Gawi. Discussion on differences of parameters and statistical indexes found from each technique are included in the result and discussion section. Finally, recommendation and improvement of the research are included in the conclusion section to enhance water demand management in Malaysia and other countries.

2 Dataset

The investigation was performed based on the dataset collected from the study area of Pengkalan Gawi, Kenyir Lake. Pengkalan Gawi is located Pulau Dula section of Kenyir Lake. The area is the main entrance for visitors to Kenyir Lake where the jetty for boat and houseboats. The jetty acts as the starting point for all houseboats and boats before heading to tourist's desired location. The premises considered in Pengkalan Gawi, Kenyir Lake are Lawit Lodge, Kenyir Elephant Conservation Village (KECV), Development Authority Terengganu Tengah (KETENGAH) and Tourist Information Center (TIC) office, public toilets, food stalls, prayer rooms.

The data for this research is being collected based on the parameters involved in each of the technique. For MCA, the data need to be gathered are maximum number of people and water-use pattern at the respective study area. Many MCA studies emphasized the significant of disaggregating usage by end-use appliance to find the actual water consumption [7]. Hence, the data for water use pattern at each premises comprise of proportion, frequency, and volume of water use appliances. The base predictions practiced by water companies is also on proportion-frequency-volume of water using fixtures [19].

As for SPAN Guidelines, the parameters involved in water demand calculation are average daily water demand according to type of premise and maximum number of people fits each premise. The values of average daily water demand are listed in

UTG from SPAN Guidelines [20] which can be chosen restrictively to the type of premise covered. While maximum number of people for each premise is the same as the number gathered for water demand estimation using MCA. And the data needed to apply statistical analysis on performance of MCA and SPAN Guidelines are the actual water consumption at Pengkalan Gawi and forecasted water demand for MCA and SPAN Guidelines individually. The actual water consumption at Pengkalan Gawi is gathered from metered water supplied by Terengganu Water Company (SATU).

3 Methodology

Two techniques namely, MCA and SPAN Guidelines are applied to estimate water demand at Pengkalan Gawi are described briefly in this section. The degree of understanding through methodology used by researchers are solely determined by them by the accurate data and approaches taken [21]. The result gained from water demand computation of MCA and SPAN Guidelines are then being compared on their performance accuracy by statistical analysis. The description on the statistical analysis implemented in this research also being discussed in this section.

3.1 Micro-Component Analysis (MCA)

Micro-Component Analysis (MCA) originates from Herrington's work and has been used widely in water industry and research [22, 23]. The approach used by MCA is per capita consumption to determine water demand of an area. The per capita consumption revolves on ownership, frequency and volume of water use appliances or activities [24]. The mathematical equation of MCA in general as shown below:

$$pcc = \sum (O_i \cdot F_i \cdot V_i) + pcr \tag{1}$$

where pcc is per capita consumption, O_i is the proportion of households using appliance or activity, F_i is the average frequency of use of appliance or activity, V_i is the volume of water consumed by appliance or activity per use, and pcr is per capita residual demand. Summation of per capita consumption following the mathematical equation above is adopted as total water demand of an area per person for this study. In addition, pcr value acts as emergency water demand which taken as constant value of 0.5 from pcc [23, 25].

Kame'enui [26] highlighted on the significant step to have a feasible and valid methodology is by providing correct flow of experiment and sufficient data. Hence, Eq. 1 works as a basis to establish Eq. 2 which includes multiplying factor. The outcome of Eq. 2 will provide water demand value of a premise. Multiplying factor is the maximum number of people fits a premise.

$$Total\ pcc = \left[\sum (O_i \cdot F_i \cdot V_i) \times Multiplying\ Factor\right] + pcr \tag{2}$$

3.2 National Water Services Commission (SPAN) Guidelines

In accordance with Malaysia's water requisite, National Water Service Commission (SPAN) Guideline is included in the water demand estimation at Pengkalan Gawi. The guideline used from SPAN is Uniform Technical Guidelines (UTG) for Water Reticulation and Plumbing which act as basis for housing and developers to estimate water demand for a premise or building proposed [20]. Estimation of water demand using SPAN Guideline is the multiplication of daily average water demand according to type or premise and the multiplying factor of a premise. The mathematical equation for SPAN Guideline is presented below:

$$\begin{aligned} Water\ demand = {} & Average\ daily\ water\ demand\ from\ SPAN \\ & Guidelines \times Multiplying\ Factor \end{aligned} \tag{3}$$

3.3 Statistical Analysis

Performance of each technique applied in this study is computed using statistical analysis. Singh et al. [27] discussed that accuracy of a technique can be measured through value of disparity between forecasting results and actual data of the study. The statistical analysis implemented for MCA and SPAN Guidelines computation of water demand at Pengkalan Gawi is Mean Absolute Deviation (MAD), Mean Square Error (MSE) and Root Mean Square Error (RMSE).

Mean absolute deviation (MAD) measured the accuracy of forecasting data [28], mean square error (MSE) computed the squares of all errors in the factors used in each premise and dividing them by total number of premises investigated [29] and root mean square error (RMSE) compared the actual and forecasted value to identify errors in actual water consumption [30]. The equation of MAD, MSE and RMSE is portrayed below:

$$MAD = \frac{1}{n}\sum_{i=0}^{n} |Y_i - F_i| \tag{4}$$

$$MSE = \frac{1}{n}\sum_{i=0}^{n} (Y_i - F_i)^2 \tag{5}$$

$$RMSE = \frac{1}{n}\sum_{i=0}^{n}\left|\sqrt{(Y_i - F_i)}\right| \tag{6}$$

where Y_i is the actual water consumption, F_i is the forecast value of water consumption using MCA and SPAN Guidelines, and n is the number of premises.

4 Result and Discussion

4.1 Actual Water Consumption and Forecasted Water Consumption (MCA and SPAN Guidelines)

The actual and forecasted monthly water consumption at Pengkalan Gawi is established in Table 1. Terengganu Water Company (SATU) provided the actual monthly water consumption at Pengkalan Gawi and has been used to compare with the forecasted monthly water consumption using MCA and SPAN Guidelines.

Outcome of the result showed a variation between the values of actual and forecaster water consumption. The total monthly water consumption was found to be highest for MCA than actual water consumption and SPAN Guidelines at 10,068.0 m^3, 6160.4 m^3 and 5937.0 m^3, respectively. However, the actual monthly water consumption recorded at highest usage for premises of Lawit Lodge, Kenyir Elephant Conservation Village (KECV), KETENGAH and TIC offices and food stalls. This is because local people and communities there utilised water thriftly which leads to higher usage of water [31]. Another reason may cause by the location of Pengkalan Gawi that is the main entrance for visitors to Kenyir Lake [32], so the tourists tend to

Table 1 Monthly water consumption for actual data, MCA, and SPAN guidelines

Type of buildings/Premises	Monthly water demand (m^3)		
	Actual water consumption	Micro-component analysis (MCA)	SPAN guidelines
Lawit lodge	1108.0	285.0	450.0
Kenyir elephant conservation village (KECV)	724.0	360.0	300.0
Offices of KETENGAH and tourist information center	1393.0	162.0	207.0
Public toilet	2154.3	8730.0	3654.0
Prayer rooms	250.1	300.0	831.0
Food stalls	531.0	231.0	495.0
Total water consumption	6160.4	10068.0	5937.0

Table 2 Statistical analysis of MCA and SPAN guidelines

Technique	Micro-component analysis (MCA)	SPAN guidelines
Mean absolute deviation (MAD)	28.32	58.42
Mean square error (MSE)	2165.89	17128.23
Root mean square error (RMSE)	46.54	130.87

use water from public utility first before continuing their journey exploring Kenyir Lake.

4.2 Statistical Analysis

The performance of a technique is a determination how incorporated and suitable the technique to be applied to research. Each method has different criteria and steps of evaluation that make it performs differently. Two techniques of MCA and SPAN Guidelines have been used to forecast water usage at Pengkalan Gawi. The performance comparison between the techniques is done using different statistical indices namely, MAD, MSE and RMSE. The performance of each method is shown in Table 2.

Result of statistical indices of MAD, MSE and RMSE in Table 2 showed lower value for Micro-Component Analysis (MCA) rather than SPAN Guidelines which means MCA performed better in terms of accuracy and differences with the actual value of water consumption. The variables involve in SPAN Guideline is lesser than MCA, but it does not affect the performance accuracy of the technique. This is proven by Vijai and Sivakumar [33] that explained the connection of input variables and output variables is not always linear in actual world problems.

In terms of assessment on the performance of MCA, the MAD, MSE and RMSE are 28.32 and 2165.89 and 46.54, respectively. And for SPAN Guidelines, MAD, MSE and RMSE are 58.42, 17,128.23 and 130.87, respectively. From the results, it can be inferred that MCA provide better forecasting of monthly water demand at Pengkalan Gawi than SPAN Guidelines. However, the statistical indices for both techniques are not close to zero. The value of zero is an indication of low consideration in variability of response data so it performs better [33]. Improvement of the performance in terms of accuracy and correlation of statistical analysis can be made with consideration of various other factors of water demand like number of household members, occupation, weather, water price and water usage time [30].

5 Conclusions

The performance accuracy result shows that Micro-Component Analysis (MCA) has better accuracy of water demand estimation model for Kenyir Lake rather than National Water Service Commission (SPAN) Guideline. The value of Mean Absolute Deviation (MAD), Mean Square Error (MSE) and Root Mean Square Error (RMSE) of MCA was found at 28.32, 2165.89 and 46.54, respectively. Instead, statistical indices of MAD, MSE and RMSE for SPAN Guideline are 58.42, 17,128.23 and 130.87, respectively. The values for MCA were much smaller than the values of SPAN Guideline. Hence, the MCA method was verified as the best performance accuracy of water demand forecasting model practiced in this study.

With the results stated in the previous part, water authorities can analyse water demand and supply easily and instantly using MCA specifically for Kenyir Lake. Water authorities have saved their time in finding the most suitable water demand method for the study area. The analysis of water demand at Kenyir Lake by water authorities eventually aid stakeholders and government in managing and planning water demand there. Same type of area with the same environmental condition as Kenyir Lake can also apply MCA as water demand forecasting model instead of applying numbers of water demand estimation methods to be explored.

Expansion of this study can be done by adaptation of other water demand estimation methods such as Artificial Neural Network (ANN) and hybrid model. Invasive exploration of water demand data and parameters also required as parallel to the application of more complex water demand forecasting techniques. Government and water authorities should focus more on analysing water demand and supply condition at rural area as the area always being taken lightly.

Acknowledgements Authors wishing to acknowledge Yayasan Canselor Universiti Tenaga Nasional for providing research grant for this study (202101018YCU) and Innovation Research Management Centre (IRMC), Universiti Tenaga Nasional.

References

1. Papacharalampous G, Langousis A (2021) Probabilistic water demand forecasting using quantile regression algorithms. ArXiv 2104.07985
2. Pacchin E, Gagliardi F, Alvisi S (2019) A comparison of short-term water demand forecasting models
3. Ristow DCM, Henning E, Petersen CE et al (2021) Models for forecasting water demand using time series analysis: a case study in Southern Brazil. J Water Sanit Hyg Dev 1–9. https://doi.org/10.2166/washdev.2021.208
4. Liu X, Qin M, Xiang X (2021) Forecasting on China's water demand by industry in 2021. IOP Conf Ser Earth Environ Sci 772(1):012097. https://doi.org/10.1088/1755-1315/772/1/012097
5. VanBerlo B, Ross MAS, Hsia D (2021) Univariate long-term municipal water demand forecasting. arXiv Prepr [Online]. http://arxiv.org/abs/2105.08486

6. Shirkoohi MG, Doghri M, Duchesne S (2021) Short-term water demand predictions coupling an artificial neural network model and a genetic algorithm. Water Supply 1–13. https://doi.org/10.2166/ws.2021.049
7. Abu-bakar H, Williams L, Hallett SH (2021) Quantifying the impact of the COVID-19 lockdown on household water consumption patterns in England. npj Clean Water 4(13). https://doi.org/10.1038/s41545-021-00103-8
8. Knox AJ (2020) Modelling water demand for residential households by segregating indoor and outdoor uses. Stellenbosch University
9. Xenochristou M, Kapelan Z, Hutton C (2020) Using smart demand-metering data and customer characteristics to investigate influence of weather on water consumption in the UK. J Water Resour Plan Manag 146(2):1–12. https://doi.org/10.1061/(asce)wr.1943-5452.0001148
10. Ahmad MT, Daura HA (2019) Domestic water consumption under unimproved water supply in semi-arid region of northern Nigeria. Sustain Water Resour Manag 5(2):415–424. https://doi.org/10.1007/s40899-017-0177-5
11. Guragai B, Hashimoto T, Oguma K et al (2018) Data logger-based measurement of household water consumption and micro-component analysis of an intermittent water supply system. J Clean Prod 197:1159–1168. https://doi.org/10.1016/j.jclepro.2018.06.198
12. Wills P, Memon FA, Savic D (2017) High-resolution domestic water consumption data—scope for leakage management and demand prediction
13. Sadr S et al (2016) An analysis of domestic water consumption in Jaipur, India. Br J Environ Clim Chang 6(2):97–115. https://doi.org/10.9734/bjecc/2016/23727
14. Lim JR, Kutty SRM, Ghaleb AAS et al (2020) Development of dead-end system calculation model for water reticulation design using Microsoft Excel with optimized algorithm: a case study at regional operations center (ROC) Melaka, Malaysia. IOP Conf Ser Mater Sci Eng 849(1). https://doi.org/10.1088/1757-899X/849/1/012094
15. Gani AA, Hamid R (2018) Undergrounds water pipe mapping using ground penetrating radar and global positioning system. J Adv Res Appl Mech 50(1):1–11. ISSN 2289-7895
16. Mohamad ND, Hanan Z, Izzati N et al (2020) Water demand estimation based on land use in urban city. Int J Sci Technol Res 9(6):545–550
17. JBSB (2016) Cadangan Pembangunan 162 Unit 2 Blok Pangsapuri Kos Tinggi Di Atas Lot 76103, Jalan Bazar U8/101, Seksyen U8, Bukit Jelutong, Shah Alam, Selangor
18. Goharian E, Burian SJ (2018) Developing an integrated framework to build a decision support tool for urban water management. J Hydroinform. 20(3):708–727. https://doi.org/10.2166/hydro.2018.088
19. Parker JM, Wilby RL (2013) Quantifying household water demand: a review of theory and practice in the UK. Water Resour Manag 27:981–1011. https://doi.org/10.1007/s11269-012-0190-2
20. SPAN (2020) Uniform technical guidelines water reticulation and plumbing. https://www.span.gov.my/article/view/guidelines-for-water. Accessed 05 Aug 2020
21. Abuhamda E, Ismail IA, Bsharat TRK (2021) Understanding quantitative and qualitative research methods: a theoretical perspective for young researchers. Int J Res 8(2):70–87. https://doi.org/10.2501/ijmr-201-5-070
22. Anderson B, Manouseli D, Nagarajan M (2018) Estimating scenarios for domestic water demand under drought conditions in England and Wales. Water Sci Technol Water Supply (September):2100–2107. https://doi.org/10.2166/ws.2018.035
23. Butler D, Memon FA (2006) Water consumption trends and demand forecasting techniques. Water Demand Manag 1–25
24. Jannet JS, Thilakam MR (2021) Micro-component review of domestic water consumption in selected households of Coimbatore city. Psychol Educ 58(4):2753–2764
25. Butler D (1993) The influence of dwelling occupancy and day of the week on domestic appliance wastewater discharges. Build Environ 28(I):73–79
26. Kame'enui AE (2003) Water demand forecasting in the Puget Sound Region: short and long-term models. University of Washington

27. Singh K et al (2019) Implementation of exponential smoothing for forecasting time series data. Int J Sci Res Comput Sci Appl Manag Stud 8(1)
28. Fauziah FN, Gunaryati A (2017) Comparison forecasting with double exponential smoothing and artificial neural network to predict the price of sugar. Int J Simul Syst Sci Technol 18(4):1–8. https://doi.org/10.5013/IJSSST.a.18.04.13
29. Oni OV, Akanle YO (2018) Comparison of exponential smoothing models for forecasting cassava production. Int J Sci Res Math Stat Sci 5(3):65–68. https://doi.org/10.26438/ijsrmss/v5i3.6568
30. Koo KM, Han KH, Jun KS et al (2021) Performance assessment for short-term water demand fore-casting models at an end-use level in Korea. Sustainability 13. https://doi.org/10.20944/preprints202104.0332.v1
31. Kamaludin M, Abd Aziz A (2018) Issues and challenges in domestic water services in Terengganu, Malaysia. Greater Kenyir landscapes social development and environmental sustainability: from ridge to reef, pp 287–299
32. Kamaruddin IS, Kamal ASM, Christianus A et al (2011) Fish community in Pengkalan Gawi - Pulau Dula section of Kenyir Lake, Terengganu, Malaysia. J Sustain Sci Manag 6(1):89–97
33. Vijai P, Sivakumar PB (2018) Performance comparison of techniques for water demand forecasting. Procedia Comput Sci 143:258–266. https://doi.org/10.1016/j.procs.2018.10.394

Numerical Validation of Hydrodynamic Responses and Mooring Top Tension of a Turret Moored FPSO Using Simulation and Experimental Results

I. A. Ja'e, M. O. A. Ali, and A. Yenduri

Abstract Numerically validated models are frequently used in the analysis of hydrodynamic responses and mooring line tensions of offshore floating platforms. This approach is very useful especially where access to laboratory facility is a challenge, or the limitation of available wave tank dimensions poses a great constraint to allow for proportionate scaling down of water depth. Thus, the numerical validation of a turret moored FPSO operating in a water depth of 1829 m is presented in this paper. The numerical model was developed in MAXSURF and perfected in DesignModeler. Time-domain coupled analysis was conducted in ANSYS AQWA over a simulation period of 12000 sec using a time step of 0.02 sec. All AQWA model analysis results including static offset, free decay, platform response and line tensions compared reasonably well with the published simulation (WINPOST) and experimental (OTRC) results. The variation recorded in AQWA results might be due to non-uniformity in FPSO hull geometry, possible mismatch in the prediction of wind and current coefficients, and the non-inclusion of hull viscous effect in the numerical simulation. The mooring tension spectrum generally compares very well. The close agreement of the validated model with published results indicated proper modelling of the referenced FPSO platform. Hence, the validated model can be used as a benchmark for further studies concerning hydrodynamic responses, mooring line tension, and restoring behavior of a turret mooring system.

Keywords Turret FPSO · Numerical models · Validation · Hydrodynamic responses · Mooring line tension

I. A. Ja'e (✉) · M. O. A. Ali
Department of Civil Engineering, Universiti Teknologi PETRONAS, 32610 Bandar Seri Iskandar, Perak, Malaysia
e-mail: Idris_18001528@utp.edu.my

M. O. A. Ali
e-mail: montasir.ahmedali@utp.edu.my

A. Yenduri
Global Engineering Centre, Subsea Engineering, TechnipFMC, Chennai 600032, India

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_20

1 Introduction

The hydrodynamic responses together with the mooring line tensions form an important aspect of interest in analyzing Floating Production Storage and Offloading (FPSO) operating under the action of varying environmental loading. Several floating platforms have been successfully deployed for deep-water oil and gas production activities with FPSOs accounting for the highest number of these platforms in operations [1]. The acceptance of FPSO is attributed to its unique advantages including a large top working area, huge storage, and stable hull. Thus, many studies have been conducted to better understand the dynamic characteristics of FPSOs operating in varying combinations of waves, wind, and currents [2–6].

The effectiveness of FPSOs during operation is dependent on the efficiency of their mooring system. Thus, the selection of mooring line materials, configuration and other mooring parameters especially for deep-water operations have a great influence in terms of cost and effectiveness of the overall mooring system [7]. Mooring lines are widely analyze using lumped mass method [8, 9], where every mooring line is discretized into several segments with the assumption that external forces and weight of each segment are lumped and distributed at the nodes, which are connected by a massless spring. The mooring line dynamics is investigated based on lumped mass formulations with the contact between the line and seabed modelled using bi-linear springs at the nodes [10].

The hydrodynamic responses and mooring tensions of floating production systems can be assessed using physical model testing, numerical simulations, or a combination of both. However, although the experimental approach is considered as most reliable, the limitation of available wave tank dimensions poses a great constraint to allow for proportionate scaling down of the water depth [3, 11]. Hence, to account for this shortcoming, equivalent truncated mooring lines are utilized in such cases. In recent times, due to the limited access to the laboratory facilities because of the pandemic, the use of numerical simulation to access the dynamic interactions between FPSO hull and mooring lines using validated numerical models have increased. ANSYS AQWA is one of the commercial software being utilized for this purpose.

In this paper, the numerical validation of a turret moored FPSO anchored with twelve taut mooring lines is presented using the commercial software AQWA. The responses of the FPSO model in six degrees of freedom and line tension is compared with OTRC experimental results and simulation results from WINPOST software. The content of this paper is arranged as follows: Sect. 2 contains the dynamics of mooring line and FPSO hull hydrodynamics. In Sect. 3, the detailed description of the FPSO model and the mooring system is presented, including the prediction of wind and current coefficient. Also, detail of the implementation of the Numerical validation is presented. Section 4 contain the results and discussion. While the conclusion is presented in Sect. 5.

2 Governing Equations and Formulations

2.1 Dynamics of Mooring Lines

The ANSYS AQWA software which is used in this study utilises the discrete lump-mass model in solving mooring line responses. The effect of line mass, drag, inline elastic tension and bending moment are considered [12].

In analysing the mooring lines while assuming no torque or twisting moment, the equation of motion of the mooring line can be written as:

$$\frac{\partial \vec{T}}{\partial L_e} + \frac{\partial \overrightarrow{S_F}}{\partial L_e} + \vec{w} + \vec{P}_h = m\frac{\partial^2 \vec{R}}{\partial t^2} \tag{1}$$

where $\overrightarrow{T}$ and $\overrightarrow{S_F}$ are the tension and shear force at the first node of the element. The symbols $m, \overrightarrow{w}$, and $\overrightarrow{P}_h$ represents the structural mass, element weight and external force, all per unit length. $\overrightarrow{R}$ is the position at the first node of the element, and,L_e, is the cable length.

The total gravitational forces at nodes j and j + 1, are expressed in a 6 × 1 matrix as given in (2).

$$\mathbf{w} = \left(\overrightarrow{w}_j,\ \overrightarrow{w}_{j+1}\right)^T = \left\{\ 0,\ 0,\ -\tfrac{1}{2}\left(mL_j + M\right)g,\ \ 0,\ 0,\ -\tfrac{1}{2}mL_j g\ \right\}^T \tag{2}$$

where L_j = unstretched element length.

The wave excitation force is ignored on the dynamic cable; thus, the hydrodynamic force (P_{hd}) is the summation of the buoyant force (P_b), drag force (P_D) and added mass radiation force (P_a), as shown in Eqs. 3–8:

$$P_{hd} = P_b + P_D + P_a \tag{3}$$

$$\mathbf{P}_{hd} = \mathbf{P}_b + \mathbf{P}_D - \mathbf{m}_a\left[\overrightarrow{a}_j,\ \overrightarrow{a}_{j+1}\right]^T \tag{4}$$

where $\overrightarrow{a}_j$ = acceleration at node *j*.

The element buoyant force matrix is expressed as:

$$\mathbf{P}_b = \left\{\ 0,\ 0,\ \tfrac{1}{2}\rho A_{cj} L_j g,\ \ 0,\ 0,\ \tfrac{1}{2}\left(\rho A_{cj} L_j + M_b\right)g\ \right\}^T \tag{5}$$

where A_{cj} = equivalent cross-sectional area, and M_b = mass of buoy.

The time-dependent drag force of an element is given by Eq. (6).

$$\mathbf{P}_d(t) = \left\{ \begin{array}{c} \mathbf{f}_d(j) - \frac{1}{2} C_{dc} S_c \rho_w \left| \mathbf{U}_j(t) - \mathbf{V}_j(t) \right| \left\{ \mathbf{U}_j(t) - \mathbf{V}_j(t) \right\} \\ \mathbf{f}_d(j+1) - \frac{1}{2} C_{db} S_b \rho_w \left| \mathbf{U}_{j+1}(t) - \mathbf{V}_{j+1}(t) \right| \left\{ \mathbf{U}_{j+1}(t) - \mathbf{V}_{j+1}(t) \right\} \end{array} \right\} \quad (6)$$

where C_{dc} is the drag coefficient of clump weight, C_{db}, the drag coefficient of intermediate buoy and, S_c is the surface area of clump weight. S_b represents- the surface area of an intermediate buoy, while $\mathbf{U}_j$ is the structural velocity matrix at j, and $\mathbf{V}_j$ = current velocity matrix at j.

Segment tension of the line is determined using (7) as presented in [13].

$$T^{k+1}(\tau + \Delta\tau) = T^k(\tau + \Delta\tau) - [\Delta\psi(\tau)]^{-1}\psi^k(\tau) \quad (7)$$

where ψ= segment length error vector, T^k= tentative segment tension vector at the *k-th* iteration, $\Delta\psi$ is the length error derivative matrix.

For each time step, the system of equation is solved until an acceptable convergence of $T^{k+1}(\tau + \Delta\tau)$ is obtained. Tentative tension is used as initial tension in the previous step. Each node j is connected to the adjacent nodes $j - 1$ and $j + 1$.

2.2 FPSO Hull Hydrodynamics

During simulation, the platform is treated as a rigid body. The motion of the floating system is expressed in a convolution integral form, since $F(t)$ is not periodic with a constant amplitude [14]. Thus, the time domain equation of motion is as shown (8):

$$[\mathrm{M} + A_\infty]\ddot{a}(t) + c\dot{a}(t) + Ka(t) + \int_0^t h(t-\tau)\ddot{a}(\tau)d\tau = F(t) \quad (8)$$

where, M is the structural mass matrix, and A_∞, is the added mass matrix at infinite frequency. The symbol c stands for damping matrix, while K and *h(t)* are the total stiffness matrix and acceleration impulse function, respectively.

Combining the vessel response with the mooring line equation, the time domain equation of motion can then be described through the following:

$$[\mathrm{M} + A_\infty]\ddot{a}(t) = P^{(1)}(t) + P^{(2)}(t) + P_c(t) + P_w(t) + P_m(t) + P_{WD}(t) + P_{hs}(t) - c\dot{a}(t) - Ka(t)$$

$$-\int_0^t h(t-\tau)\ddot{a}(\tau)d\tau \quad (9)$$

where, $P^{(1)}$, is the 1st order wave forces, $P^{(2)}$, the 2nd order wave forces, and P_c, is the current hull drag force. In addition, F_w is the wind drag force, while P_m is the mooring force and P_{WD} is the wave drift damping force.

ANSYS AQWA solves the integrated system of hull-mooring using the coupled time-domain analysis [12].

3 Numerical Modelling and Validation

3.1 Description of FPSO Model and the Mooring System

A turret moored FPSO operating in 1829 m water depth together with the mooring system was adopted as presented in [3]. The FPSO model is very similar to those used in the DeepStar study [15, 16] having an equivalent displacement of 186,051MT, a draft of 15.12 m, and an L_{pp} of 310 m. The turret is 15.85 m in diameter, positioned at 12.5% of L_{pp} from the forward and located at an elevation of 1.52 m from the hull base. The general arrangement mooring system used in both Numerical (WINPOST) and Experiment (OTRC) consist for equivalent mooring lines. However, in this study 12 moorings lines as used in the prototype was adopted [3]. The moorings are installed in 4 groups (G1, G2, G3 and G4) each consisting of 3 moorings 5^o apart, i.e., 4 × 3 configuration. Central mooring line of each group is 90^o from the adjacent group. Layout of the vessel and mooring lines is illustrated in Fig. 1. Each of the mooring lines is made of three segments: chain-polyester-chain with the mooring parameters as shown in Table 1.

The FPSO platform is subjected to the wave condition as illustrated in Table 2, which is a 100-year storm condition for the Gulf of Mexico comprising of a unidirectional random wave propagating in the direction from the vessel bow (where the turret is located) to stern. The JONSWAP spectrum model was adopted, given as:

$$S(\omega) = \frac{\propto g^2\gamma^2}{\omega^5} exp\left(-\frac{(5_{\omega_p}^4}{4\omega^4}\right) \tag{10}$$

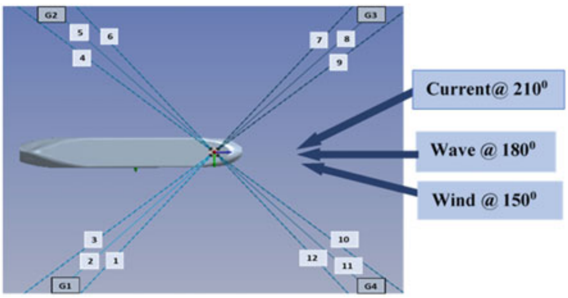


Fig. 1 FPSO-Mooring layout with environmental loading propagation

Table 1 Environmental condition [3]

Parameter	Units	Value
Wave		
Significant wave height, H_s	m	12.19
Peak period, T_p	s	14
Spectrum	JONSWAP	–
Gamma factor, γ	–	2.5
Direction	^{0}	180
Current		
at free surface (0 m)	m/s	0.9144
at 60.96 m	m/s	0.9144
at 91.44 m	m/s	0.0914
on seabed	m/s	0.0914
Direction	^{0}	210
Wind		
Spectrum	NPD	–
Speed at 10 m above msl	m/s	41.12
Direction	^{0}	150

Table 2 Mooring line details [3]

Legend	Top segment	Middle segment	Lower segment
Type	Chain	Polyester	Chain
Diameter(mm)	95.3	160	95.3
Length (m)	91.4	2438	91.4
Wet weight (kg/m)	164.63	4.5	164.63
Effective Modulus (kN)	820,900	168,120	820,900
Breaking Load (kN)	7553	7429	7553
Normal drag coefficient, C_{DN}	2.45	1.2	2.45
Normal added inertia coefficient, C_{IN}	2.0	1.15	2.0

where, ω_p = peak frequency, γ = peak enhancement factor and α = constant relating the wind speed (0.0081).

The JONSWAP spectrum with a significant wave height of 12.19 m and a peak period of 14 s was used, and the wind loading was generated from the NPD spectrum. The mean wind velocity of 41.12 m/sec at 10 m height was used.

3.2 Prediction of Wind and Current Coefficient

Prediction of wind and current coefficients for the prediction of forces and moments acting on the FPSO was done using formulations provided in OCIMF 1994 [17].

Resultant wind force and moments acting on the moored FPSO at the respective angle of attack are calculated using the following formulations:

$$F_{Xw} = \frac{1}{2} C_{Xw} \rho_w V_w^2 A_T \tag{11}$$

$$F_{Yw} = \frac{1}{2} C_{Yw} \rho_w V_w^2 A_L \tag{12}$$

$$M_{XYw} = \frac{1}{2} C_{XYw} \rho_w V_w^2 A_T L_{BP} \tag{13}$$

where, F_{Xw}, F_{Yw} and M_{XYw} stands for surge, sway wind forces and yaw wind moment, respectively. $C_{Xw}, C_{Yw} and C_{XYw}$ are the wave coefficients to be extracted from the OCIMF curves. Water density is represented by ρ_w. $V_w^2 and A_T$ are the current velocity and hull transverse area respectively. L_{BP} is the length between perpendiculars of the FPSO.

Corresponding current/moment acting on the FPSO was calculated using the formulations

$$F_{Xc} = \frac{1}{2} C_{Xc} \rho_c V_c^2 L_{BP} T \tag{14}$$

$$F_{Yc} = \frac{1}{2} C_{Yc} \rho_c V_c^2 L_{BP} T \tag{15}$$

$$M_{XYc} = \frac{1}{2} C_{XYc} \rho_c V_c^2 L_{BP} T \tag{16}$$

Component of Eqs. 11, 12 and 13 are the same as highlighted in Eqs. 14, 15 and 16 but with "*c*" substituted as a subscript to represent current. In addition, T is the draft.

3.3 FPSO Hull Modelling

The 3D model of the FPSO hull with dimensions 315*47.17*28.04 m was modelled in Maxsurf software then modified in DesignModeler, a component of ANSYS workbench. The turret bed having a diameter of 15.2 m and 1.52 m thickness was modelled and connected to the FPSO hull. The modified model was imported to AQWA where mooring line configuration including line properties, hydrodynamic properties of the hull was defined as shown in Fig. 2.

The mooring lines are hinged at distributed coordinates on the turret bed. Coordinates of the moorings at the turret and seabed as modelled in AQWA are presented in Table 3.

A sufficient mesh quality of a numerical model is required to ensure a quality result. ANSYS AQWA specifies that panel size should ideally be $^1/_7$th of the wavelength. In this study, a max mesh size of 3.5 was used, with a defeaturing tolerance of 1.75 m, resulting in 9295 elements and 6577 diffracting elements as shown in Fig. 3.

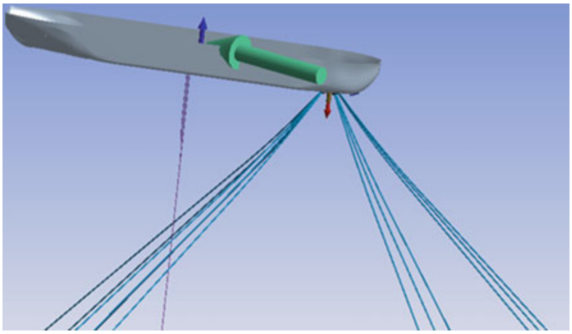


Fig. 2 FPSO model with mooring lines

Table 3 Coordinates of moorings at turret and seabed

Coordinates at turret				Coordinates seabed		
S/N	X	Y	Z	X	Y	Z
1	111.7847	5.3216	16.641	1145.8846	1506.287	1829
2	111.3191	4.9309	16.641	1272.4776	1390.7276	1829
3	110.8877	4.4995	16.641	1388.4787	1264.1346	1829
4	110.9081	4.4824	16.641	1388.4787	1264.1346	1829
5	111.3003	4.9497	16.641	1272.4776	1390.7276	1829
6	111.7505	5.3623	16.641	1145.8846	1506.4287	1829
7	120.7495	5.3623	16.641	1378.3846	1506.4287	1829
8	121.1997	4.9497	16.641	1504.9776	1390.5276	1829
9	121.6123	4.4995	16.641	1620.9787	1264.1346	1829
10	121.5716	4.4653	16.641	1620.9787	1264.1346	1829
11	121.1809	4.9309	16.641	1504.9776	1390.6276	1829
12	120.7495	5.3623	16.641	1378.3846	1506.4287	1829

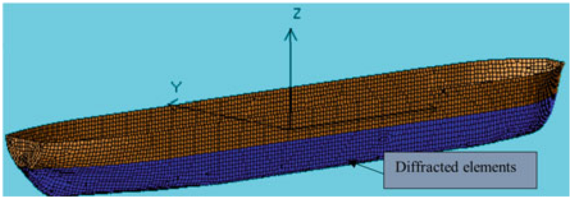


Fig. 3 Generated mesh of numerical model

3.4 Numerical Validation

The validation process focuses on static and free decay tests, hydrodynamic responses of FPSO in 6DOF and mooring top tension.

3.4.1 Static Offset

Adequate line restoring force is required in preventing excessive vessel offset resulting from mean and low-frequency environmental loading. Hence, the Static offset test was conducted in AQWA imitating calm water (by suppressing wave, wind and current in the analysis tab) to get the restoring behavior of the mooring system.

The force-excursion relationship of the mooring system was obtained by incrementally displacing the FPSO in the surge direction (using the starting position) and the resultant horizontal force at each specified displacement recorded and manually plotted.

3.4.2 Free Decay Test

The natural periods of floating platforms are greatly influenced by the mooring system characteristics in the horizontal plane (that is, surge, sway, and heave) [4]. Thus, it is very significant to conduct a free decay test to determine the total damping of the hull/mooring system [3]. The damping in the oscillations of a floating body arises from the wave drift damping of the hull (wave radiation and diffraction). To determine the natural periods, the FPSO was numerically displaced and released to allow for oscillation in each of the degrees of freedom (DOF) considered. The test was simulated using time domain in calm water (by deactivating wave, wind and current in the analysis tab).

3.4.3 Hydrodynamic Responses and Mooring Tension of Numerical Model

The responses of the model in 6DOF were obtained by conducting time-domain coupled analysis in AQWA. Diffraction analysis was performed to determine the hull hydrodynamics including hydrostatics, added mass, radiation damping, diffraction forces and QTF. The QTF were taken into consideration in the analysis maintaining a frequency range of 0.24 rad/sec to 1.8 rad/sec to account for second-order wave force. AQWA utilizes the 3D radiation/diffraction method in the diffraction analysis by employing the panel method in solving velocity potential. The time-domain analysis was conducted for 12,000 s, in batches of 1800secs utilizing a time step of 0.02 s.

4 Results and Discussions

4.1 Static Offset

The comparison of mooring line restoring forces of AQWA and WINPOST in surge direction is shown in Fig. 4 using force – excursion relationship while Fig. 5 compares corresponding tensions of the most loaded and least loaded mooring lines.

The comparison of results from Figs. 4 and 5 reveals strong agreement for both simulations in terms of restoring force and mooring tension, with slight variations of maximum difference of 3% for restoring forces and variations of 5% and 13% respectively for the most loaded moorings and least moorings. In addition, the taut line tension is observed to increases linearly with the surge static offset, while the slacked line tension decreases in a non-linear pattern.

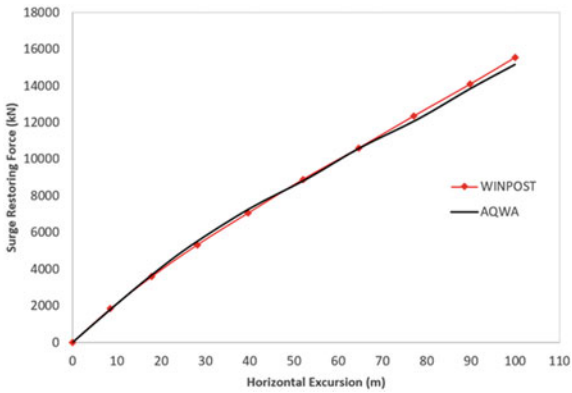


Fig. 4 Comparison of restoring behavior of models from WINSPOST and AQWA

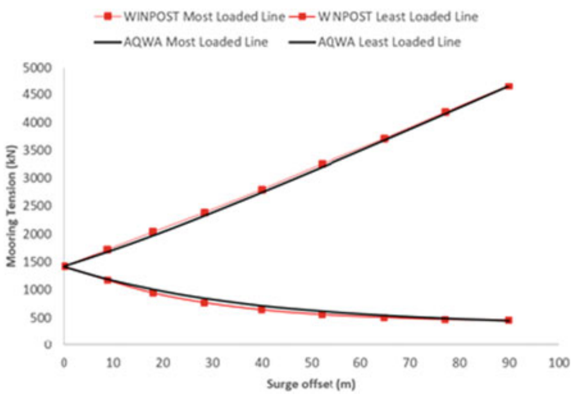


Fig. 5 Comparison of mooring tension in surge static offset for WINPOST and AQWA models

4.2 *Free Decay Test*

Figures 6, 7, 8 and 9 shows the comparison of free decay plots of AQWA and WINPOST models for Surge, Sway, Heave and Pitch are shown in Figs. 6, 7, 8 and 9. The natural periods from the free decay plots and corresponding damping ratios of the

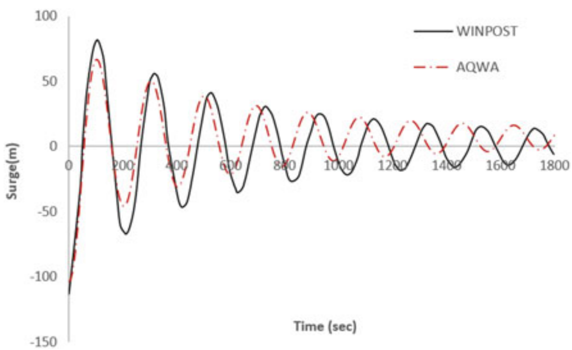


Fig. 6 Surge free decay time series

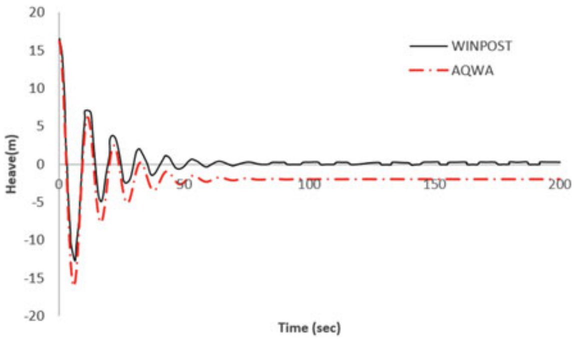


Fig. 7 Heave free decay time series

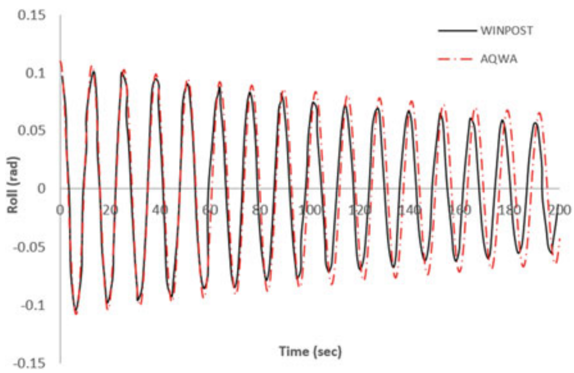


Fig. 8 Roll free decay time series

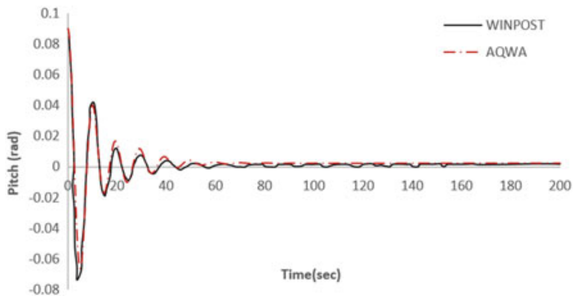


Fig. 9 Pitch free decay time series

AQWA model compared very well with OTRC and WINPOST results as presented in Table 4, thereby affirming proper numerical modelling of the referenced system.

From Table 4, the surge, AQWA records a slightly lower natural period, but greater damping compared to OTRC and WINPOST. Overall, the results compare well among the three tests, particularly with AQWA and WINPOST.

Table 4 Comparison of free decay test results

	Periods(sec)			Damping (%)		
	AQWA	WINPOST	OTRC	AQWA	WINPOST	OTRC
Surge	205.2	204.7	206.8	3.7	4.4	3.0
Heave	10.8	10.8	10.7	4.5	11.8	6.7
Roll	12.7	12.7	12.7	3.2	0.7	3.4
Pitch	10.7	10.8	10.5	7.5	10.5	8.0

4.3 Hydrodynamic Responses in 6DOF

Comparison of numerical simulation results from AQWA with WINPOST and OTRC is shown in Figs. 10, 11, 12, 13, 14, 15. Statistical comparison is also presented in Table 4. Observing from the motion spectral density plots in Figs. 10, 11, 12, 13, 14, 15, the surge, sway, and yaw are seen to be dominated by Low Frequency (LF) motions, while the heave, roll and pitch are Wave Frequency (WF) dominated. Except for the slight deviation observed, both LF and WF spectrums to a large extent agrees well with the published result.

The Statistical comparison presented in Table 5 also compares well with the published results. A variation of 1.564% and 9.301% was recorded in AQWA surge mean value when compared with OTRC and WINPOST, respectively. For sway, the AQWA mean value is 25% lower than the OTRC result and quite higher than the WINPOST result. An increase of 9.345% and 14.813% in mean yaw value was

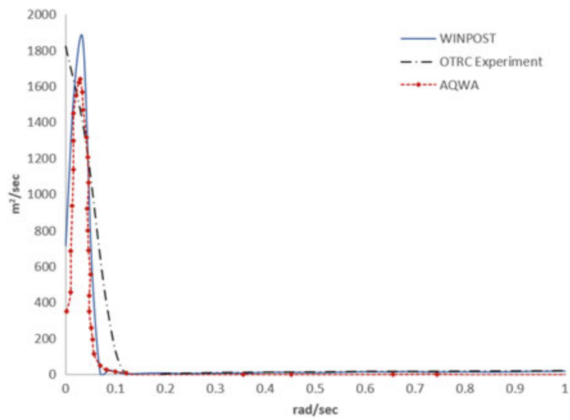


Fig. 10 Surge spectrum

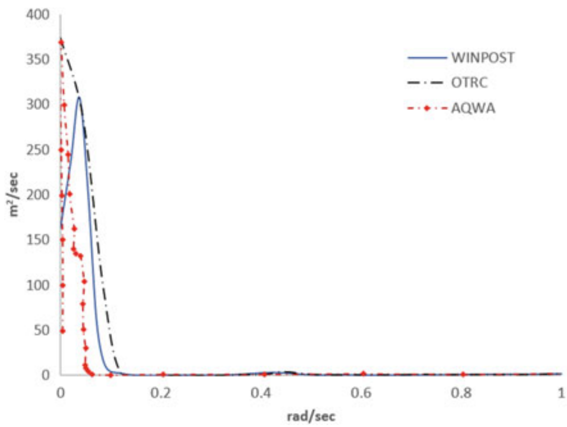


Fig. 11 Sway spectrum

Fig. 12 Heave spectrum

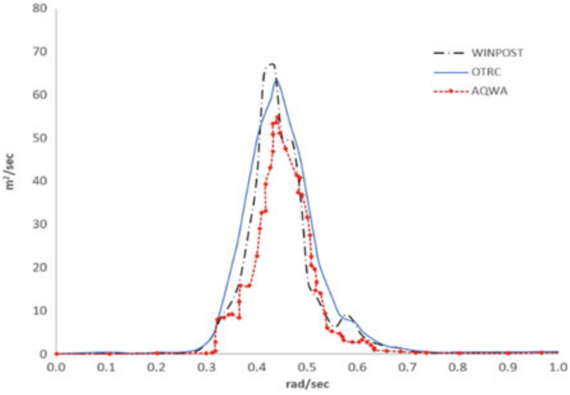


Fig. 13 Roll spectrum

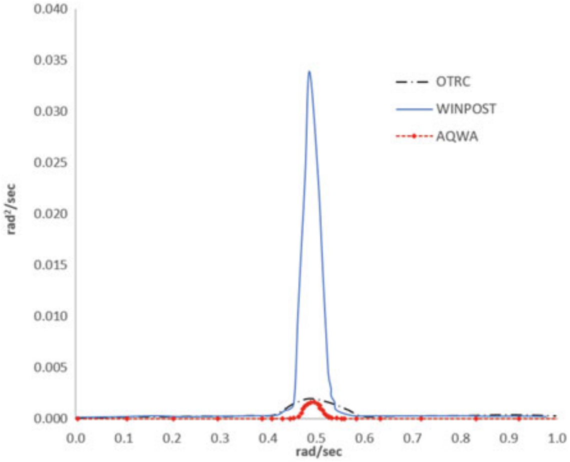


Fig. 14 Pitch spectrum

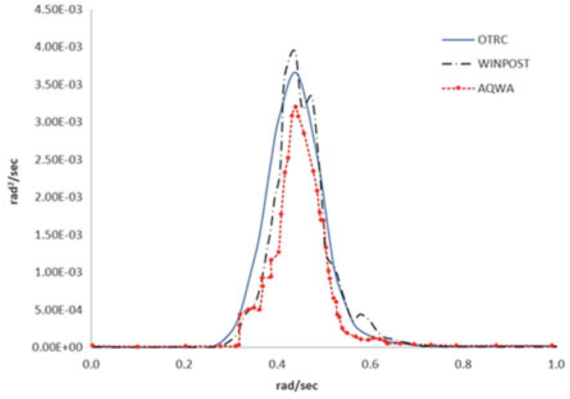


Fig. 15 Yaw spectrum

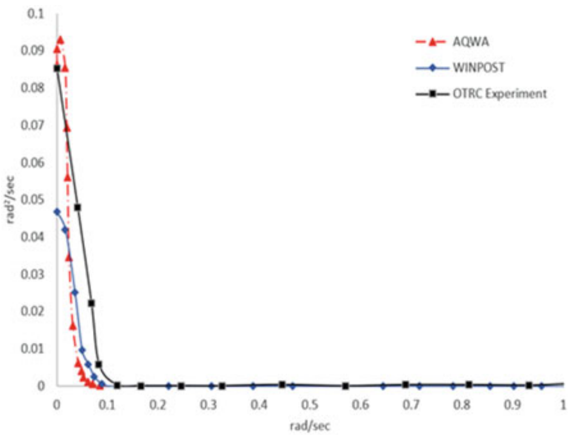


Table 5 Statistical comparison of hydrodynamic responses in 6DOF

	Models	Max	Min	Mean	SD
Surge(m)	AQWA WINPOST OTRC	4.44 2.29 6.30	60.22 61.30 54.10	20.77 22.90 21.10	7.97 9.72 8.78
Sway(m)	AQWA WINPOST OTRC	11.2 13.1 10.9	20.04 21.4 13.6	0.48 0.09 0.64	4.55‘ 4.57 4.05
Heave(m)	AQWA WINPOST OTRC	8.33 10.9 9.11	10.45 11.3 9.52	0.11 0.14 0.06	2.92 3.08 2.81
Roll(^{o})	AQWA WINPOST OTRC	8.2 3.5 9.57	7.26 3.6 8.77	0.06 0.1 0.08	1.45 0.9 2.18
Pitch(^{o})	AQWA WINPOST OTRC	3.37 4.45 4.2	4.37 4.99 4.07	0.17 0.01 0.03	1.19 1.31 1.26
Yaw(^{o})	AQWA WINPOST OTRC	15.21 3.4 8.69	29.72 24.6 23.3	18.37 16 16.8	5.03 3.8 2.46

recorded for OTRC and WINPOST, respectively. The variation observed between AQWA results and WINPOST might be due to nonuniformity in modelling of the FPSO hull or from the prediction of the wind and current coefficients or both. Except for the major variation between AQWA and WINPOST mean values, the LF results appears to agree well with the published results and in most cases, the AQWA result is closer to experimental results (OTRC).

An increase of 21.428% in the mean heave value of AQWA was recorded when compared with WINPOST. However, a major variation between both numerical simulations (AQWA and WINPOST) and the experimental result (OTRC) might be due to possible variation in the hull drag coefficient. On the other hand, the mean values of roll and pitch for the three models agree well. On a general note, comparing the standard deviation of responses in all degrees of freedom reveals close agreement with both WINPOST and OTRC.

4.4 Dynamic Mooring Tension

Figures 16, 17, 18, 19, 20 illustrate the tension spectrum of each mooring line group (G1, G2, G3 and G4), mooring groups are illustrated in Fig. 1. While Table 5 shows statistical comparisons of mooring top tensions for the three models. All simulations results are converted from time series to Spectral density using Fast Fourier Transform (FFT).

Close observation of the line tensions spectra in Figs. 16, 17, 18, 19, 20 reveals that LF components are also significantly higher than the WF components, showing that the tensions are mainly influenced by the slowly varying surge and sway motions. However, in Figs. 16 and 17, the WF components from WINPOST are observed to be higher than both AQWA and OTRC for mooring line groups G1 and G2.

Responses of AQWA model reveals good agreement with the published results in terms of mooring line tension. From Table 6, the OTRC statistical results tend to be smaller for the taut side G3 and G4 but larger for the slack side G1 and G2. This is mainly due to the distorted modelling of the OTRC truncated system [3]. It is also indicating that while mooring line restoring force in the surge direction

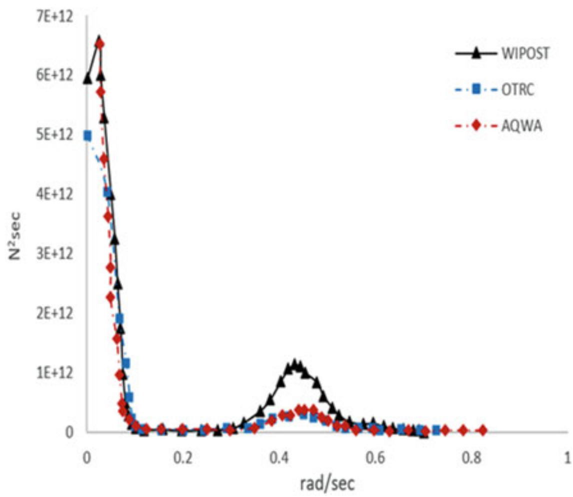


Fig. 16 Tension spectrum of mooring group G1

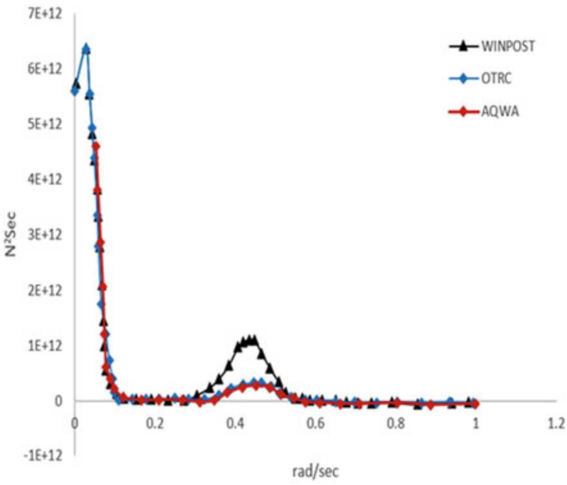


Fig. 17 Tension spectrum of mooring group G2

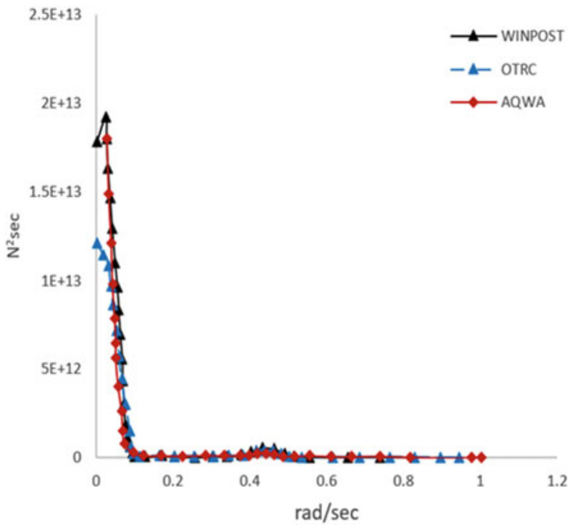


Fig. 18 Tension spectrum of mooring group G3

can be matched, it is difficult to simulate the dynamic characteristics of a full-depth system using a truncated model. It is also clear that the results of truncated lines (OTRC and WINPOST) are higher than AQWA results. Variation between mean taut side mooring lines of AQWA and OTRC is between 2 to 12% which is due to the mismatch between truncated and full mooring length.

Considering the overall simulation results of the AQWA model, results are generally found to be appreciably comparable with the referenced results.

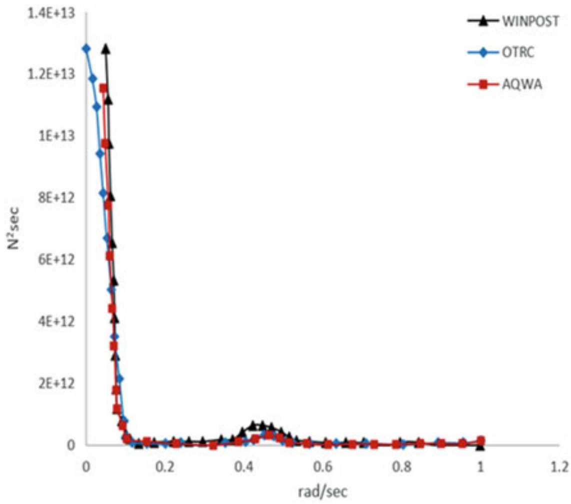


Fig. 19 Tension spectrum of mooring group G4

Table 6 Statistical comparison of mooring tension

Group		AQWA	WINPOST	OTRC
G1 (kN)	max	5170	6360	5340
	min	615	1900	733
	mean	2363	3800	2760
	SD	699	640	711
G2 (kN)	max	5395	5560	5750
	min	324	1410	529
	mean	2540	3430	2660
	SD	809	587	722
G3 (kN)	max	11,006	8130	9710
	min	3507	2930	3450
	mean	7086	5600	6320
	SD	1205	801	997
G4 (kN)	max	11,011	10,400	10,700
	min	3161	3680	3100
	mean	6309	5910	6470
	SD	1033	827	1080

5 Conclusions

Numerical modelling, analysis, and validation of a turret moored FPSO operating in deepwater were conducted using ANSYS AQWA. Modelling of the FPSO hull was initiated in MAXSURF Software and perfected in DesignModeler, respectively.

While the turret mooring bed was also separately modelled in DesignModeler and attached to the FPSO hull. The time-domain simulation was conducted for 12,000 s and a time step of 0.02 s. Simulation results from the AQWA model consisting of 12 mooring lines were compared with simulation results (WINPOST) and experimental results (OTRC) from the referenced paper, both consisting of 4 truncated equivalent mooring lines.

The following specific conclusion can be drawn from the study:

(1) The AQWA simulation result is appreciably comparable with both experimental and simulation results, thereby affirming proper numerical modelling of the reference FPSO platform.
(2) The AQWA model can be used as a benchmark for further parametric study on the hydrodynamic responses of FPSO, mooring tension and restoring behaviour of turret moored FPSO operating in deep water.
(3) Simulation results indicated that FPSO responses in the horizontal plane (surge, sway and yaw) are low frequency dominated, while heave, roll and pitch are wave frequency dominated.
(4) The low-frequency components of the mooring tension spectrum appear significantly higher than the wave frequency components, indicating that mooring tension is significantly influenced by slowly varying surge and sway motions.
(5) Base on a comparison of AQWA results (with 12 moorings) and published result results (with 4 equivalent moorings), the use of truncated moorings for deepwater analysis can be justified.

Acknowledgements The authors acknowledged the Universiti Teknologi PETRONAS, Malaysia for supporting this research under the YUTP Grant 015LCO-116.

References

1. IMA (2020) Floating production sector continues to rebound. In: World energy research database, International Maritime Associates, Inc, 3131 Connecticut Ave NW #2115, Washington D.C. 20008 USA. Accessed: 2/22/2020, 2:45am. http://www.imastudies.com/Articles/Article/floating-production-sector-continues-to-rebound-500040
2. Ali MOA, Ja'e IA, Hwa MGZ (2019) Effects of water depth, mooring line diameter and hydrodynamic coefficients on the behaviour of deepwater FPSOs. Ain Shams Eng J
3. Kim M, Koo B, Mercier R, Ward E (2005) Vessel/mooring/riser coupled dynamic analysis of a turret-moored FPSO compared with OTRC experiment. Ocean Eng 32(14–15):1780–1802
4. Ji C, Cheng Y, Yan Q, Wang G (2016) Fully coupled dynamic analysis of an FPSO and its MWA system with mooring lines and risers. Appl Ocean Res 58:71–82 (2016). https://doi.org/10.1016/j.apor.03.008
5. Nishanth R, John KV, Whyte A (2016) Dynamic behaviour of FPSO in Kikeh field under different loading conditions. ARPN J Eng Appl Sci 11(4):6. http://www.arpnjournals.org/jeas/research_papers/rp_2016/jeas_0216_3643.pdf
6. Howell BG, Duggal AS, Heyl C, Ihonde O (2006) Spread moored or turret moored FPSO's for deepwater field developments, presented at the Offshore West Africa

7. Maffra SARDS, Pacheco MAC, de Menezes IFMG (2003) Genetic algorithm optimization for mooring systems. Generations 1(3):2003
8. Cui J, Li Q, Cheng Y, Ji C-Y, Deng X-K (2019) Addition of dynamic mooring line force based on lumped-mass method in SPH. Ocean Eng 182:90–101
9. Hall M, Goupee A (2015) Validation of a lumped-mass mooring line model with DeepCwind semisubmersible model test data. Ocean Eng 104:590–603
10. Robertson AN et al (2017) OC5 project phase II: validation of global loads of the DeepCwind floating semisubmersible wind turbine. Energy Proc 137:38–57
11. Ahmed Ali MO, Ja'e IA, Zhen Hwa MG (2020) Effects of water depth, mooring line diameter and hydrodynamic coefficients on the behaviour of deepwater FPSOs. Ain Shams Eng J 11(3):727–739, 2020/09/01. https://doi.org/10.1016/j.asej.2019.12.001
12. ANSYS A (2016) AQWA user's manual release 14.5, USA (2016), vol 2020R1, p 1122016. ANSYS Inc., Canonsburg (PA)
13. Van den Boom HJJ (1985) Dynamic behaviour of mooring lines. Behav Offshore Struct, 359–368
14. Chakrabarti SK (1987) Hydrodynamics of offshore structures. Mid-County Press, London
15. Yong Y, Baudic S, Poranski P, Wichers J, Stansberg CT, Ormberg H (2004) Deepstar study on predicting FPSO responses-model tests VS numerical analysis. In: Offshore technology conference
16. Wichers J, Devlin PV (2004) Benchmark model tests on the deepstar theme structures FPSO, SPAR and TLP. In: Offshore technology conference
17. OCIMF (1994) Prediction of wind and current loads on VLCCs. In: Technical Report, Oil companies international marine forum

Architectural Value in Tanggam System on the Traditional Malay House

Noraslinda Binti Abdul Rahman, Mohd Hamdan Ahmad, Rohayu Daud, Siti Azira Abd Rahim, Nasrudin Sharkawi, Samsiah Abdullah, Wan Nur Rukiah Arshard, and Sharifah Salwa Syed Mahdzar

Abstract In to preserve this great heritage, the Centre for the Study of Built Environment in the Malay World (KALAM) has collected more than 600 buildings, mostly using the tanggam system. Malay house construction has an architectural value especially on the system used. Besides, features of traditional Malay houses can be refined from their spatial structure, function rooms that make up the various rituals and customs as well as artistic carvings on them. Interestingly, the construction

N. B. A. Rahman (✉)
Center for the Study of Built Environment in the Malay World (KALAM), Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, 81310 Skudai, Malaysia
e-mail: noraslinda.ar@utm.my

M. H. Ahmad · S. Abdullah · S. S. S. Mahdzar
Architecture Department, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, 81310 Skudai, Malaysia
e-mail: b-hamdan@utm.my

S. Abdullah
e-mail: samsiah@utm.my

S. S. S. Mahdzar
e-mail: ssmahdzar@utm.my

R. Daud
Kolej Kemahiran Tinggi MARA Rembau, 71400 Pedas, Negeri Sembilan, Malaysia
e-mail: rohayu.daud@mara.gov.my

S. A. A. Rahim
Faculty of Engineering & Quantity Surveying, INTI International University, 71800 Nilai, Negeri Sembilan, Malaysia
e-mail: sitiazira.rahim@newinti.edu.my

N. Sharkawi
Jabatan Seni Bina, Fakulti Kejuruteraan Dan Alam Bina, Universiti Sains Islam Malaysia, Bandar Baru Nilai, 71800 Nilai, Negeri Sembilan, Malaysia
e-mail: nasrudin@usim.edu.my

W. N. R. Arshard
Department of Built Environment Studies and Technology, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA Perak Branch, 32610 Perak, Malaysia
e-mail: wnrukiah@uitm.edu.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_21

of the traditional Malay house is measured using the human body scale. In general, the height of the housing is according to the size of the man's body (husband) while the area and size of the house are preferred by the size of the woman's (wife) hand. Other than that, construction of Malay traditional houses according to local customs. Most of the traditional Malay houses using wood in construction with the unique method by applying the tanggam. 'Tanggam' system is a method of joining woods (Sabil and Uterberta in Adv Mater Res 984–987, 2011). According to the understanding of Malays, tanggam means wooden building frame assembly in the experimental stage. The full pronunciation is '*tanggam-menanggam*', while the tanggam means insert and match. The function of the use of tanggam is notched wood joints so close and sturdy (DBP in https://prpm.dbp.gov.my/cari1?keyword=tanggam). This system is shown the least exposed and documented as a reference in the construction of Malay traditional houses. Based on the material in KALAM, this study will provide exposure related to the types of tanggam as well as their installation methods. The purpose of the tanggam is to connect wooden structures, strengthen the construction, maintain the aesthetic nature of the building and it makes it easier for craftsmen to sew and remove the construction because no nails are used. The researchers will share about the construction of traditional houses belong to Daeng Haddadek bin Kafitang Wallingah located in Johor, Malaysia. The original study of this house was from a group of Universiti Teknologi Malaysia researchers to study and record information related to this architecture in the year 2011. The study began with a qualitative method that is by observation of the house. Then, a group of researchers obtained information by conducting interview sessions with owners, local communities, and local authorities. Next, they prepared a measurable drawing of the building. Therefore, the study was continued by a group of new researchers who have expertise in the field of architectural structure as well as evaluating its architectural value in this paper at the same time sharing the available data as a reference to government agencies, private agencies, stakeholder, researchers and others.

Keywords Tanggam · Malay construction · Traditional house · Jointing · Daeng Haddadek

1 Traditional Malay House

Malays strongly adhere to the characteristics of Islam to be the basis of behavior and action, form and relationship, the essence of values, attitudes, and views [1]. Religion is a very important stake and creating a culture in Malay's life with Islam has grown and established in society. This affects the construction of their house starting from the site selection, building orientation, and arrangement of space in it. The house that will be discussed by the researcher in this study belongs to Daeng Haddadek bin Kafitang Wallingah located in Pontian, Johor, Malaysia. The house has 26 columns where all the columns do not have the same height based on their position. Other than that, it has five stairs at the house; entrance, *serambi* to *rumah* *ibu*, *rumah ibu* to *jambatan*, *jambatan* to *kolong* and at the back of house. As for, the staircase at the front has a high aesthetic value. The stairs differentiate the level of the space while each space has a different height according to the hierarchy and use of the spaces. In addition, the number of stairs in this house has an odd number based on Islamic influence [2]. Each movement should start with a right step and the right foot will step in the house first based on the odd stair calculation. According to local beliefs, if the position of the staircase faces the main road, it reflects the status of the homeowner as an influential person while the main staircase located on the side is a house belonging to common people (Fig. 1).

Daeng Haddadek house has the shape of a frigate and is symmetrical to the scale used by the Malay community. The Malays believe the height of the traditional house affects the destiny of a family who inhabits a house. The house to be built will look attractive if it is measured in a uniform and orderly. Commonly, to measure the height of the house, the height of a man (husband) is used while for an area of the house, a woman's (wife) hand length is used as a measurement [3]. Daeng Haddadek house is one example of a Malay house with a beautiful scale construction. Overall, this perfect scale can be seen in the elevation design. The front elevation is shown as the most important in the Malay house, the architecture has three windows each of which has four panels. Other than that, the front of it has a *serambi* as a space to celebrate guests with a balustrade made of wood as well as having very fine measurements. Malay house is always cool because there are openings for natural lighting and maximum ventilation. Interestingly, it can be seen that the design of the Daeng Haddadek house has recurring elements in walls, doors, windows, decoration as well as roof. It makes the design of this house more harmonious. All these elements have openings or holes at the same time making the interior cozy and comfortable. The shape of the roof is in the shape of a *Limas* roof meanwhile, the walls are made of connected wallboard using a *Tanggam* system. In addition, Malay traditional houses built by adapting the surrounding element including weather, construction technology, material, and other spatial elements that are also influenced by the visual aspects of the dwellers to the accommodation of spaces for the visitors into their home [4, 5] (Figs. 2 and 3).

2 Architectural Value in Tanggam System

Malay house construction method has a unique architectural value which tanggam system is an important subject during its construction. Tanggam is notched wood joints so close and sturdy [6]. These methods have a major impact on the Malay traditional house as it can dismantle, reassemble and relocate accordingly. The carpenter uses this system because it is easily customizable at the experimental stage as it can insert and match. Malay house using a skeleton structure of wood. The first part erected was the *Rumah Ibu* before being followed by other spaces. Construction began with the erection of columns and beams. Daeng Haddadek house has used a column with a pedestal size is 25 cm × 25 cm. There are 22 concrete columns in this house with a floral motif to raise the aesthetic. The main column is selected from the

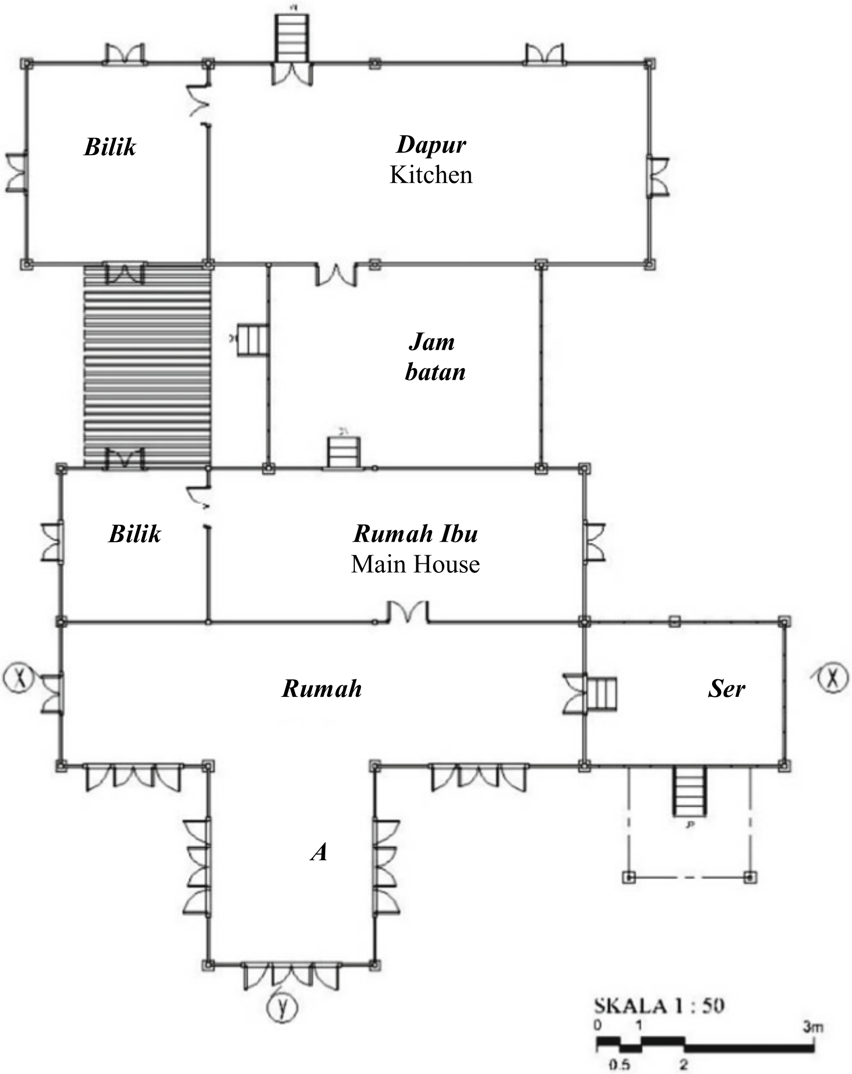


Fig. 1 Floor plan of Daeng Haddadek house. *Source* Centre for the study of built environment in the Malay world (KALAM)

finest wood as *Tiang Seri* was the first structure erected followed by other columns. It is important to make sure the height of the house is appropriate. On the column is placed a beam of Balau wood with a size 20 cm × 5 cm, *tanggam temu* is used as a medium to connect these beams so that it can function as a beam with a strong frame system. When the column, beams, and ceiling beams are completely installed then the construction of the roof will be carried out, this house uses a *limas* roof. Next is the installation of floor and wallboards (Fig. 4).

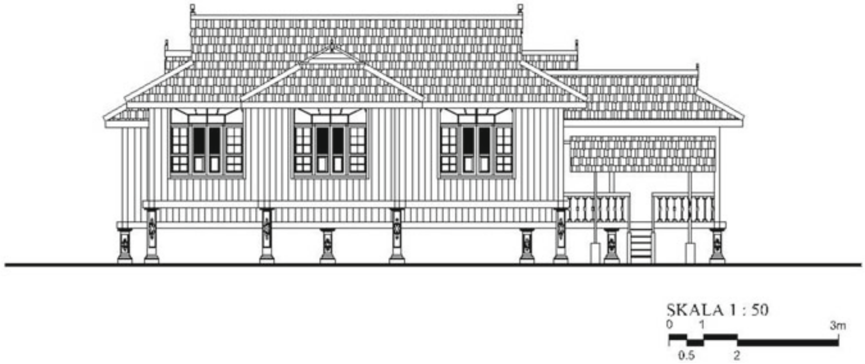


Fig. 2 Front elevation of Daeng Haddadek house. *Source* Centre for the study of built environment in the Malay world (KALAM)

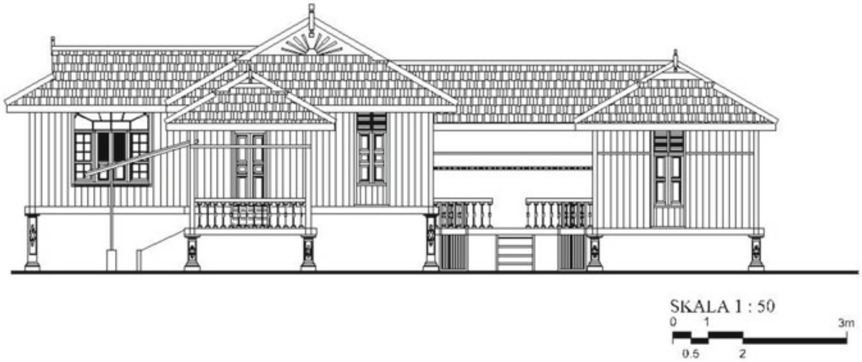


Fig. 3 Right elevation of Daeng Haddadek house. *Source* Centre for the study of built environment in the Malay world (KALAM)

Three main components in the Malay house construction are building framework, flooring structure, and roof structure [7]. Each component is supported by other sub-components. To ensure the strength of these components; the connection system must be neat, effective, and robust. Hence, this is where the architectural value of tanggam is involved in the house. Zulkifli Hanafi stated that to ensure the stability of the building, 'tanggam tebuk' system is the main connection used because this connection can reduce lateral and shear stress. There are several types of tanggam in Malay house construction; *Tanggam Melebar*, *Tanggam Pemidang*, *Tanggam Memanjang*, *Tanggam Siku* as each tanggam has its own cut shape according to the suitability of the structure. *Tanggam Melebar* is used to connect pieces of small boards to wide pieces of the board as furniture surfaces, walls, floors, and so on. *Tanggam Pemidang* is used in the construction of a *pemidang* wooden frame shaped like the wooden part is connected on the ends from edge to edge. *Tanggam Memanjang* is used when

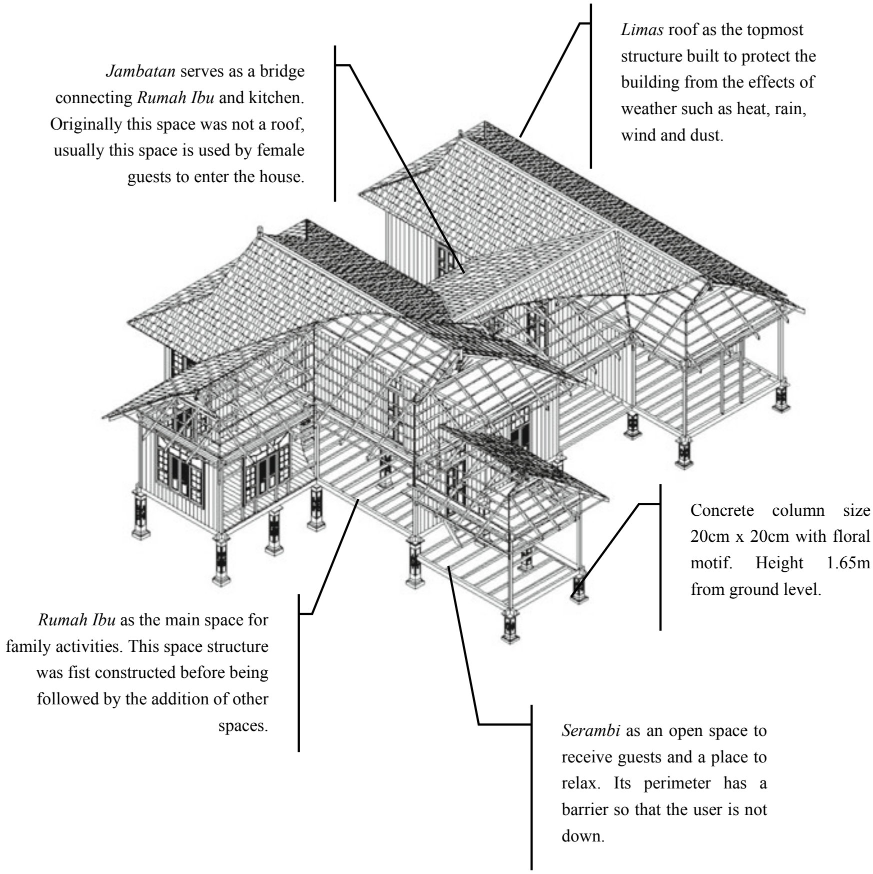


Fig. 4 Construction structure of Daeng Haddadek house. *Source* Centre for the study of built environment in the Malay world (KALAM)

connecting two pieces of wood to be made longer and Tanggam Siku making two surfaces that meet in a way at right angles either an angle or a section middle (Figs. 5, 6 and 7).

3 Discussion and Conclusion

- Tanggam system is very cost and material-saving. In addition, tanggam is sustainable and resilient compared to other modern construction because the installation of the house can be dismantling, reassemble and relocate for 'open and install' or diverting as a whole.

Fig. 5 Tanggam systems on floor and wall installations. *Source* Centre for the study of built environment in the Malay world (KALAM)

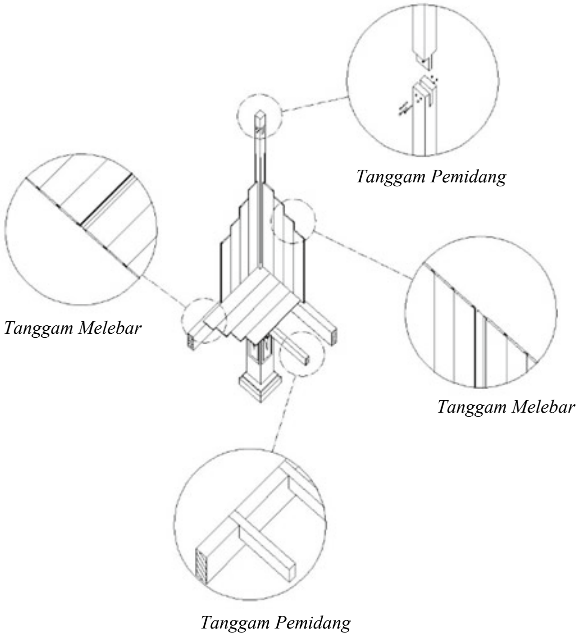
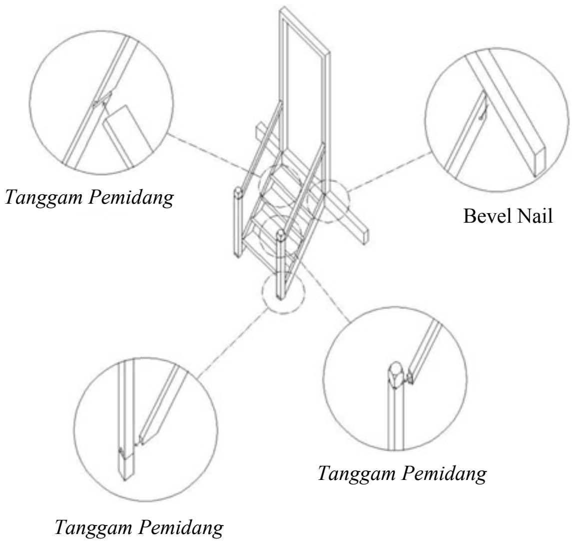


Fig. 6 Tanggam systems on staircase structure. *Source* Centre for the study of built environment in the Malay world (KALAM)



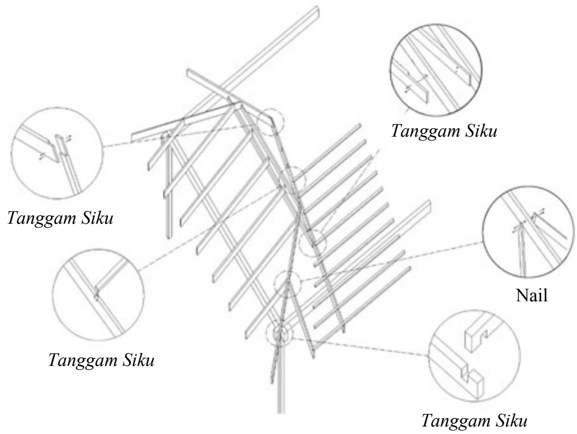


Fig. 7 Tanggam systems on roof structure. *Source* Centre for the study of built environment in the Malay world (KALAM)

- Wood was widely used in ancient times in a variety of daily activities including the construction work in the Malay traditional buildings. Malay home builder's joinery to apply the system because the method is very flexible, can be changed and adjust easily.
- The art of carpentry has a high architectural heritage value. Beauty Malay house design is the result of an understanding of materials and techniques that are appropriate. Apart from the attractive design, the artisans of traditional Malay houses also demonstrate proficiency and understanding of connecting a unique structure in terms of durability, flexibility, effectiveness, and simplicity.

Acknowledgements The authors sincerely acknowledge the Centre for the Study of Built Environment in the Malay World (KALAM) of Universiti Teknologi Malaysia and all original researchers involved in this study; Alice Sabrina Binti Ismail, Ahmad bin Mohd Isa, Azizaini Juhaidi bin Abd Rahman, Nor Hayati binti Rosli, Noor Farahin binti Zamri and Stella Wong Sik Sing.

References

1. Rashid NA (2015) Nilai Kesantunan Dalam Konteks Sosiobudaya Masyarakat Melayu. Jurnal Pengajian Melayu Jilid 15:232–253
2. Ismail AS, Isa AM, Rahman AJ, Rosli NH, Zamri NF, Sing SW (2011) Rumah Daeng Haddadek B. Kafitang Wallingah. KALAM UTM, Johor Malaysia
3. Aziz NF (2021) Adat Resam, Kepercayaan dan Kebudayaan Terhadap Pembinaan Rumah Tradisional Melayu. Universiti kebangsaan Malaysia, Selangor, Malaysia
4. Mahdzar SS, Yahya AS (2017) The visual graph analysis of Malay traditional houses. In: 8th international science, social science, engineering and energy conference
5. Sabil A, Uterberta N (2011) Documentation and analysis of sustainable design and application of Tanggam system in Malay traditional house. Adv Mater Res 984–987

6. DBP DB (2021) Kamus Bahasa Melayu. https://prpm.dbp.gov.my/cari1?keyword=tanggam
7. Hanafi Z (1996) Pembinaan Bangunan Tradisional Melayu. Amber~Solara Publication, Kedah Malaysia

Covid-19 Pandemic: Strategies to Improve Daylighting and Visual Comfort for Building Occupants

Fazidah Hanim, Azhan Abdul Aziz, Mayamin Yuhaniz, and Sabarinah Sheikh Ahmad

Abstract Sufficient lighting has a substantial impact on the health, comfort, and performance of building occupants. Researchers frequently focus on daylighting for its psychological, physiological, and economic benefits to human well-being. However, the COVID-19 pandemic demonstrated that these wellness considerations are no longer optional features of a building, but rather a necessary component of providing a comfortable and healthy living environment. Everyone must adhere to the stay-at-home order to mitigate pandemic transmission. This study aims to review the literature and recommends strategies that will improve building occupants' daylighting and visual comfort. For the review, this study identified 41 peer-reviewed journal articles using a keyword search followed by a filter based on SCOPUS and Web of Science inclusion criteria. However, once the inclusion and exclusion criteria were applied, only 31 papers were chosen for evaluation. Thematic analysis of these 31 publications revealed eight tentative criteria for effective daylighting in buildings, categorised into three clusters: passive design, active design, and projected ideal daylighting based on daylight simulation tests. The results demonstrate that a passive design strategy provides improved illumination and is a more cost-effective way to achieve appropriate daylight and visual comfort in a facility. Despite its limitations, the study recommends the hybrid technique of passive and active design as a helpful experimental tool for future research targeted to increase the interior environment's quality.

Keywords Daylighting · Visual comfort · Passive design strategy · IEQ

F. Hanim (✉) · A. A. Aziz · M. Yuhaniz
Centre of Studies for Architecture, Department of Built Environment Studies & Technology, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Perak Branch, Seri Iskandar Campus, 32610 Seri Iskandar, Perak, Malaysia
e-mail: fazid896@uitm.edu.my

S. S. Ahmad
Centre of Studies for Architecture, Faculty of Architecture, Planning and Surveying, Selangor Branch, Universiti Teknologi MARA, Puncak Alam Campus, 42300 Puncak Alam, Selangor, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_22

1 Introduction

Through its dynamic luminous and thermal features, sunlight is a multisensory phenomenon that can enhance occupants' comfort, health, and connection to the natural world [1]. The primary and most preferred source of illumination is daylight. Daylighting helps reduce energy consumption, alleviate negative environmental impacts, improve human performance, and increase building occupant's productivity [2, 3]. Daylight is increasingly becoming acknowledged as an important synchroniser of circadian rhythms, as it connects us to the 24-h solar day. Daylight illumination becomes a substantial source of illumination for the building's interior areas [4, 5]. However, excessive natural light in the form of glare causes eye discomfort for building occupants, which is why many owners opt for direct shading in building operations management [6]. The shape of the building's facade significantly affects how much usable daylight reaches the interior space. The importance of daylighting cannot be overstated for visual comfort and energy economy. Controlling lighting through daylighting can aid in the reduction of energy use in buildings. The Green Building Index (GBI) for residential projects includes daylighting as an important criterion under the category of interior environmental quality, accounting for one-quarter of the total points. A sustainable building design aims to maximise tenant satisfaction while minimising the facility's negative environmental impact [7]. Visual discomfort from glare is a crucial issue in day lit buildings, yet a consensus on glare indices and their criteria is difficult to achieve, as any objective values considered must demonstrate a substantial correlation with occupant experience.

The Health Ministry stated that the work-from-home directive is being implemented to control the increase in Covid-19 cases in Malaysia, noting that the Health Ministry has identified multiple Covid-19 clusters involving workplaces, particularly in high-density areas such as Selangor and Kuala Lumpur. Malaysia's government recently increased the value of home-based offices in order to encourage residents to work from home [8]. During the day, workers generally undertake desk-related tasks (reading, writing, and computing) at their home workrooms [9, 27]. Thus, visual comfort is vital in residential constructions just as it is in commercial structures. While previous research in Malaysia on daylighting has focused on office buildings, this study analyzes strategies for improving daylight in domestic buildings.

This study asks a research question—what is the strategy to improve daylight and visual comfort for building occupants? Hence this study aims to review the literature and recommends strategies that will improve building occupants' daylighting and visual comfort.

2 Methodology

This study adapted the research approaches of Zairul [33] and Azril et al. [4] for methods to perform a systematic review of the literature. The first stage is a comprehensive evaluation of research articles to ascertain the current trend of academic understanding surrounding daylighting in buildings. Published articles are retrieved from SCOPUS and Web of Science websites using the keywords "Daylighting" and "Visual Comfort," as indicated in Table 1. When the results of the two databases were combined, this resulted in approximately 41 articles. Four papers were deleted due to the review's restriction to peer-reviewed journals and theses, as well as the identification of multiple duplications. Following that, Tables 2 and 3 detailed the papers evaluated and published within the last five years (2017 until 2021 inclusively). After removing duplicates and reviewing all abstracts, a total of 31 papers were chosen for analysis.

Table 1 Search strings from Scopus and web of science

Databases	Keyword used	
SCOPUS	TITLE-ABS-KEY (daylighting AND visual AND comfort AND effects AND building AND occupants) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SRCTYPE, "j"))	14 results screening: 13
Web of Science	(((TS = (daylighting)) AND TS = (visual comfort)) AND TS = (effects on)) AND TS = (building comfort) Refined By:Publication Years: 2021 or 2020 or 2019 or 2018 or 2017Document Types: ArticlesLanguages: EnglishResearch Areas: Architecture or Science Technology Other Topics or Engineering	27 results Screening: 18

Table 2 The inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Timeline	2017–2021	2017 and before
Language	English	Non-english
Document type	Article	Article Review, Conference Proceeding, Chapters in Book, book series

Table 3 The theme according to year

	2017	2018	2019	2020	2021
External strategy	3	1	6	7	2
Internal strategy	2	1	–	2	1
Simulation studies	2	–	3	–	–

Following that, ATLAS.ti 8 tool was used to import and create primary documents for all 31 metadata. Numerous groupings within the code group were initiated automatically as a result of the information generated in Mendeley, as demonstrated in Fig. 2. ATLAS.ti 8's classification has streamlined and standardised the sorting process. During the initial round of coding, the study generated 11 initial codes. Later, the codes were divided into numerous themes. Then the codes are merged into a final set of three primary categories to address the research question "What is the strategy in improving daylight and visual comfort for building occupants?" Then they were combined into a final set of three major categories which are passive design, active design, and daylighting simulation studies as shown in Table 4.

3 Results and Discussion

Active strategies are primarily concerned with energy consumption, whereas passive strategies include building orientation, air sealing, continuous insulation, window openings and daylighting, and designing a structure to utilise natural ventilation and natural lighting. Passive design strategies utilise natural sources of heating and cooling, such as the sun and cooling breezes. Passive design is accomplished by correctly positioning the buildings within its site and meticulously planning the building envelope (roof, walls, windows and floors). Well-designed building envelopes prevent unwanted heat gain and loss. The term "external strategy" refers to a method of daylighting and designing the shell and core of a building by utilizing exterior features. These include shading devices, fenestration design, daylighting methods, and material selection.

Dynamic solar shading is commonly used as a strategy to control overheating in well-insulated residential structures while allowing for appropriate daylight and solar irradiation [12]. In Swiss, electric illumination consumes around one-fifth of the energy utilised by buildings. Sun shading and artificial lighting control integrated into a single system can reduce this demand while maintaining user comfort [13]. Moreover, the authors examined the effect of exterior shade systems on cognitive function, attentiveness, and visual comfort of visual display terminal (VDT) users in two realistic workplace lighting conditions [4]. However, one shortcoming of contemporary building control systems is that they disregard one of the most crucial aspects of human-centric lighting: visual comfort (Fig. 1) [13].

Rapid urbanisation raises the need for skyscrapers, which typically contain reflective materials on the building's front for aesthetic purposes [14]. Dynamic electrochromic (EC) windows are the next generation of adaptive facades; they use an external voltage to dynamically control the quantity of sunlight and solar energy entering buildings. Windows play a crucial role in determining a building's energy balance and environmental impact. These structural components are being optimised by emerging technology [15]. On the other hand, outdoor glare or reflected brightness from a highly reflective building front may cause visual and thermal discomfort to inhabitants of adjacent buildings and pedestrians. This condition can create an

Table 4 Document to a theme

	References	Passive design					Active Design	Day-lighting Simulation Studies
		External strategy				Internal Strategy		
		Shading devices	Material	Daylighting Approach	Fenestration			
1	Skarning et al. [26]	/						
2	Chinazzo et al. [9]					/		
3	Leccese et al. [19]	/						
4	Gutierrez et al. [13]			/				
5	Ishak et al. [16]		/					
6	Bas and Kazanasmaz [5]							/
7	Motamed et al. [22]	/						
8	Ma'bdeh and Al-Khatatbeh [20]			/				
9	Freewan and Al Dalala [11]			/				
10	Sun et al. [28]				/			
11	Giovannini et al. [12]				/			
12	Alawadhi [2]				/			
13	Pan and Du [23]					/		
14	Potocnik and Kosir [24]					/		
15	de Vries et al. [10]	/						
16	Cannavale et al. [8]		/					
17	Toftum et al. [29]						/	
18	Wagdy et al. [31]							/
19	Lapisa et al. [18]			/				

(continued)

Table 4 (continued)

	References	Passive design					Active Design	Day-lighting Simulation Studies
		External strategy				Internal Strategy		
		Shading devices	Material	Daylighting Approach	Fenestration			
20	Bian et al. [7]			/				
21	Hosseini et al. [14]				/			
22	Abboushi et al. [1]				/			
23	Bas and Kazanasmaz [5]				/			
24	Vaisi and Kharvari [30]							/
25	Zomorodian and Tahsildoost [34]							/
26	Yi et al. [32]			/				
27	Im [15]						/	
28	Basurto et al. [6]				/			
29	Amundadottir et al. [3]							/
30	Jones and Reinhart [17]							/
31	Mangkuto et al. [21]					/		
	Totals	4	2	6	7	4	2	6

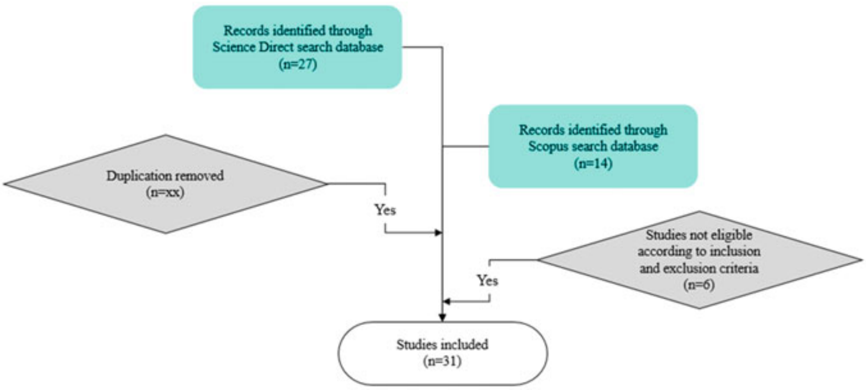


Fig. 1 The flow diagram of the study

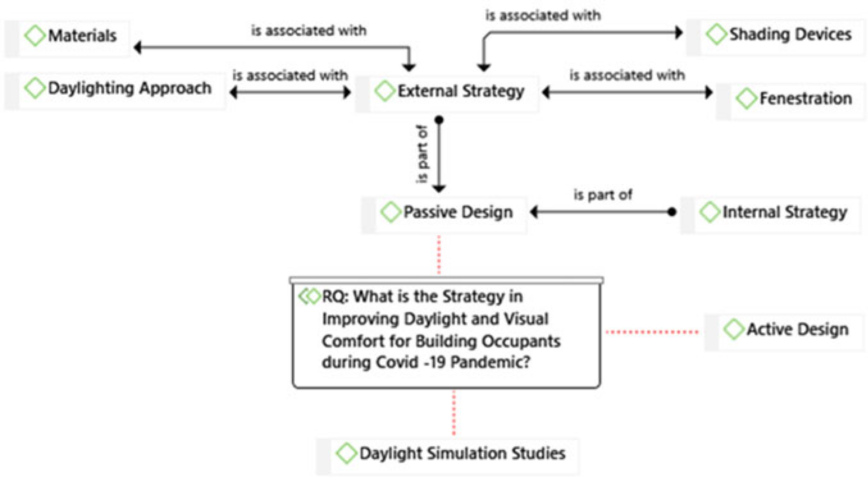


Fig. 2 The network view according to themes

unwanted glare for people on the exterior of the structure. In tropical climates, glare is more apparent due to the year-round availability of solar energy (Fig. 2) [14].

The building envelope, and more specifically the fenestrations, are the primary interfaces between the inside and outside environments. As a result, an effective shade structure for windows is highly desirable, as it may provide adequate illumination while maintaining an acceptable level of visual comfort via glare management. Static daylight management systems are frequently designed to darken the façade completely or to admit and divert sunlight to the interior. Dynamic control systems modify the amount of sunlight absorbed with the assistance of users or the mechanical system [16]. While adding skylights to low- to high-rise buildings could reduce energy consumption through daylighting, it might also increase the indoor temperature and occupants' thermal discomfort [17]. Early research demonstrated that respondents' glare perceptions are not continuous, meaning that conventional shading control logic may be irrational and erroneous [6].

To enhance internal comfort and energy efficiency, significant developments in the design of glass facades and window systems have resulted in enhanced thermal resistance while maintaining daylight access [18]. Due to its ability to adjust its optical properties in reaction to changes in material temperature, thermochromic switchable glass has gained popularity among dynamic building envelope systems to reduce energy consumption in tertiary buildings [19]. This material permits passive solar load management, and so the performance of thermochromic glass is contingent on successful material design.

The geometrical qualities of a building's windows play a crucial role in providing and diffusing daylight [5]. Windows are crucial as they help reduce energy consumption related to electrical lighting and enhance the indoor visual experience [7].

Balancing tenant visual comfort and daylight consumption is always tricky. Therefore, investigating complex, geometric forms screens such as Orosi patterns can be an excellent strategy for encouraging visual comfort while also improving aesthetics. Orosi serves three separate tasks in Iranian vernacular architecture as a daylight-related component: daylight performance, heat performance, and decorative role [20]. Apart from that, complex fenestration systems (CFS) are often put on the upper area of a window to improve the dispersion of sunlight inside [21].

Increased heat gain and a visual discomfort environment may arise from excessive sunlight penetration through the windows. As a result, external shading devices, such as solar screens control the quantity of sunlight that enters and therefore mitigates its negative effects [7]. One gap in the current body of knowledge on solar exposure is the lack of investigation of sunlight patterns and their potential impact on visual comfort [1]. The objective is to increase the potential for buildings to make the best use of direct and diffuse natural light while maintaining and improving occupant visual comfort, particularly at greater distances from peripheral walls [5]. With the advent of improved fenestration and daylighting systems, it is necessary to create better measuring and analytic tools to aid in daylighting optimisation. Due to their additional solar protection role, their use may assist offset the detrimental effects of daylight admission, particularly in buildings located in mostly sunny climates prone to glare and heat [21].

Lighting's Correlated Colour Temperature (CCT) may affect occupant visual perception and perceptions of other characteristics of the interior environment, such as thermal climate or air quality [22]. In evaluating luminous surroundings, high dynamic range (HDR) photography using a fisheye lens has opened new paths for visual comfort research [23]. The measurement of visual discomfort using photographs has a significant potential for detecting glare and estimating occupant satisfaction within a space [24]. The effects of temperature-colour interaction on subjective perception and physiological responses are investigated using a novel hybrid experimental design that incorporates thermal and visual stimuli from both real and virtual reality (VR) environments [25]. The majority of research has focused on post-calibration vignetting correction in high dynamic range (HDR) imagery. However, the lens projection contributes to the defects in luminous maps due to its inherent distortion. Currently, there is no simple way for resolving this distortion issue in glare analysis [23]. For glare analysis, precise calibration is essential to acquire accurate luminous maps and reliable glare data. Architects must be able to foresee glare through renderings, not photographs, when designing buildings with occupant visual comfort in mind [24].

The right materials selection and daylighting approach can improve daylight intake and maintain good visual perception in the building. According to Potocnik & Kosir [24], a more spectrally neutral non-visual environment can be created using materials with a higher spectrally neutral transmissivity or reflectance than those with spectrally non-neutral properties but a lower transmissivity or reflectance. Furthermore, Gutierrez et al. [13] stated that the proposed louvre system could supply sufficient sunshine and visual comfort within the area, while ceramics are proven to be a good material for fabricating complex daylighting systems. Meanwhile, Freewan and

Al Dalala [11] reported that lightshelf, anidolic daylighting systems, and windows at the rear areas of the glazed corridor worked better in terms of increasing the light level by an average of more than 100% in the rear portion.

The fact that the amount of daylight varies significantly depending on the window geometry and sky conditions, as stated by Ramesh and Ramachandraiah [25], motivates (i) the exploration of fractal patterns suitable for window designs and (ii) the quantification of the effect of fractal windows using the relationship between the fractal pattern, size, orientation, and glazing properties. Additionally, there is a strong correlation between daylight availability, solar exposure, and the probability of glare. Furthermore, optimisation of daylighting parameters such as illuminance and glare shows a clear correlation between the case study location and its associated sun angles and the performance of the shading structure, as Yi et al. [32] demonstrated in their studies of auxetic structures and advanced control systems.

In terms of daylight simulation programme, according to Amundadottir et al. [3], a parallel and comparative method to daylight simulation enables the designer to adjust the architectural space based on the program's use and the needs of the occupants. Additionally, Jones & Reinhart [17] demonstrated that by applying Accelerate, it is possible to achieve a speedup of between 16 and 44 times faster than RADIANCE when making accurate glare predictions. The modelling framework presented here can be used to assess the performance of alternative switchable glazing technologies.

Based on the studies carried by Bas and Kazanasmaz [5], Zomorodian and Tahsildoost [34] and Amundadottir et al. [3], it can be concluded that the implications of this study can assist architects in obtaining feedback on how to save energy for each final energy use (heating, cooling, and lighting) reduction in window space and communicating this message to their designs via suggested optimal wall to window ratios (WWR). The findings indicate that daylight and glare thresholds should be reconsidered based on global field surveys, as occupants' ability to adapt to increased or decreased amounts of daylight may differ culturally and geographically. A comparative and parallel method enables the designer to tailor the architectural space to the program's intended function and the requirements of the occupants (Fig. 3).

4 Conclusions

In summary, given Malaysia's rapid growth of home-based businesses, it is vital to enhance the interior visual comfort of existing residential buildings, which account for the vast majority of building types in the country's central urban zones. Apart from commercial buildings, it is necessary to examine existing residential structures for visual comfort and daylighting design. This study centered on passive design in tropical climates, a way to building design that makes use of the structure's architecture to reduce energy usage. Thus, the goal of this paper was to provide techniques for boosting daylighting and visual comfort in existing residential buildings in Malaysia's internal region of tropical daylight.

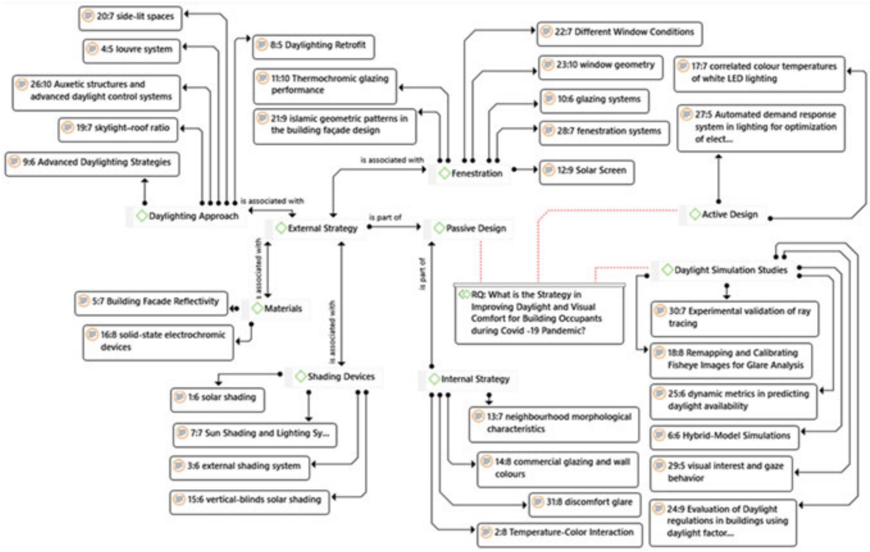


Fig. 3 A network view on how to answer research questions through thematic review

The network view, depicted in Fig. 3, shows the relationships between the three key clusters that contribute to the study topic. Passive design, active design, and a study of daylight simulation are included in these clusters. Under passive design, the cluster represents external strategies that represent the daylighting approach appropriate for the building architecture, whereas the internal strategies encompass the design elements that contribute to enhancing the distribution of daylight within a space through approaches such as material and colour selection. This is illustrated further in Table 4, which shows the categorization of publications according to theme. Using this table, the researcher previously investigated the usefulness of passive design strategies for boosting daylighting and visual comfort within a room. It collects solar energy naturally, requiring a negligible amount of primary energy and leaving sufficient energy for future generations without causing significant environmental impact. Fundamentally, passive measures are employed to mitigate the impact of a building on the surrounding environment. While daylighting is a vital design strategy that must be included from the start, retrofitting existing structures is another way to boost daylighting.

References

1. Abboushi B, Elzeyadi I, Van Den Wymelenberg K, Taylor R, Sereno M, Jacobsen G (2020) Assessing the visual comfort, visual interest of sunlight patterns, and view quality under different window conditions in an open-plan office. LEUKOS—J Illum Eng Soc North Am. https://doi.org/10.1080/15502724.2020.1785309
2. Alawadhi EM (2019) Comparative performance of a solar screen with respect to perforation ratio: illuminance and energy saving. J Solar Energy Eng Trans ASME 141(1). https://doi.org/10.1115/1.4041103
3. Amundadottir ML, Rockcastle S, Sarey Khanie M, Andersen M (2017) A human-centric approach to assess daylight in buildings for non-visual health potential, visual interest and gaze behavior. Build Environ 113:5–21. https://doi.org/10.1016/j.buildenv.2016.09.033
4. Azril H, Shaffril M, Abu A, Farid S, Ali Z (2019) Mirror-mirror on the wall, what climate change adaptation strategies are practiced by the Asian' s fishermen of all? J Cleaner Prod 232:104–117. https://doi.org/10.1016/j.jclepro.2019.05.262
5. Bas H, Kazanasmaz T (2020) Hybrid-model simulations to equilibrate energy demand and daylight autonomy as a function of window-to-wall ratio and orientation for a perimeter office in Izmir. Megaron 15(4):537–552. https://doi.org/10.14744/MEGARON.2020.42223
6. Basurto C, Kämpf JH, Scartezzini JL (2017) Multi-criteria analysis for the integrated performance assessment of complex fenestration systems. Build Res Inform 45(8):926–942. https://doi.org/10.1080/09613218.2016.1235911
7. Bian Y, Dai Q, Ma Y, Liu L (2020) Variable set points of glare control strategy for side-lit spaces: daylight glare tolerance by time of day. Sol Energy 201:268–278. https://doi.org/10.1016/j.solener.2020.03.016
8. Cannavale A, Martellotta F, Cossari P, Gigli G, Ayr U (2018) Energy savings due to building integration of innovative solid-state electrochromic devices. Appl Energy 225:975–985. https://doi.org/10.1016/j.apenergy.2018.05.034
9. Chinazzo G, Chamilothori K, Wienold J, Andersen M (2021) Temperature-color interaction: subjective indoor environmental perception and physiological responses in virtual reality. Hum Factors 63(3):474–502. https://doi.org/10.1177/0018720819892383
10. de Vries SB, Loonen RC, Hensen JL (2021) Multi-state vertical-blinds solar shading–performance assessment and recommended development directions. J Build Eng. https://doi.org/10.1016/j.jobe.2021.102743
11. Freewan AAY, Al Dalala JA (2020) Assessment of daylight performance of advanced daylighting strategies in large university classrooms; case study classrooms at just. Alexandria Eng J 59(2):791–802. https://doi.org/10.1016/j.aej.2019.12.049
12. Giovannini L, Favoino F, Pellegrino A, Lo Verso VRM, Serra V, Zinzi M (2019) Thermochromic glazing performance: from component experimental characterisation to whole building performance evaluation. Appl Energy 251. https://doi.org/10.1016/j.apenergy.2019.113335
13. Gutierrez RU, Du J, Ferreira N, Ferrero A, Sharples S (2019) Daylight control and performance in office buildings using a novel ceramic louvre system. Build Environ 151:54–74. https://doi.org/10.1016/j.buildenv.2019.01.030
14. Hosseini SN, Hosseini SM, Pour MH (2020) The role of Orosi's islamic geometric patterns in the building façade design for improving occupants' daylight performance. J Daylighting 7(2):201–221. https://doi.org/10.15627/jd.2020.18
15. Im KM (2017) Automated demand response system in lighting for optimization of electricity cost. Energy Effi 10(6):1329–1341. https://doi.org/10.1007/s12053-017-9519-2
16. Ishak NM, Jenatabadi HS, Mustafa S, Abdullah J (2021) The impact of building facade reflectivity on pedestrian visual comfort with the application of Bayesian structural equation modeling. Eng J Thailand 25(1):211–219. https://doi.org/10.4186/ej.2021.25.1.211
17. Jones NL, Reinhart CF (2017) Experimental validation of ray tracing as a means of image-based visual discomfort prediction. Build Environ 113:131–150. https://doi.org/10.1016/j.buildenv.2016.08.023

18. Lapisa R, Karudin A, Martias M, Krismadinata K, Ambiyar A, Romani Z, Salagnac P (2020) Effect of skylight–roof ratio on warehouse building energy balance and thermal–visual comfort in hot-humid climate area. Asian J Civil Eng 21(5):915–923. https://doi.org/10.1007/s42107-020-00249-9
19. Leccese F, Salvadori G, Öner M, Kazanasmaz T (2020) Exploring the impact of external shading system on cognitive task performance, alertness and visual comfort in a daylit workplace environment. Indoor Built Environ 29(7):942–955. https://doi.org/10.1177/1420326X19864414
20. Ma'bdeh S, Al-Khatatbeh B (2019) Daylighting retrofit methods as a tool for enhancing daylight provision in existing educational spaces-a case study. Buildings 9(7). https://doi.org/10.3390/buildings9070159
21. Mangkuto RA, Kurnia KA, Azizah DN, Atmodipoero RT, Soelami FXN (2017) Determination of discomfort glare criteria for daylit space in Indonesia. Sol Energy 149:151–163. https://doi.org/10.1016/j.solener.2017.04.010
22. Motamed A, Deschamps L, Scartezzini JL (2019) Eight-month experimental study of energy impact of integrated control of sun shading and lighting system based on HDR vision sensor. Energy Build 203. https://doi.org/10.1016/j.enbuild.2019.109443
23. Pan WJ, Du J (2021) Effects of neighbourhood morphological characteristics on outdoor daylight and insights for sustainable urban design. J Asian Arch Build Eng. https://doi.org/10.1080/13467581.2020.1870472
24. Potocnik J, Kosir M (2020). Influence of commercial glazing and wall colours on the resulting non-visual daylight conditions of an office. Build Environ 171. https://doi.org/10.1016/j.buildenv.2019.106627
25. Ramesh KG, Ramachandraiah A (2020) A fractal approach for optimization of daylighting by exploring the window geometry. Int J Adv Res Eng Technol 11(2):36–47. https://doi.org/10.34218/IJARET.11.2.2020.005
26. Skarning GCJ, Hviid CA, Svendsen S (2017) The effect of dynamic solar shading on energy, daylighting and thermal comfort in a nearly zero-energy loft room in Rome and Copenhagen. Energy Build 135:302–311. https://doi.org/10.1016/j.enbuild.2016.11.053
27. Sulaiman R, Salbiah S, Shariff M (2012) The transformation of home-based businesses into electronic-home-based businesses. 38:93–98
28. Sun Y, Liang R, Wu Y, Wilson R, Rutherford P (2017) Development of a comprehensive method to analyse glazing systems with Parallel Slat Transparent Insulation material (PS-TIM). Appl Energy 205:951–963. https://doi.org/10.1016/j.apenergy.2017.08.041
29. Toftum J, Thorseth A, Markvart J, Logadottir A (2018) Occupant response to different correlated colour temperatures of white LED lighting. Build Environ 143:258–268. https://doi.org/10.1016/j.buildenv.2018.07.013
30. Vaisi S, Kharvari F (2019) Evaluation of daylight regulations in buildings using daylight factor analysis method by radiance. Energy Sustain Dev 49:100–108. https://doi.org/10.1016/j.esd.2019.02.002
31. Wagdy A, Garcia-Hansen V, Isoardi G, Pham K (2019) A parametric method for remapping and calibrating fisheye images for glare analysis. Buildings 9(10). https://doi.org/10.3390/buildings9100219
32. Yi YK, Sharston R, Barakat D (2019) Auxetic structures and advanced daylight control systems. J Facade Design Eng 7(1):63–74. https://doi.org/10.7480/jfde.2019.1.2620
33. Zairul M (2020) A thematic review on student-centred learning in the studio. J Crit Rev 7(2):504–511
34. Zomorodian ZS, Tahsildoost M (2019) Assessing the effectiveness of dynamic metrics in predicting daylight availability and visual comfort in classrooms. Renew Energy 134:669–680. https://doi.org/10.1016/j.renene.2018.11.072

The Impact of Wind Behavior on University Building Configurations in Iraq

Aqeel Qusay Al-Mosawi and Ali Hussein Khan

Abstract Recently, wind flow behavior surrounding buildings (Pedestrian Level Wind (PLW)) is gaining more attention among researchers and architects. The current study focuses on building configurations thereby generating various cases depending on analysis of wind variables. Some Wind flow around buildings poses problems and inconvenience for the inhabitants of the buildings. In university campuses in Iraq there are many issues observed in the building design process, like buildings arrangement, shapes and the orientation of the blocks which affects wind flow around these buildings. For this study, the researchers depended on simulation program analyses to obtain the optimal results of outdoor air movement guidelines and employed Kufa University buildings in Najaf-Iraq as a case study through generating three cases of buildings configurations on PLW by using Autodesk Computational Fluid Dynamics (CFD) simulation. The study outcomes concluded that the impact of different building configurations have an important effect on PLW and also, determined whether areas in outdoor spaces of the buildings are comfortable or not. Hence, this may assist urban designers and architects to develop university campuses suited to the local environmental conditions.

Keywords Pedestrian level-wind (PLW) · Building configurations · Computational fluid dynamics (CFD) · University campuses

1 Introduction

Wind effects on buildings can be harmful or uncomfortable to both the indoor and outdoor environments. In urban areas, pedestrian-level wind plays a direct role in people's daily life. It affects the thermal comfort of the pedestrians, the dispersal of

A. Q. Al-Mosawi
Department of Architecture, Faculty of Engineering, University of Kufa, Al-Najaf, Iraq
e-mail: aqeel.almusawi@uokufa.edu.iq

A. H. Khan (✉)
Department of Architecture, Faculty of Design and Architecture, Universiti Putra Malaysia, UPM, 43400 Serdang, Selangor, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_23

traffic-related wind, the efficiency of natural ventilation, and the pollutants around buildings. In Iraq in order to provide the best outdoor thermal environment in the urban areas, wind effects surrounding buildings are of vital importance [1]. Ali et al. [2] presented experimental data which are considered as a basis for the urban planning or design of different wide zones.

Nowadays this is a challenge that is regularly encountered by engineers, architects, and urban designers. Of concern are wind effects, natural or man-made on ventilation of buildings; ventilation in urban areas, the air quality and pedestrian comfort. Therefore, to supply a comfortable environment, it is important to consider the reciprocal relationship between the shape of the building and the airflow. Considering all the above-mentioned aspects, although the most common shapes of building configurations are (L- and U-shaped), studies for such shapes are very limited at the local level under different wind directions [3]. Different studies addressed the relation between the wind behavior and building configurations. Stathopoulos and Zhou [4] in their study on buildings with sharp corners, employed numerical simulations to anticipate the wind pressure on all the sides of the building, whereas Gomes et al. [3] explored the wind impacts on (U and L-shaped) building samples using wind tunnel testing as well as numerical simulation methods. Gu [5] conducted tests on 27 typical models of high buildings and evaluated the attributes of wind forces with regard to all the building models through a wind tunnel method. Cluni et al. [6] and Li et al. [7] used high order moment statistical analysis to compare the wind impacts on irregular and regular high constructions by. A further numerical study by Gomes et al. investigated velocity field and surface pressures using wind tunnel study, respectively in respect of irregular-building (U- and L-) shapes [8]. The study observed that pressure distribution may frequently alter with the wind incidence angle and building shape. Consequently, for these irregular-shape buildings, the numerically acquired flow behavior in direct surrounding area regarding inner-faces are correspondent with the distributions of measured pressure. Iqbal et al. [9] proposed that the recent importance of wind pattern modeling in urban areas comes as a result of an increase in high-rise buildings and urbanization. They found that the building arrangement which is close to square-shaped resulted in agreeable wind velocity zone at lower aspect ratio. Nevertheless, a high wind velocity zone has been occasionally noticed which is desired for contaminants dispersal. In respect of both high and agreeable wind velocities zones, L-shaped and U-shapes configurations created higher-level yield due to unconstrained airflow because of open spaces for all the sides of the building.

Building design processes currently employ outdoor wind comfort analyses and various numerical techniques have been employed around outdoor buildings within the pedestrian level and at the canopies to estimate the patterns of wind-flow, [10–12]. Advancements in modeling techniques enable the use of parameters of the building during the design stage like orientations of building and separation based on the patterns of wind flow in the respective area, these parameters in the respective area lead to a direct effect on the wind-flow patterns hence altering the surrounding wind environment. Some research has been conducted depending on outdoor investigations to create convenient wind movement around buildings. As an example Stathopoulos

[13] tested the criteria of all existing outdoor comfort like air, temperature, relative humidity affecting thermal comfort around various buildings, and wind speed. Blocken et al. [14] revealed a comprehensive analysis of PLW environment evaluations from 1960 onwards. Additionally, Some researchers emphasised on outdoor thermal comfort standards and wind assessments like Yang et al. [15] who suggested a way to set up a full comforts index. Stathopoulos et al. [16] suggested PLW comfort standards and debated a baseline method for the design of the buildings. Blocken et al. [17] presented some recommendations to the current PLW standards. The intensity of wind affects the environment of outdoor spaces of buildings in different aspects such as wind noise, ground-level wind acceleration, pedestrian comfort, and vegetation [18].

To investigate the behavior of wind flow, some of the methods that are used widely are the experiments of wind tunnel or field investigations, which are both time consuming and expensive. A breakthrough in wind engineering came with advancements in computational power especially computational fluid dynamics (CFD). Nowadays, this computer program (CFD) is a substitutional tool for research and for examining outdoor wind flow between the buildings. In wind engineering, CFD matched with a virtual wind tunnel proves flow physics across the building and has abilities to produce environmental flows. The examination of wind through an urban configuration in the lower part of the buildings [19] is vital in numerous wind environmental problems, including pedestrian comfort, air pollutant dispersion, and natural ventilation design [12, 20]. In their investigation of urban wind environments, a considerable number of studies have adopted CFD dynamics with the expansion of computing resources and grid-generation techniques [21, 22]. The CFD simulations accuracy depends on several aspects: representation of conditions and computational domains are necessary to get real time outcomes [23]. The wind flow in urban spaces is oftentimes influenced by the buildings due to the channeling, sheltering effects, and buffeting particularly in urban areas [24, 25]. Van Hooff and Blocken [26] Noticed that to obtain accurate results, it is important to construct a sensible representation of the surroundings in the CFD simulations, thus concluded that the change in air rate per hour in a building was extremely dependent on the shape of the buildings [27]. The CFD procedure in wind scientific studies was established by many global engineering associations through pioneers which led to development of the CFD applications [19, 28–30].

The main aim of this paper is to find a suitable method to assess the effect of airflow under hot dry climate conditions on different building configurations depending on wind conditions analysis at PLW. This is of importance because previous studies in Iraq have not fully determined the relationship between the urban configuration and wind flow at PLW, or the total of constructions allowed nearby a target model in a real urban area. The airflow around several buildings is considered more complex than that around isolated buildings which results in a recirculating airflow in the outdoor spaces across the building. Thus, the different wind behaviors may affect the occupants at the pedestrian level.

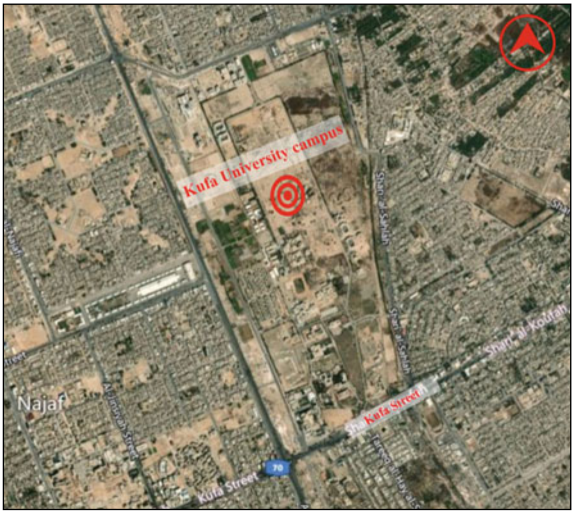


Fig. 1 The boundaries of Kufa University campus [31]

2 Research Methodology

The study discusses the current practices of wind flow and its impact to the building architectural design in the university campuses in Iraq, which is a country characterized by its dry and hot prevailing climate. The case study was executed in the Kufa University campus which is located in Najaf government, 100 miles south of Baghdad as shown in (Fig. 1). Consequently, the study presented the research method, which is a qualitative method and case study research by applying Autodesk© 2018 CFD simulation software. The study applied numerical simulation to investigate the different building configurations regarding wind flow behavior between the architectural mass models. The (k-ε) turbulence model is used in Autodesk CFD to analyze wind flow conditions during the simulation process.

The data have been taken from the meteorological organization in Al-Najaf which includes the records of weather data. The data collections and many scenarios in the case study were simulated to obtain the best results. At the end of the research, the investigations presented different outcomes for the case study by using special software such as Revit Software to form buildings models and after that using CFD simulation software to evaluate the input data.

3 Analysis Scope for Buildings Configurations by Using Autodesk CFD Software

Building models configurations were simulated by using Autodesk CFD simulation. Figure 2 shows all three scenarios, Configuration 1 includes six building blocks,

Fig. 2 The measurement positions at 1.75 m from the ground on the university campus

and configurations 2, and 3 consists of two and three building blocks, respectively. The number of building blocks and the blockage effect on wind circulation were investigated by representing wind velocity positions as measured points during the simulation process. The buildings models represent the university campus building blocks in the case study and they have been fabricated at full scale as shown (Fig. 2). However, the study conducts only wind flow parameter.

In 2019, the average annual rate of wind speed was approximately 2.1 m/s according to the Meteorological Organization in Najaf. The prevailing wind is North-West direction in order to determine the outdoor wind conditions to the simulation process. Hence, the wind direction and wind pressure are considered during the simulation process in the case study. The computational domain comprised the height and width in CFD simulation at full scale in the Kufa University campus modeling. The highest building in this model is 12 m. Based on the surface-grid extrusion technique, the grid of computational domain was generated as recommended by Van Hooff and Blocken [32], which enabled maximum control over the grid quality and its individual cells that comprised the tetrahedral cells (as shown in Fig. 3).

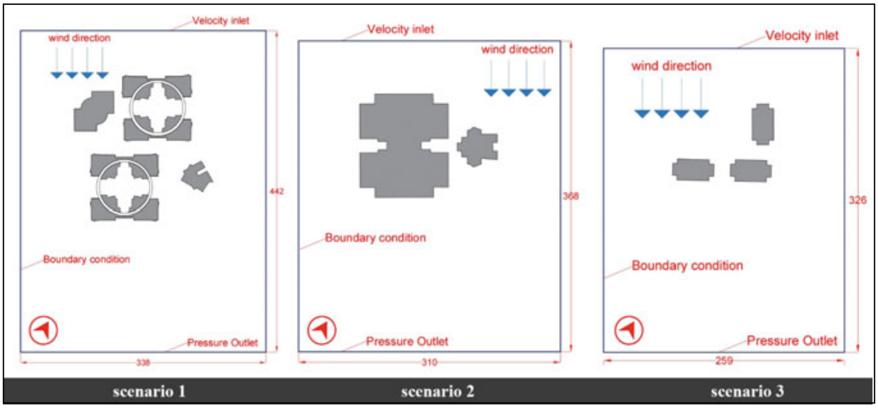


Fig. 3 The computational domain dimensions and boundary condition for three scenarios

Table 1 The standard of Land Beaufort that showing wind impact on humans at the pedestrian level [14, 34, 35]

Beaufort number	Description	Wind speed at 1.75 m height (m/s)	Effect
0	Calm	0.0–0.1	
1	Light air	0.2–1.0	No noticeable wind
2	Light breeze	1.1–2.3	Wind felt on face
3	Gentle breeze	2.4–3.8	Hair disturbed, clothing flaps, newspaper difficult to read
4	Moderate breeze	3.9–5.5	Raises dust and loose paper, hair disarranged
5	Fresh breeze	5.6–7.5	Force of wind felt on body, danger of stumbling when entering a windy zone

The study evaluated the outdoor thermal comfort at the PLW around the case study configurations using the Land Beaufort's standard. The range speed of 1 m/s–3.8 m is considered the most comfortable and acceptable speed for the building's occupants and outdoor thermal environment at the pedestrian level [33]. Table 1 presents the standard of Land Beaufort that showing wind impact on people at the pedestrian level [14, 34, 35]. Generally, the study shows various choices to get optimal results.

4 Results and Discussion

The simulation has been conducted for three different scenarios by Autodesk CFD simulation so as to define the outdoor thermal environment at the pedestrian level. In the Kufa University Campus, the buildings configuration is nearly integrated with the outdoor space in which the perimeter constructions shape the essential enclosure of the outdoor space in scenario 1. U-shaped building configurations are linked up by connecting the architectural elements to create spatial transition.

Figure 4 presents the wind velocity effects on outdoor buildings with eight points at PLW. The wind speed in P1, P2, P4, P6, and P8 is about 1 to 1.8 m/s at the pedestrian level height of 1.75 m, which is within a comfortable range. Apparently, some areas especially in P5 and P7 had a rather large calm zone which is lower than 0.8 m/s in the most time because it is situated under blockage effect and the prevailing wind can't smoothly exceed throughout outdoor spaces. Thus, the U-shaped configuration had a negative outdoor thermal comfort impact regarding natural ventilation which resulted in a poor wind environment and created a rather large calm zone in most places on the campus.

In respect of most measured points regarding closed-shaped buildings, the wind velocity in P1, P2, and P5 was 1.2 to 2,2 m/s which are considered quite agreeable as

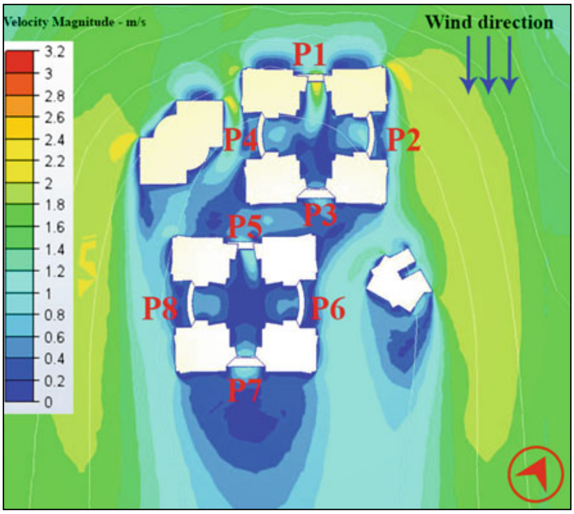


Fig. 4 The result of scenario 1 by using Autodesk CFD simulation

(Fig. 5). While the wind velocity in P3 and P4 was lower than 1 m/s. This is because the building shape has a massive block of convective air in outdoor spaces which cause a poor wind environment, and creates a rather large calm zone at the pedestrian level.

In contrast, the study results spotted that usage of L-shaped configuration enhanced the wind speed in most areas as shown in (Fig. 6). In most measured points, the wind speed exceeded from 1.6 to 2 m/s at the pedestrian height of 1.75m. These values are considered within a comfortable range according to Table 1. Thus,

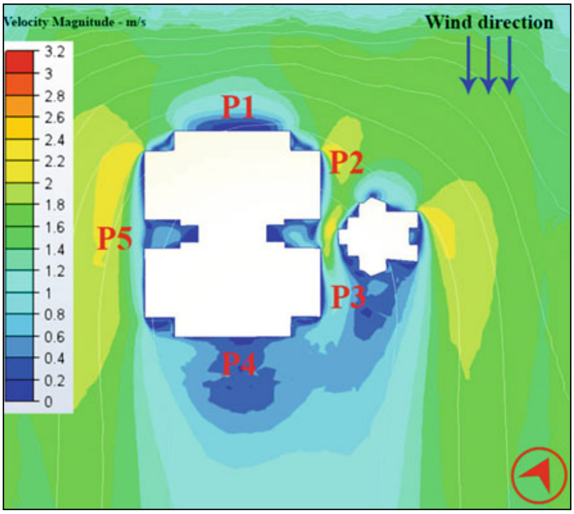


Fig. 5 The result of scenario 2 by using Autodesk CFD simulation

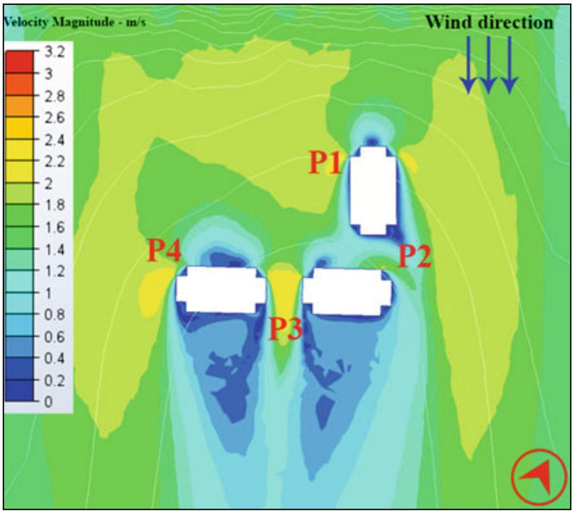


Fig. 6 The result of scenario 3 by using Autodesk CFD simulation

the wind velocity has been influenced by the shape of the building configuration to change the thermal comfort in outdoor spaces.

In general, the result of this study evaluated the outdoor thermal comfort at the PLW by using the Land Beaufort's standard [14, 34, 35] as shown in Table 1. The comparison was conducted by using U-shaped, closed-shaped, and L-shaped building configurations with the previous studies. Gomes et al. [8] study concluded that distribution of pressure wind could extremely alter with the shape of building and the flow patterns are unchangeable especially near to inner faces of buildings configurations which is correspondent with the results of buildings configuration applied in this study. In contrast, the flow patterns are obviously different especially near to inner faces of L-shaped configurations. Iqbal et al. [9] pointed out that U- and L-shaped configurations created higher outcomes due to the unlimited wind flow resulted by open outdoor spaces. However, the study results of this paper observed that usage of L-shaped configuration enhanced the wind speed in most areas and it is considered within a comfortable range according to Table 1. Regarding the square-shaped building configuration, this resulted in high wind speed area which is considered unstable [9]. The results of previous studies to some extent agree with the results of this study which were attributed to the building shape with a massive block of convective air in outdoor spaces that causes a prevailing poor wind environment, and create a rather large calm zone at the pedestrian level. Thus, the investigation results for the study could be more suitable for application in a hot dry climate.

5 Conclusion

This study carried out Autodesk CFD simulations of outdoor thermal comfort in the Kufa University Campus to determine the thermal behavior of wind flow around buildings with different shapes and configurations. The paper discussed three types of buildings configurations, namely U-shaped, L-shaped, and closed-shaped in order to present some concepts for generating optimal wind environment in PLW. The study concludes that the wind velocity was influenced by the shape of the building configuration which in turn affects the thermal comfort of outdoor spaces at PLW in the buildings of university campuses in Iraq. Consequently, it will give the architects comprehensive viewpoint to create sustainable architectural design for buildings in university campuses.

References

1. Khan AH, Herman SS, Jaafar MFZ (2020) The influence of wind effects on street canyon width at the pedestrian level in Iraq. In: Advances in civil engineering materials: selected articles from international conference on architecture and civil engineering. Springer Nature, p 39
2. Ali OH, JaAfar NH, Sulaiman MKAM, Khalaf OA (2019) Square as urban space in Iraq: the effectiveness of design attributes on social interaction. Int J Recent Technol Eng 7(6):305–310
3. Gomes MG, Rodrigues AM, Mendes P (2005) Experimental and numerical study of wind pressures on irregular-plan shapes. J Wind Eng Ind Aerodyn 93(10):741–756
4. Stathopoulos T, Zhou YS (1993) Numerical simulation of wind-induced pressures on buildings of various geometries. J Wind Eng Ind Aerodyn 46:419–430
5. Gu M (2009) Study on wind loads and responses of tall buildings and structures. In: The seventh Asia-pacific conference on wind engineering, pp 8–12
6. Cluni F, Gusella V, Spence SMJ, Bartoli G (2011) Wind action on regular and irregular tall buildings: higher order moment statistical analysis by HFFB and SMPSS measurements. J Wind Eng Ind Aerodyn 99(6–7):682–690
7. Li Y, Li QS, Chen F (2017) Wind tunnel study of wind-induced torques on L-shaped tall buildings. J Wind Eng Ind Aerodyn 167:41–50
8. Gomes MG, Rodrigues AM, Mendes P (2015) Wind effects on and around L- and U-shaped buildings. Buildings 1993:0–3
9. Iqbal QMZ, Chan ALS (2016) Pedestrian level wind environment assessment around group of high-rise cross-shaped buildings: effect of building shape, separation and orientation. Build Environ 101:45–63
10. Ng E (2009) Policies and technical guidelines for urban planning of high-density cities–air ventilation assessment (AVA) of Hong Kong. Build Environ 44(7):1478–1488
11. Blocken B, Stathopoulos T (2006) Editorial to virtual special issue: CFD simulation of pedestrian-level wind conditions around buildings: past achievements and prospects
12. Blocken B (2015) Computational fluid dynamics for urban physics: importance, scales, possibilities, limitations and ten tips and tricks towards accurate and reliable simulations. Build Environ 91:219–245. https://doi.org/10.1016/j.buildenv.2015.02.015
13. Stathopoulos T (2006) Pedestrian level winds and outdoor human comfort. J Wind Eng Ind Aerodyn 94(11):769–780
14. Blocken B, Carmeliet J (2004) Pedestrian wind environment around buildings: literature review and practical examples. J Therm Envel Build Sci 28(2):107–159
15. Yang F, Qian F, Lau SSY (2013) Urban form and density as indicators for summertime outdoor ventilation potential: a case study on high-rise housing in Shanghai. Build Environ 70:122–137

16. Stathopoulos T, Wu H, Bédard C (1992) Wind environment around buildings: a knowledge-based approach. J Wind Eng Ind Aerodyn 44(1–3):2377–2388
17. Blocken B, Roels S, Carmeliet J (2004) Modification of pedestrian wind comfort in the Silvertop Tower passages by an automatic control system. J Wind Eng Ind Aerodyn 92(10):849–873
18. Rajasekarababu KB, Vinayagamurthy G, Rajan SS (2019) Experimental and computational investigation of outdoor wind flow around a setback building. Build Simul 12(5):891–904
19. Blocken B, Stathopoulos T, Carmeliet J (2007) CFD simulation of the atmospheric boundary layer: wall function problems. Atmos Environ 41(2):238–252
20. Abd Razak A, Hagishima AYA, Awang Sa ZA, Zaki SA (2016) Progress in wind environment and outdoor air ventilation at pedestrian level in urban area. Appl Mech Mater 819:236–240
21. Tamura Y, Yoshie R (2016) Advanced environmental wind engineering. Springer
22. Ramponi R, Blocken B, Laura B, Janssen WD (2015) CFD simulation of outdoor ventilation of generic urban configurations with different urban densities and equal and unequal street widths. Build Environ 92:152–166
23. Tominaga Y et al (2008) AIJ guidelines for practical applications of CFD to pedestrian wind environment around buildings. J Wind Eng Ind Aerodyn 96(10–11):1749–1761
24. Asfour OS (2010) Prediction of wind environment in different grouping patterns of housing blocks. Energy Build 42(11):2061–2069
25. Mara TG, Ho TCE, Isyumov N (2012) Interference and influence of nearby buildings: a discussion of the design approach. Struct Congress 2012:798–808
26. Van Hooff T, Blocken B (2010) On the effect of wind direction and urban surroundings on natural ventilation of a large semi-enclosed stadium. Comput Fluids 39(7):1146–1155
27. Liu S et al (2018) Influence of surrounding buildings on wind flow around a building predicted by CFD simulations. Build Environ 140:1–10
28. Franke J, Hellsten A, Schlünzen H, Carissimo B (2007) Cost action 732-Best practice guideline for the CFD simulation of flows in the urban environment. Brussels, COST
29. Franke J, Hellsten A, Schlunzen KH, Carissimo B (2011) The COST 732 best practice guideline for CFD simulation of flows in the urban environment: a summary. Int J Environ Pollut 44(1–4):419–427
30. Tominaga Y, Stathopoulos T (2010) Numerical simulation of dispersion around an isolated cubic building: model evaluation of RANS and LES. Build Environ 45(10):2231–2239
31. https://zoom.earth, “Map.” https://zoom.earth/#view=32.033058,44.331837,18z
32. Van Hooff T, Blocken B (2010) Coupled urban wind flow and indoor natural ventilation modelling on a high-resolution grid: a case study for the Amsterdam ArenA stadium. Environ Model Softw 25(1):51–65
33. Guo W, Liu X, Yuan X (2015) A case study on optimization of building design based on CFD simulation technology of wind environment. https://doi.org/10.1016/j.proeng.2015.08.1060
34. Lawson TV (1975) The effect of wind on people in the vicinity of buildings
35. Janssen WD, Blocken B, van Hooff T (2013) Pedestrian wind comfort around buildings: comparison of wind comfort criteria based on whole-flow field data for a complex case study. Build Environ 59:547–562

Development of Corrosion Hazard Map in Peninsular Malaysia Using Inverse Distance Weighting (IDW) Interpolation

Nur Fadilah Adriyanshah, Nor Hazwani Nor Khalid, Fathoni Usman, Aina Shazwana Mohd Izhar, Jamry Abd Jawas, and Wan Nazri Wan Jalal

Abstract The combination of extreme weather conditions and economic activities has increased the number of corrosive agents in the air. This phenomenon will lead to rust formation in various assets, such as vehicles and steel properties. A Corrosion Hazard Map of Peninsular Malaysia was produced by considering parameters from climate and wet deposition information that influenced atmospheric corrosion: wetness, rainfall, chloride, nitrate, and sulphate. The inverse distance weighting interpolation technique was applied to generate the map. The study discovered that the corrosion rate at the southern and central part of Peninsular Malaysia is at level five, while the highland area is at level one. The Corrosion Hazard Map produced from this study would become as additional information that possibly will benefit various sectors such as metal industries, construction, land development, automotive coating technology, and others.

Keywords Atmospheric corrosion · Corrosion hazard map · Geographical information system · Corrosion rate · Inverse distance weighting

1 Introduction

Atmospheric corrosion which will cause structural deterioration has generally affected multiple sectors of the economy, such as transportation (vehicles), communication (electronics), and infrastructure (bridges, transmission towers, and roads). This

N. F. Adriyanshah (✉) · A. S. M. Izhar
College of Graduate Studies, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia
e-mail: nur.fadilah@uniten.edu.my

N. H. N. Khalid
Civil Engineering Department, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

F. Usman
Institute of Energy Infrastructure, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

J. A. Jawas · W. N. W. Jalal
Civil Solution Expertise, Jabatan Grid Solution Expertise, Grid Division, Tenaga Nasional Berhad, Kuala Lumpur, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_24

phenomenon happens when electrochemical processes occur, where the cathodic and anodic reactions occur as electrolyte film accumulates on the surface of a metal, thereby fostering it [1]. Atmospheric corrosion happens mainly in damp environments, where relative atmospheric humidity sees relative humidity equilibrium over another saturated solution found on the surface of the metal [2]. Furthermore, atmospheric corrosion only occurs with a thin aqueous layer formed on the surface material.

Past research has revealed that multiple environmental factors have simultaneously influenced the process of atmospheric corrosion, such as relative humidity, temperature, solar radiation, precipitation, wind, and pollutant [1–4]. Atmospheric corrosion is also greatly differing in the environments. Field test studies showed that industrial and coastal areas had the highest corrosion rate. In contrast, the urban and rural areas had a lower corrosion rate than industrial and coastal [3–7]. The high corrosion rate in the industrial and coastal areas is due to the high concentration of pollutants such as chloride (Cl), sulphate (SO_4), and nitrate (NO_3).

Nevertheless, climate conditions such as rainfall (rain), temperature, relative humidity, and time of wetness (TOW) also play an important role in determining corrosion rate. Hence, a corrosion hazard map was developed to identify the corrosion level of Peninsular Malaysia. The new corrosion hazard map developed from this study was also compared to the previous map developed for Peninsular Malaysia. Besides presenting the information graphically, the corrosion hazard map would be a piece of valuable information to sectors that are involved in metal, as additional information to properties developer for future development, a good guide to the automotive sector in improving their coating technology, as well as to the local authorities in planning and strategizing the land utilization.

2 Study Area

The study was conducted for the overall area of Peninsular Malaysia (Fig. 1). Located in Southeast Asia between Singapore and Thailand at latitudes 1–6.5° N and longitudes 100–104° E, Peninsular Malaysia has a total of 132,090 km^2 land area and accommodate 25.9 million of the population [8]. The land experienced two monsoon seasons: the Southwest monsoon in April to October and the Northwest monsoon in October to February, where both bring the rainy season to the country [9]. It has a tropical climate with high temperatures, high rainfall, dry spells, thunderstorms, strong winds, hot and humid all year. The relative humidity is high, with average monthly relative humidity ranging between 70 and 90%, and the typical temperature is 21–32 °C [9, 10]. The locations of tabulated 17 weather stations involved in data collection for this study were marked on the map. The weather stations' locations cover different geographical and land classifications, such as rural areas, urban areas, industrial zones, residential zones, highlands, coastal areas, and others.

Fig. 1 Map of Peninsular Malaysia

3 Methodology

The study was utilized data gathered from 17 weather stations owned by the Malaysian Meteorological Department (MMD). The data considered for the study were collected from the year 2010 until 2019. It consists of daily climate data (rainfall, humidity, and temperature) and wet deposition data or air pollution data (chloride, sulphate, nitrate, and pH). Those data were analyzed to identify the pattern of climate and pollution conditions of Peninsular Malaysia.

Headed to generate the Corrosion Hazard Map, the data was filtered to form parameters needed to generate the map, which are the time of wetness (TOW), rainfall, chloride (Cl), sulfate (SO_4), and nitrate (NO_3). The first step in producing the map was generating the inverse distance weighted (IDW) interpolation for each parameter using SAGA software. The IDW was preferred due to its capability to perform a good interpolation of point data with the basis that the data decrease as the distance increases. On the other hand, it also assumes that far apart objects are less reliable than close together objects [11]. The method was suitable for the study since all data was in point form. Next, the IDW of all parameters was transferred and overlayed into QGIS software. Equation 1 was applied in the raster calculator to generate the corrosion hazard map. Finally, the map was classified into five levels to represent the level of corrosion rate [12].

$$CR = f(NO_3,\ SO_4,\ Cl,\ Rain,\ TOW) \tag{1}$$

4 Analysis and Discussion

4.1 The Pattern of Climate and Pollution Conditions of Peninsular Malaysia in Ten Years Duration

The climate conditions between rainfall and temperature of Peninsular Malaysia over ten years, from 2010 to 2019, were illustrated by a graph in Fig. 2 It shows that Malaysia has experienced extreme weather conditions for the past ten years. According to MMD, the normal annual average rainfall precipitation for Peninsular

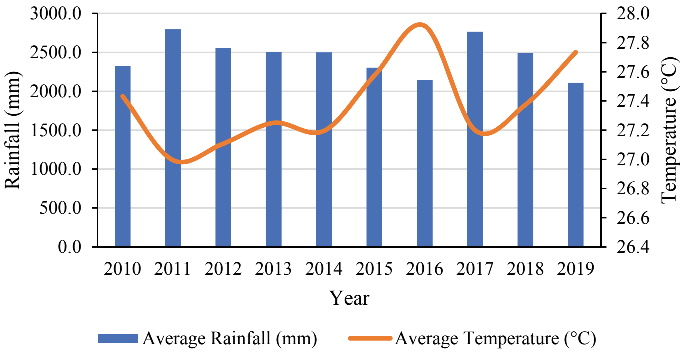


Fig. 2 Average temperature, rainfall, and humidity in Peninsular Malaysia

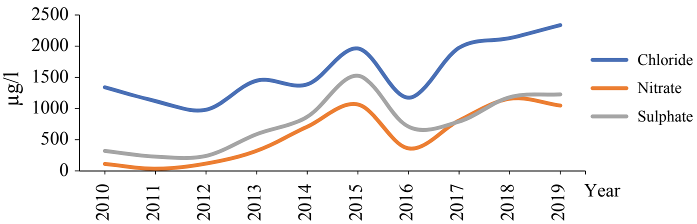


Fig. 3 Chloride, nitrate and sulphate pollution in Peninsular Malaysia

Malaysia is 2420 mm [13]. However, the analysis shows that the rainfall has gone beyond the normal precipitation for 2011, 2012, 2013, 2014, 2017 and 2018. One of the reasons was due to the global warming that worsened the rainfall precipitation, especially during the monsoon seasons. A study conducted by Kuok Ho Daniel Tang also found that global warming has affected the world and tremendously change the normal climate condition [14]. It is seen in the graph, whereas rainfall raises, temperatures fall.

The graph in Fig. 3 was plotted to present the status of pollution data. Over the ten-year duration, each parameter shows linear increment, except for 2015 and 2016. The value of Cl, $NO_{3,}$ and SO_4 was spiked in 2015 and slightly dropped in 2016. This is due to the Southeast Asian haze of 2015 caused by widespread illegal burning in Indonesia. This occurrence lasted for almost a month in Malaysia, Singapore, and Thailand, which deteriorated the country's air quality [15]. Because of the devastating haze in 2015, Southeast Asia has decided to strengthen the ASEAN Agreement on Transboundary Haze Pollution Act (THPA), which aims to tackle haze and air pollution at the core level [16]. As a result, a significant reduction in the value of Cl, $NO_{3,}$ and SO_4 dispersion was reduced in 2016. However, after 2016, the trend of air pollution is still increasing. This might be due to the increased usage of motorized transportation, uncontrol industrial emission, and other economic activities that contribute to air pollution [17].

4.2 Generation of the Corrosion Hazard Map

The IDW results for all parameters that involve in generating the corrosion hazard map are shown in Fig. 4a–e. The results were classified into five categories, where blue representing the lowest level, green for the second-lowest, yellow for middle level, orange for the second-highest level, and red for the highest level. Each level has a value presented in a range, and it is different for each parameter.

Figure 4a shows that the Cl concentration is high in the east coast area where Kuala Terengganu and Kota Bharu are located. The exact value for these areas is 753.38 and 786.17 µg/l, respectively. According to Huade Guan, this is due to the phenomenon when seawater is blown into the atmosphere by the wind [18]. The

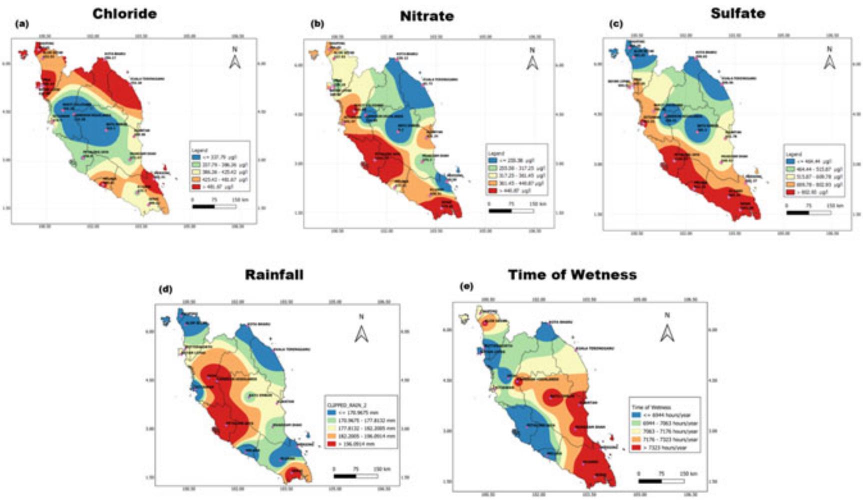


Fig. 4 The parameter of corrosion hazard map

lowest Cl concentration is at Cameron Highland. As expected, the highland area will have a very low Cl content. On the other hand, in Fig. 4b, it was found that the NO_3 level is high in areas that have a combination of an industrial and urban, such area marked as Petaling Jaya (on the west coast) and Senai (on the southern part). The highest level of NO_3 content for Peninsular Malaysia was recorded by Petaling Jaya, which was 1563.76 µg/l.

Based on Fig. 4c, the highest level of SO_4 was found in the southwest part of Peninsular Malaysia. The area marked as Petaling Jaya again recorded the highest level, which is 1196.91 µg/l for SO_4. The main source of sulfate is the burning of fossil fuels, such as thermal power plants, oil refineries, and industrial areas. Petaling Jaya was located in a well-developed zone and about 22 km from the capital city of Malaysia, Kuala Lumpur. The surrounding areas were well developed, complete with residential and industrial areas which indirectly contribute pollution to the atmosphere.

Rainfall is a special factor in the corrosion hazard map as rainfall acts as a washout factor that rinses pollutants from the metal object. Hence, the higher the amount of rainfall, the lower the rate of corrosion. Referring to Fig. 4d, areas that received the highest rainfall were in the southeast and the central part where the Senai and Petaling Jaya are located. The occurrence was caused by the North-East Monsoon wind that originates from China through the North Pacific Ocean. It brings more rainfall to the northwest and northeast part of Peninsular Malaysia.

TOW is defined as the time when the metallic surface is coated by liquid layers, causing corrosion to accumulate on the metal's surface [3]. The computed data on the TOW is very useful for the estimation of atmospheric corrosivity as the higher the TOW, the higher the corrosion rate of the location. From Fig. 4e, the TOW level is at the highest from Kuantan all the way to Senai with TOW of more than 7323 h/year and the lowest at Petaling Jaya and Melaka with TOW of fewer than 6944 h/year.

The corrosion hazard map generated from this study is shown in Fig. 5a, while the corrosion hazard map generated from the previous study is in Fig. 5b [12]. Both maps are divided into five levels, the same as the division for the parameters as explained earlier. From levels one to five, one is the lowest, and five is the highest level of corrosion rate. The data used for the previous study was from the year 1996 to 2005, while for this study was from the year 2010 to 2019. Comparison of these two maps discovered that the high corrosion level originated in the Petaling Jaya area has broadened in the southwest part. To be Specific, the changes result from substantial industrial growth in the southwest area during the last 10 years. Aside from that, there are changes in the highland area, where corrosion rate is at level one in the current map and level three in the prior map. The changes might be associated with an increase in rainfall precipitation in the highland area from 2010 to 2019. Meanwhile, corrosion rates in Alor Setar and Batu Embun remain the same for both present and prior maps.

To compare the level of corrosion rate and its parameters, the graph in Fig. 6 was plotted to summarize the result according to the weather station locations. For the area around Cameron Highland and Batu Embun, the corrosion rate is at level one. This cause by the combination of low pollution (level one) and a high level of TOW and rainfall (level three to five). Rainfall acts as a wash-out agent that rinses the pollutant. High rainfall will lead to a low corrosion rate level.

From the generated map (Fig. 5a), Muadzam Shah, Kuala Terengganu, and its surrounding area are classified under corrosion rate levels two and three. Even though the amount of Cl in these areas is high, the corrosion rate remains low due to the high level of rainfall. Corrosion rates at levels four and five have the same characteristic, where both have high levels of pollutants and rainfall levels ranging from one to five

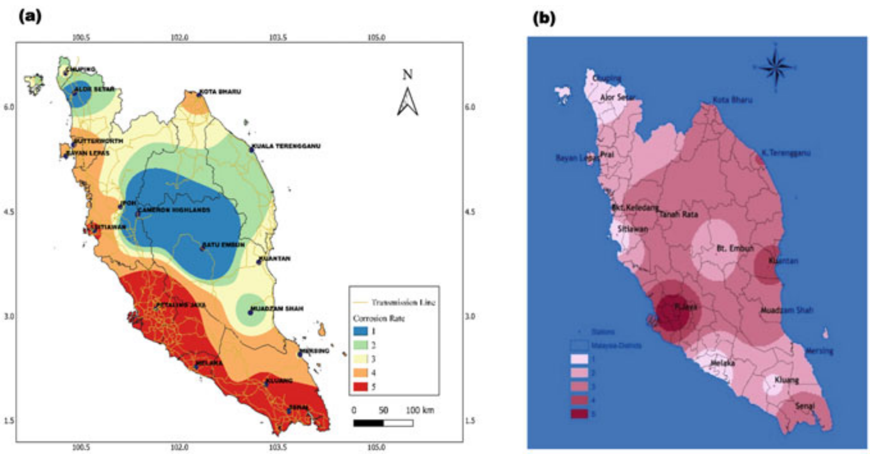


Fig. 5 **a** Corrosion hazard map of Peninsular Malaysia from this study using data from 2010 to 2019; **b** Corrosion hazard map of Peninsular Malaysia from a previous study using data from 1996 to 2005 [12]

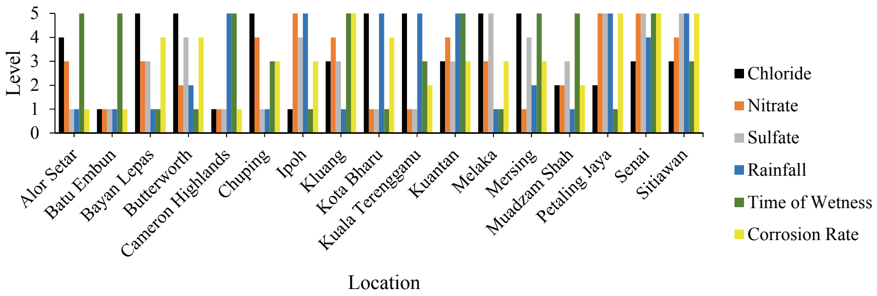


Fig. 6 Summary of parameter and corrosion rate

with a high level of TOW. The difference between level four and level five is the pollutant level, where for level four, the range of pollutant level is between level one to five, while for level 5, the range is between level three to five. The developed map shows that the Westcoast area (Sitiawan, Petaling Jaya, Melaka) and the Southern area (Kluang and Senai) have the highest corrosion rate compared to other places.

5 Conclusion

The corrosion hazard map was made by using the climate and wet deposition data from the past ten years. The data shows that the lowest corrosion rate has occurred at the highlands, while the highest corrosion rate was found at the west coast and southern region of Peninsular Malaysia. The map generated from this study serves as a useful guideline for sectors that are affected by corrosion, such as steel structure, shipping, automotive, and others (coating quality and thickness). Further study on verification work based on field tests will be conducted to validate the generated corrosion hazard map.

Acknowledgements The authors would like to acknowledge Tenaga Nasional Berhad (TNB) for funding the study.

References

1. Cai Y, Xu Y, Zhao Y, Ma X (2020) Atmospheric corrosion prediction: a review. Corros Rev 38:299–321
2. Zaki A (2006) Principles of corrosion engineering and corrosion control
3. Corvo F, González-Sánchez J, Castañeda A (2009) Atmospheric corrosion in tropical humid climates
4. Santana JJ, Cano V, Vasconcelos HC, Souto RM (2020) The influence of test-panel orientation and exposure angle on the corrosion rate of carbon steel. Mathematical modelling. Metals (Basel) 10:1–13

5. Nishikata A, Ichihara Y, Hayashi Y, Tsuru T (1997) Influence of electrolyte layer thickness and pH on the initial stage of the atmospheric corrosion of iron. J Electrochem Soc 144
6. Huang J, Meng X, Huang Y et al (2020) Atmospheric corrosion of carbon steels in tropical and subtropical climates in Southern China. Mater Corros 71:1400–1406
7. Díaz I, Cano H, Lopesino P et al (2018) Five-year atmospheric corrosion of Cu, Cr and Ni weathering steels in a wide range of environments. Corros Sci 141:146–157
8. Pour SH, Wahab AKA, Shahid S (2020) Physical-empirical models for prediction of seasonal rainfall extremes of Peninsular Malaysia. Atmos Res 233:104720
9. Mariam WMW, Husni S (2006) Influence of malaysian climate on the efficiency of polycrystalline solar cells. In: First international power and energy conference (PECon 2006) proceedings, pp 54–57
10. Vaghefi N, Nasir Shamsudin M, Makmom A, Bagheri M (2011) The economic impacts of climate change on the rice production in Malaysia. Int J Agric Res 6:67–74
11. Apaydin H, Kemal Sonmez F, Yildirim YE (2AD) Spatial interpolation for climate data. Spat Interpolat Clim Data
12. Fathoni U, Zakaria CM, Rohayu CO (2013) Development of corrosion risk map for Peninsular Malaysia using climatic and air pollution data. In: IOP Conference Series: Earth and Environmental Science, vol 16
13. Ahmad F, Ushiyama T, Sayama T (2017) Determination of Z-R relationship and inundation analysis for Kuantan River. Res Publ No 2:1–39
14. Tang KHD (2019) Climate change in Malaysia: trends, contributors, impacts, mitigation and adaptations. Sci Total Environ 650:1858–1871
15. Ahmed M, Guo X, Zhao XM (2016) Determination and analysis of trace metals and surfactant in air particulate matter during biomass burning haze episode in Malaysia. Atmos Environ 141:219–229
16. Heilmann D (2015) After Indonesia's ratification: the ASEAN agreement on transboundary haze pollution and its effectiveness as a regional environmental governance tool. J Curr Southeast Asian Aff 34:95–121
17. Afroz R, Hassan MN, Ibrahim NA (2003) Review of air pollution and health impacts in Malaysia. Environ Res 92:71–77
18. Guan H, Simmons CT, Kayaalp AS (2009) Factors influencing chloride deposition in a coastal hilly area and application to chloride deposition mapping. Hydrol Earth Syst Sci Discuss 6:5851–5880

Comparison of Corrosion Hazard Map in 10 Years Duration Using Air Pollution and Climate Data

Aina Shazwana Mohd Izhar, Nor Hazwani Nor Khalid, Fathoni Usman, and Nur Fadilah Adriyanshah

Abstract Atmospheric corrosion is a severe challenge for most common metals due to its effect on the service life and strength of structural materials, especially steel structures. In a tropical climate country such as Malaysia, high humidity, temperature, and rainfall precipitation contribute to the high time of wetness in the atmosphere. The wetness condition and air pollution will accelerate corrosion formation. Rapid economic growth and development of industrial areas have significantly increased the number of corrosion agents immerse in the atmosphere. Since corrosion is influenced by the atmosphere, the changes in corrosion level would be identified by comparing the corrosion hazard map for 10 years duration. The climate and air pollution data were analyzed using the inverse distance weighting (IDW) method to form a Corrosion Hazard Map of Peninsular Malaysia. Observation on the maps discovered that throughout the 10 years, southern and west coast areas have the highest corrosion level, while the lowest corrosion level occurred around the center part of Peninsular Malaysia. Information on the corrosion level will benefit highly dynamic industries in planning and decision-making, indirectly reducing losses.

Keywords Corrosion · Corrosion hazard map · Atmospheric corrosion · Metal corrosion · Geographical information system

1 Introduction

Corrosion is a natural process that commonly occurs on both protected and unprotected metals such as metals in the chemical reaction of the metal with oxygen and air [1]. It is also an unintentional and destructive deterioration process caused by

A. S. M. Izhar (✉) · N. F. Adriyanshah
College of Graduate Studies, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia
e-mail: aina.shazwana@uniten.edu.my

N. H. N. Khalid
Civil Engineering Department, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

F. Usman
Institute of Energy Infrastructure, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_25

the surrounding environment, reducing its efficiency. Corrosion prevention costs are approximately 5% of the gross domestic product for any country, implying a colossal economic cost to society [2]. Unfortunately for metals, almost all conditions could trigger some corrosive environment, as the material is quite sensitive to any atmospheric conditions that may vary substantially by area. There are coastal, industrial, highlands, urban and rural areas with a vast array of different levels of corrosion [3]. The coastal regions are usually very corrosive considering the exposure to salts ions such as Cl and the tendency to be exposed to the gust of wind, especially during the monsoon season [4]. Meanwhile, industrial areas are correlated with large-scale industrial processes and may contain Sulfate (SO_4), Chloride (Cl), Phosphate (PO_3), and Nitrate (NO_3) [5]. The highlands in Malaysia have high humidity, temperature, and pressure, which led to the formation of algae and may significantly impact corrosion by interrupting the corrosion protection layers [6].

Typically, rural areas are affected the least by corrosive pollutants as it is rarely exposed to air pollution. However, the urban areas are comparable with rural areas due to the existence of industrial activities in addition to pollutions from vehicles and industrial fuel emissions [7]. Corrosion of metals can be identified by different types and forms, including intergranular, uniform, pitting, and crevice corrosion, a typical failure in facilities. Rust is a common form of corrosion that occurs on iron and steel structural elements and especially reacts to aggressive environments, which hasten the corrosion rate, also known as atmospheric corrosion, which happens every single day. Metal corrosion in the atmosphere is affected mainly by the time of wetness (TOW), which relies on climatic parameters such as temperature and humidity corresponding to the international standard ISO 922 [8–10]. Moreover, dust and deposited substances such as Cl, SO_4, NO_3 materials also accelerate the corrosion phase.

For most common metals, atmospheric corrosion has been the most dominant form of corrosion. It is a severe challenge due to its effect on structural material service life and strength, especially on steel structures. In Malaysia, the atmospheric condition of TOW is always very high based on the high humidity, temperature, and rainfall precipitation [11]. As a result, the corrosion of metal materials becomes a significant challenge to various sectors, especially when it causes financial reduction [12]. The pollution level will consequently increase in tandem with economic growth as more industrial areas were developed. Therefore, this research was conducted to observe the changes of corrosion levels for Peninsular Malaysia within 10 years duration by developing the corrosion hazard maps. Knowledge of the corrosion level will benefit industries that are heavily involved in metal. The information also will aid them in better planning and decision-making, consequently, will lead to higher profit.

Fig. 1 Map of Peninsula Malaysia

2 Study Area

Malaysia is one of the tropical countries located in Southeast Asia situated near the equator. The weather is much warmer, humid, and it experiences heavy tropical rainfall all year long. The country is also exposed to extreme weather conditions, such as the monsoon season, bringing more rain and wind. This study covers the whole Peninsular Malaysia, which involves 11 states, as shown in Fig. 1.

3 Methodology

The parameters involved in developing the Corrosion Hazard Map were obtained from climate and wet deposited data [13]. The data was gathered from 17 weather stations in Peninsular Malaysia, owned by the Metrological Department of Malaysia (MET). The 17 stations are Alor Star, Batu Embun, Bayan Lepas, Prai, Cameron Highlands, Chuping, Bukit Keledang, Kluang, Kota Bharu, Kuala Terengganu, Kuantan, Melaka, Mersing, Muadzam Shah, Petaling Jaya, Senai, and Sitiawan.

The climate data from each station consisted of daily rainfall precipitation, temperature, and humidity, while the wet deposited or air pollution data comprised salt ions which are SO_4, NO_3, and Cl [14]. The parameters collected for over 10 years, from the year 2010 until 2019, were sorted manually before for geostatistical analysis using the QGIS 3.16 Hannover software. The sorted data was then imported into QGIS for further analysis. Next, the inverse distance weighting (IDW) method [15] was applied for all parameters. The IDW was to calculate the values of cells by combining linear-weighted data from the tabulated sampling points, the so-called interpolation process. The formula expressed in Eq. 1 was applied to the IDW for all parameters to generate the Corrosion Hazard Map each year. The map was reclassified into 5 levels to indicate the corrosion rate. The same procedure was repeated to produce 10 Corrosion Hazard Maps for the year 2010 until 2019.

$$\mathrm{CR} = \mathrm{f}\,(\mathrm{Cl},\ \mathrm{NO_3},\ \mathrm{SO_4},\ \mathrm{TOW},\ \mathrm{Rainfall}) \tag{1}$$

4 Discussion and Analysis

The corrosion hazard maps were generated annually for 10 years and were compared by year to observe and investigate the corrosion rate changes. There were five levels of corrosion rate, ranked from low to the high level indicated using numbers and differentiated by different colors. From the lowest to the highest level, level one was presented in blue, level two in green, level three in yellow, level four in orange, and level five in red.

Figure 2a–j shows the generated Corrosion Hazard Map each year. The maps show that the west coast and southern parts of Peninsular Malaysia have the highest corrosion level over the ten years. Besides being located in a coastal region, these two locations also feature massive ports, Port Klang in the west coast area and Port of Tanjung Pelepas in the southern coastal area. The port turns into a business attraction and makes Selangor (marked as Petaling Jaya on the map) and Johor (marked as Senai on the map) become strategic regions for industrial zones, subsequently contributing to the increment of deposited substances in the atmosphere.

Another state that recorded level five of corrosion is located in the northeast of Peninsular Malaysia, Kuala Terengganu, Terengganu. Terengganu is a state where the majority of the economic activities are tourism, agriculture, and fisheries. A high level of corrosion might be due to the location of this state, as it is facing the South China Sea. The main parameters that increase the corrosion level might be due to high Cl content. The main factor that caused the increase in the corrosion level might be high Cl content due to the frequent exposure to sea breeze on seasonal wind such as monsoon season.

The Midwest coastal part of Peninsular Malaysia (marked as Sitiawan on the map) has shown inconsistent corrosion levels between level three to level five since 2010. However, the area has consistently recorded corrosion at level five for three consecutive years, from 2016 to 2019. The level variation might be due to the inconsistent rainfall received in that area.

Regarding the lowest corrosion level, the middle part of Peninsula Malaysia (marked as Cameron Highlands on the map) was recorded at level one for the entire 10 years. This is definitely due to the existence of a highland area in the middle

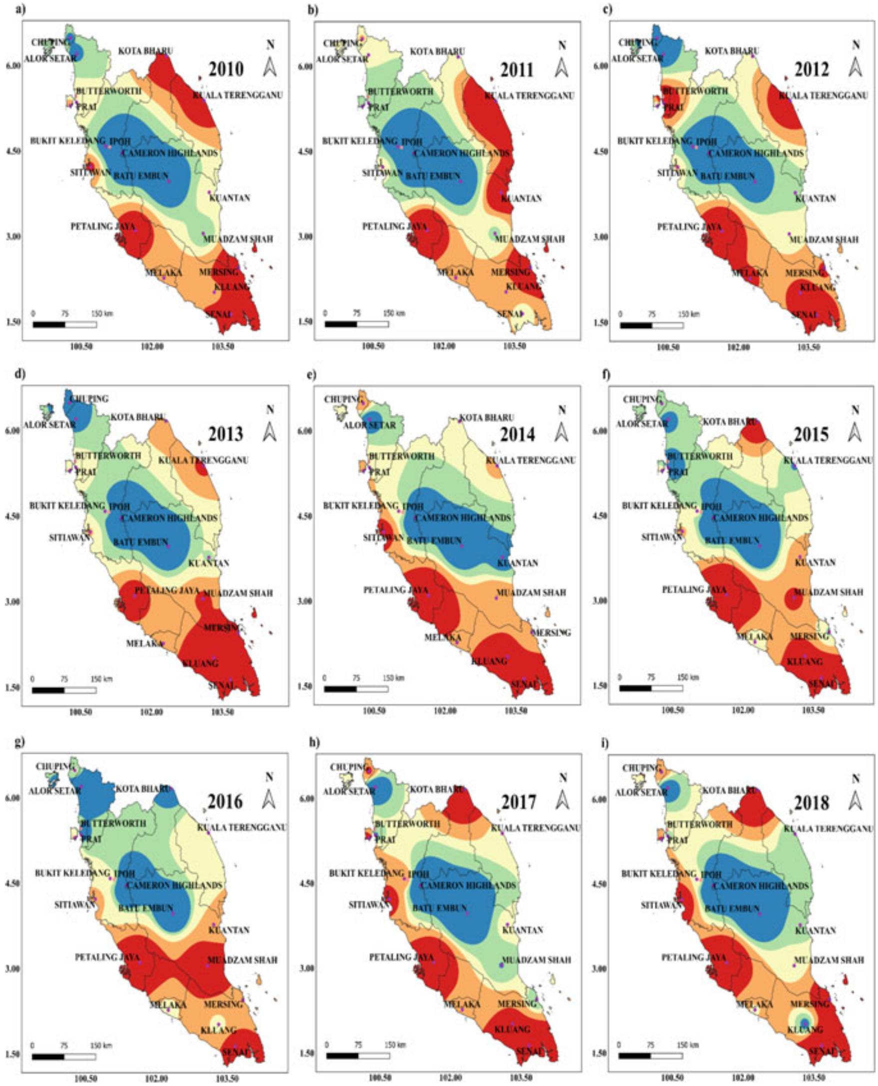


Fig. 2 Corrosion hazard map for 10 years period

of Peninsular Malaysia, named Titiwangsa Ranges. The effects of deficient human activity, geographical features, and environmental conditions of the rural area have always kept this middle part at a low corrosion level.

Observation on the generated Corrosion Hazard Map has been extended by observing the parameters involved in the analysis. Graphs in Fig. 3. were plotted from the values of the same parameters used to generate the map. The graphs show Cl, NO_3, SO_4, TOW, and rainfall throughout the 10 years duration. Referring to

Fig. 2 (continued)

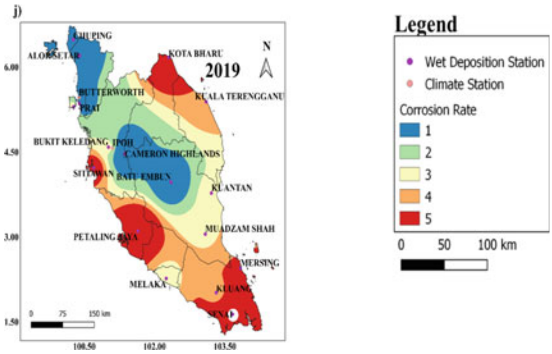


Fig. 3a–j Muadzam Shah has recorded the highest Cl content with the value of 4823 μg/l in 2016, alongside SO_4. This occurrence might be due to the industrial and agricultural activity in the oil palm plantation industry that is present in the area.

Kota Bharu and Kuala Terengganu have the highest Cl with 957 and 829 μg/l, respectively, from 2010 to 2012 due to their location near the coastal area, facing the South China Sea. Petaling Jaya has the highest NO_3 content in 2013 and 2014, with values of 1212 and 2330 μg/l, respectively. Petaling Jaya is mainly polluted with $NO_{3,}$ recorded as the highest pollutant in the area from 2017 to 2019, and it is the most commonly measured pollutant over the last decade.

Meanwhile, from 2010 to 2019, the lowest level was recorded in Cameron Highland in 2012, 92 μg/l in Cl content. The highland atmosphere is not affected by the Cl pollution since it is located far from the coastal area. It has a humid atmosphere compared to other regions, and the air pollution is also low. In addition, it is also because of the considerable high rainfall precipitation with 224 mm/year. Another observation of interest would be a high level of sulfate recorded from 2013 to 2018 in the industrial areas of Kluang, Petaling Jaya, and Prai, as Shown in Fig. 3d–i.

5 Conclusions

This study presents the comparison of corrosion hazard maps for a 10-years duration in Peninsular Malaysia. The study discovered the amount of Cl, SO_4, NO_3 that exists in the atmosphere had influenced the corrosion level during the period. The coastal area has recorded high corrosion levels primarily due to high Cl content, while industrial areas recorded high corrosion levels due to high SO_4 content. Consequently, rural and highland regions recorded the lowest corrosion rate. The corrosion hazard map would benefit and be helpful in various sectors such as metal industries, steel structures constructions, coating technology improvement, etc. It is not limited to support in decision making, planning, and maintaining processes, but it is also valuable for predicting the remaining life for metal.

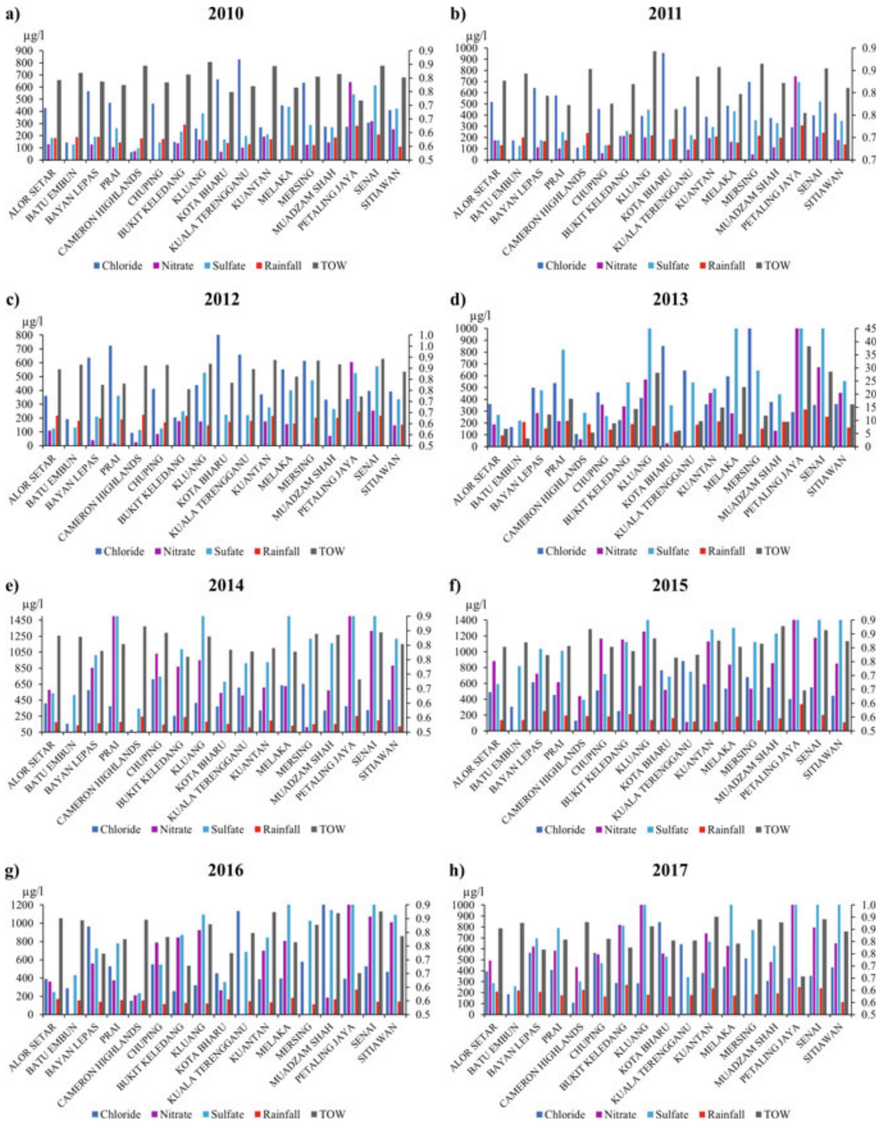


Fig. 3 Graph of composition of Cl, $NO_{3,}$ SO_4

Acknowledgements The authors would like to thank the Ministry of Higher Education (MOHE) for the research fund through the Fundamental Research Grant Scheme (FGRS), FRGS/1/2020/TK0/UNITEN/03/3.

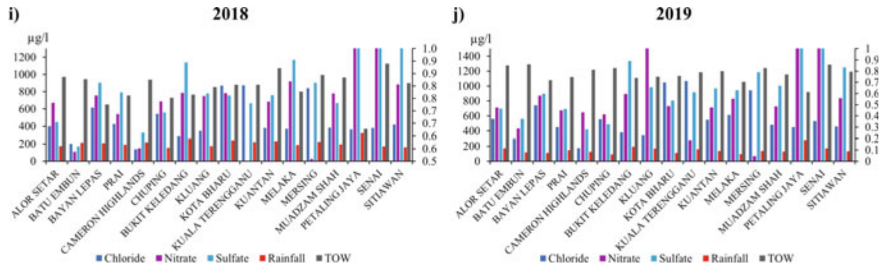


Fig. 3 (continued)

References

1. Georgiou N (2015) The risk of corrosion in structures due to carbonation using GIS tools. Cyprus University of Technology
2. Balan KP (2018) Chapter nine—Corrosion
3. Syed S (2014) Atmospheric corrosion of materials
4. Cerqueira DP, Portella KF, Portella GDOG, Cabussú M (2012) Deterioration rates of metal and concrete structures in coastal environment of the South and Northeast Brazil: case studies in the Pontal do Sul, PR, and Costa do Sauípe, Bahia. 42:384–396.https://doi.org/10.1016/j.proeng.2012.07.430
5. Zulfri M, Ali N, Husaini, et al (2021) The atmospheric corrosion of structural steel after exposure in the palm oil mill industry area of Aceh-Indonesia. 1–11. https://doi.org/10.22146/ijc.62769
6. Allwright H, Enshaei H (2016) Investigation of the impact of marine algae on the corrosion of mild steel. 6:28–37
7. Badea GE, Cret P, Lolea M, Setel A (2011) Studies of carbon steel corrosion in atmospheric conditions. 25–28
8. Castaño JG, Botero CA, Restrepo AH et al (2010) Atmospheric corrosion of carbon steel in Colombia. Corros Sci 52:216–223. https://doi.org/10.1016/j.corsci.2009.09.006
9. Usman F, Omar RC (2013) Development of corrosion risk map for Peninsular Malaysia using climatic and air pollution data My IOPscience Development of corrosion risk map for Peninsular Malaysia using climatic and air pollution data View the table of contents for this issue, or go. pp 1–6
10. Panchenko Y, Marshakov A, Igonin T et al (2019) Corrosivity of atmosphere toward structural metals and mapping the continental Russian territory Corrosivity of atmosphere toward structural metals and mapping the continental. Corros Eng Sci Technol. https://doi.org/10.1080/1478422X.2019.1594526
11. Cole I, Corrigan P, Hue NV (2012) Steel corrosion map of Vietnam
12. Cai Y, Xu Y, Zhao Y, Ma X (2020) Atmospheric corrosion prediction: a review. Corros Rev 38:299–321. https://doi.org/10.1515/corrrev-2019-0100
13. Tidblad J (2012) Atmospheric corrosion of metals in 2010 e 2039 and 2070 e 2099. Atmos Environ 55:1–6. https://doi.org/10.1016/j.atmosenv.2012.02.081
14. Pongsaksawad W, Klomjit P, Khamsuk P, et al (2021) Chloride distribution model and corrosion map of structural steels for tropical climate in Thailand. 787. https://doi.org/10.1016/j.scitotenv.2021.147465
15. Usman F, Khalid NH, Omar RC (2021) Atmospheric corrosion map for service life prediction of lattice steel tower using air pollution data and meteorological data

Drag Comparison for Coastal Species for Shoreline Protection

M. Mohd Rizuwan, W. A. Wan Mohd Shukri, and H. Tarik Mubarak

Abstract Drag coefficient commonly used to indicate the frictional resistance produce by the object in the fluent environment. This parameter has commonly used to examine the attenuation of wave towards the sea shore. However, lack of understanding on drag coefficients tree morphology density and arrangement and the minimum shoreline belt width. This study compares two coastal species and evaluates the potential or their stilt root system to dissipate the velocity. This study analyses the drag value on the cross sections of the stilt root model. The slice with maximum result of drag value will be used for the specimen preparation in velocity dissipation analysis. Both analyses were carried out using Computational Fluid Dynamics (CFD) by ANSYS Fluent program. The velocity magnitudes on the analysis path were extracted to evaluate the behaviour of the flow dissipation. Root zone of the stilt root model contributes higher dissipation on the velocity than the single stem. The highest drag value is observed at 0.5 m height of the stilt root model from ground. Higher density of forest stands contribute to higher dissipation of velocity. The study found that 135–203 m is the minimum shoreline belt width in where the result varies to diameter. This study could be applied for properly design the wave breaker for artificial protector for mangrove seedlings.

Keywords CFD · Shoreline · Belt width · Mangrove · DBH

1 Introduction

Mangroves grow in the upper intertidal zones of soft-sediment shores at tropical and subtropical latitudes [8]. This ecosystem is considered as one of the most productive natural ecosystems in the world and has a well-established ecological, economic and cultural [5]. These natural defences are attractive because they are cost-effective solutions that provide multiple benefits, contributing to community and ecological resilience [13]. This ecological system is capable of absorbing the hydrodynamic

M. M. Rizuwan (✉) · W. A. W. M. Shukri · H. T. Mubarak
Forestry and Environmental Division, Forest Research Institute Malaysia (FRIM), Selangor Darul Ehsan, 52109 Kepong, Malaysia
e-mail: rizuwan@frim.gov.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_26

turbulence and keeping the function and structure of the ecosystem [14] and attenuates the energy of tsunamis, cyclones and storm surge and by reducing velocity on channel floodplain [12]. This ecosystem could also create bed resistance by obstructing the flow of water through the forest [3] and is expected to be better than man-made structures to protect coastlines threatened by climate change [9].

The role of mangroves in reducing the sea-waves velocity has been scientifically proven. For instance, six-year-old mangrove forests of 1.5 km wide will attenuate open sea waves height from 1 to 0.05 m [7] approximately 70% of the near shore wave height [4]. Research indicates a belt of mangroves is capable of absorbing 30–40% of the total force of a tsunami [2] and up to 90% with a stand density of 3000 trees/ha [1].

A model estimates 50% declination in wave energy by going into 150 m of Rhizophora-dominated forest at high tide and 50% of energy reduction within 100 m belt width of Sonneratia forests [1] that range the total dissipation 200–300 m. This finding is similar to Mcivor et al. [11] that observed the total reduction of 35% over the first 80 m of forest which estimates 228.5 m for 100% of energy dissipation. Lee et al. [9] found that the wave energy of wind-generated surface waves is significantly attenuated by a fully grown mangrove forest by 20% per 100 m. Volvaiker et al. [15] estimate the reduction of wave height from mangrove forest was about 20% over 100 m and could reach up to 60% over 300 m width vegetation. Both Lee et al. [9] and Volvaiker et al. [15] estimate the 500 m to be total dissipation of wave energy. These studies summarize the total dissipation range 200–500 m which show the need of minimum shoreline belt width is 200 m to enable the coastal forest as natural shoreline protector.

2 Methods

The simulation of fluent was carried out using Computational Fluid Dynamics (CFD) by ANSYS Fluent program to determine the drag characteristic of stilt root system and evaluate velocity dissipation behaviour along in-line distribution specimen. The seawater properties are defined to be 1023.387 kg/m^3 density and 0.000959 kg/m s viscosity. The analysis applied water velocity in a mangrove stands, the average magnitude of the water velocity which is around 10 cm/s [8]. Shan et al. [12] also applied 10 cm/s velocity magnitude to the model, which satisfied Froude number similarity with real field scale of tidal flow and storm surge, 20–50 cm/s. Thus, this study uses 0.1 m/s as the inlet velocity for both analyses and multiplies the velocity ratio for extreme velocity conditions which is 0.5 m/s. The simulation is assumed to have significant result of drag value reduction of flow redistribution in the horizontal plane with the channel-average velocity [10].

The study site is at Lekir, Perak for stilt root model and the comparison of density and velocity dissipation from Pulau Klang, Selangor. The density of that temporary plot is 2125 with calculated tree spacing is 2.17 m. The selected stilt root models consists of two (2) models from both species (Fig. 1).

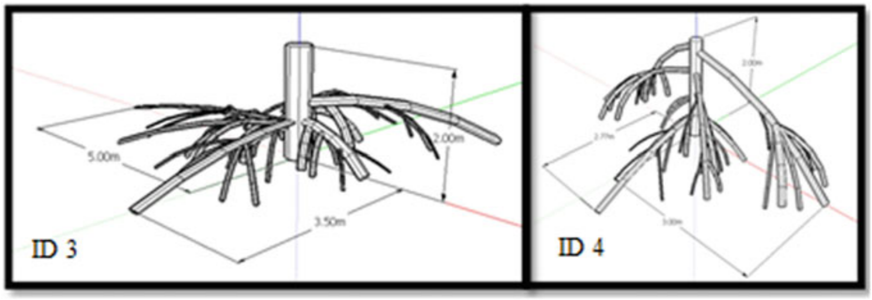


Fig. 1 Stilt root models

Height of the stilt root model that contributes to the maximum and minimum drag values was used to prepare the specimen in velocity dissipation analysis for in-line distribution. The velocity in line distribution of the model significantly diminished relative to the channel-average. A lower velocity in line with the trees would also reduce the force on the tree that will also change the drag force over the distance [10].

3 Results and Discussion

Simulation on the cross section slices of mangrove stilt root shows that the maximum drag value occurs at 0.5 m slice height from the ground level. These slices are the most influenced slices for reducing the velocity magnitude. Estimating the velocity dissipation based on the maximum drag value would provide the information of minimum shoreline belt width of coastal forest to enable the function of shoreline defence. Guannel et al. [4] mentioned that the effectiveness of dissipation is still mostly due to the frictional drag from dense trunks and roots induce in the water.

In this case, the drag values are compared to the cross section area of slices that are extracted from the stilt root models show and linear relationship with the cross section. However, value of R^2 which less than 0.8 indicates that the relationship is not strong enough to show the dependencies of both parameters (Fig. 2). This proves the flow velocity reduction is not only depending on mangrove aerial root system but also the coordination of the root [6].

From the simulation result of velocity behaviour, it is observed that the trend line shows the decrease of velocity from inlet to outlet of stilt root model in-line distribution for both analyses that referring to the maximum drag values. The estimation of shoreline belt width that refers to the maximum drag value is 27.00 and 40.60 m for Model 1 and Model 2 m consecutively. The velocity dissipation analyses for both models refer to minimum drag value shows the decrease of velocity for Model 1 while increase of velocity for Model 2. The estimation of shoreline belt width that refers to the minimum drag value is 116.6 and −17.95 m for Model 1 and Model

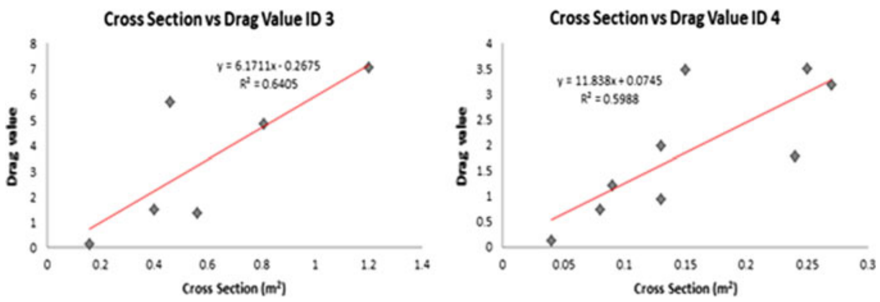


Fig. 2 Drag coefficients and cross section area of stilt root models

Table 1 Summary of dissipation length minimum shoreline belt

Density	DBH (cm)	Total drag value for Max. drag slice	Total drag value for Min. drag slice	Min. belt width (m)	Max. belt width (m)
Model 1	47.3	48.960	1.578	27.0	116.6
Model 2	23.7	10.323	0.911	40.6	−17.95

2 m consecutively (Table 1). In this case, the negative value of the shoreline belt width is considered irrelevant result. The results that show velocity dissipation prove to support Jusoh et al. [6] that estimates a 40% decrease in velocity magnitude of the initial flow. Designing the shoreline belt for the extreme event recommend by multiplying the value of belt width with the velocity ratio which in this study is 5.

Taking an example of the belt width is 27 and 40.6 m for Model 1 and Model 2 consecutively, the recommended minimum shoreline belt width is 135–203 m and this range would vary to DBH. The maximum shoreline width which refers to 116.6 is 583 m. In case of designing for coastal defence the minimum shoreline belt width are taken into account. The range of minimum shoreline belt width is 135 m–203 m obtained in this study almost similar to Alongi [1] and Mcivor et al. [11] that estimate 200 and 228.5 m consecutively to totally dissipate the wave energy. The estimation of maximum shoreline belt width, 583 m, obtained in this study also prove to Lee et al. [9] and Volvaiker et al. [15] that estimate the 500 m to be total dissipation of wave energy.

The negative value of maximum belt width indicates that the drag value is insufficient to dissipate the inlet velocity. In order to allow the root model for capable to dissipate the, the total drag value in the velocity dissipation analysis has to be higher than 1 which requires higher DBH of Model 2 of root system. Plotting the information of total drag value for minimum drag slice and would generate the equation $y = 0.0283x + 0.2418$. In this particular study the minimum DBH that would enable the root model to dissipate the velocity is 26.79 cm.

4 Conclusions

This study could conclude that distribution of drag value of stilt root model significantly influence the behavior of velocity dissipation of water that flows through the mangrove stand. The stilt root system at the coastal species is capable of reducing the sea water velocity that flows through shoreline tree stands. Higher drag value from the stilt root architecture provide better dissipation of velocity which is mainly caused by the root diameter, root density, arrangement and coordination of root structure and DBH. Therefore, this study strongly recommends the need of artificial protection such as wave breaker to support the establishment of mangrove seedlings. Information of minimum shoreline belt width spacing would be useful to forest managers to maintain the function of the shoreline ecosystem and planning for planting activities.

Acknowledgements This study was funded by Technical, Research and Development Committee (JTRD), Malaysia.

References

1. Alongi DM (2008) Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuar Coast Shelf Sci 76(1):1–13. https://doi.org/10.1016/j.ecss.2007.08.024
2. Coast Trust (2001) Mangrove forest—a potential disaster defense: threats and potentialities
3. Dasgupta S, Islam MS, Huq M, Khan ZH, Hasib MR (2019) Quantifying the protective capacity of mangroves from storm surges in coastal Bangladesh. PLoS ONE 14(3):1–14. https://doi.org/10.1371/journal.pone.0214079
4. Guannel G, Arkema K, Ruggiero P, Verutes G (2016) The power of three: coral reefs, seagrasses and mangroves protect coastal regions and increase their resilience. PLoS ONE 11(7):1–22. https://doi.org/10.1371/journal.pone.0158094
5. Jia M, Wang Z, Zhang Y, Mao D, Wang C (2018) Monitoring loss and recovery of mangrove forests during 42 years: the achievements of mangrove conservation in China. Int J Appl Earth Obs Geoinf 73(June):535–545. https://doi.org/10.1016/j.jag.2018.07.025
6. Jusoh MZM, Aziz NA, Inayatullah O (2016) Computational Fluid Dynamic simulation of flow velocities dissipation by mangrove roots structure. ARPN J Eng Appl Sci 11(16):9606–9612
7. Kathiresan K, Rajendran N (2005) Coastal mangrove forests mitigated tsunami. Estuar Coast Shelf Sci 65(3):601–606. https://doi.org/10.1016/j.ecss.2005.06.022
8. Le Minor M, Bartzke G, Zimmer M, Gillis L, Helfer V, Huhn K (2019) Numerical modelling of hydraulics and sediment dynamics around mangrove seedlings: implications for mangrove establishment and reforestation. Estuar, Coast Shelf Sci 217(April 2018):81–95. https://doi.org/10.1016/j.ecss.2018.10.019
9. Lee SY, Primavera JH, Dahdouh-Guebas F, Mckee K, Bosire JO, Cannicci S, Diele K, Fromard F, Koedam N, Marchand C, Mendelssohn I, Mukherjee N, Record S (2014) Ecological role and services of tropical mangrove ecosystems: a reassessment. Glob Ecol Biogeogr 23(7):726–743. https://doi.org/10.1111/geb.12155
10. Maza M, Adler K, Ramos D, Garcia AM, Nepf H (2017) Velocity and drag evolution from the leading edge of a model mangrove forest. J Geophys Res: Oceans 122(11):9144–9159. https://doi.org/10.1002/2017JC012945
11. Mcivor A, Möller I, Spencer T (2012) Reduction of wind and swell waves by mangroves. In: Natural coastal protection series

12. Shan Y, Liu C, Nepf H (2019) Comparison of drag and velocity in model mangrove forests with random and in-line tree distributions. J Hydrol 568(September 2018):735–746. https://doi.org/10.1016/j.jhydrol.2018.10.077
13. Shannon B, Cunniff E, Defense E (2016) Restoring natural defenses to help communities in coastal floodplains adapt to climate change 1–10
14. Takagi H (2018) Long-term design of mangrove landfills as an effective tide attenuator under relative sea-level rise. Sustainability (Switzerland) 10(4):1–15. https://doi.org/10.3390/su10041045
15. Volvaiker S, Vethamony P, Bhaskaran P, Pednekar P, Jishad M, James A (2018) Wave energy dissipation in the mangrove vegetation off Mumbai, India. Ocean Sci Discuss 1–18. https://doi.org/10.5194/os-2018-24

Indoor Radon Concentration for Buildings of Different Ages in Universiti Teknologi Malaysia

Ka Chong Ngui, Norelyza Hussein, Suhairul Hashim, Zainura Zainon Noor, Che Hafizan Che Haasan, and Nur Syamimi Zaidi

Abstract Radon is a naturally-occurring radioactive noble gas without colour, odour and taste to which humans are usually exposed. Prolonged exposure to radon gas is the second leading cause of lung cancer among smokers and non-smokers. Radon concentrations across Universiti Teknologi Malaysia (UTM) have remained a potential risk of health concerns because the old facilities on campus may contribute to the generation of radon gas. Therefore, this study aimed to compare radon levels between the old (Faculty of Science) and new (Faculty of Civil Engineering) buildings of UTM, and also to compare concentrations of radon between ground floor and second floor within the two types of buildings. The RAD-7 was selected as the equipment to measure radon concentrations at the laboratories, meeting rooms and lecturer rooms at the monitored buildings. The radon content of both the old and new buildings did not exceed the WHO reference level of 100 Bqm^{-3}. However, radon at the new building was present at higher concentrations than that at the old buildings on average due to energy efficient and airtight design of the new building.

Keywords Radon · Indoor air pollution · Air quality · Building ages

1 Introduction

Indoor air pollution refers to the deterioration of air quality inside and surrounding buildings and structures, specifically affecting the well-being and enjoyment of building occupants in a negative manner [1]. Radon has been recognized as one of the most common pollutants indoors by organizations such as Environmental

K. C. Ngui · N. Hussein (✉) · N. S. Zaidi
Faculty of Civil Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia
e-mail: norelyza@utm.my

S. Hashim
Faculty of Science, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

Z. Z. Noor · C. H. C. Haasan
Centre for Environmental Sustainability and Water Security (IPASA), Universiti Teknologi Malaysia, Johor Bahru, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_27

Protection Agency (EPA) and World Health Organization (WHO). Radon does not usually pose as a health concern in outdoor environments given its high dilution rates in the open air. Nevertheless, hazardous levels of radon can occur within indoor spaces such as basements, bedrooms, offices and houses, especially as it enters via openings in damaged pipes, floor-wall joints or grounds or via cracks in concrete floors and walls [2].

In recent years, radon gas has been classified as a common radioactive substance to which humans are usually exposed. Radon is a radioactive noble gas without colour, odour and taste that forms naturally in the atmosphere due to the decay of radium (Ra), thorium (Th) or uranium (U) in rocks, soil and groundwater [3]. Radon has no stable or nearly stable isotopes, but the most stable isotope is ^{222}Rn, with a half-life of 3.82 days, which comes from the breakdown of ^{226}Ra and ^{238}U [4]. The radon daughters such as polonium (Po) isotopes—^{218}Po, ^{214}Po and ^{210}Po release high doses of ionizing alpha rays. Following inhalation of radon gas, the particulate radon attaches to the lung surface and decays to emit highly ionizing alpha particles that interact with cells in the lung tissue, leading to damage of DNA [3]. Prolonged exposure to radon gas is the second root cause of lung cancer among smokers and non-smokers, and hence a significant health threat to public. Therefore, this study aimed to compare radon levels between the old and new buildings in UTM as the old facilities on campus may contribute to the generation of radon gas.

2 Methods

UTM was selected as study area to conduct the study UTM is a public Malaysian university located in Skudai (1° 33′ 33″ N 103° 38′ 29″ E), which is about 20 km north of the state capital—Johor Bahru. The Faculty of Science in UTM consists of Department of Mathematical Sciences, Chemistry, Physics and Biosciences. The Faculty of Civil Engineering has been established only for civil engineering students to attend lectures, tutorials and laboratory sessions. A cross-sectional comparative study was carried out inside the old and new buildings across the Faculty of Science and Faculty of Civil Engineering, respectively, at two different areas. The target older buildings of this study included 2 blocks of Physics Department, Faculty of Science which named as C21 and C22.

Meanwhile, the selected new building for this study is located at Faculty of Civil Engineering which known as M50 block. The Physics Department and M50 buildings have been open since 1988 and 2013, respectively. The radon testing sites were mainly based in the laboratories on ground floor, and meeting rooms and lecturer rooms on second floor in those 3 buildings. The duration of this study took around 10 days, from mid of August 2020 until end of August 2020.

The RAD7 radon detector from Durridge in the USA was used as the primary measurement device in this study due to its versatility and exclusive features. The RAD7 is a sophisticated sniffer that identifies the 3 min alpha radiations from ^{218}Po, without interruptions from other radiations. The radon measurements of the RAD7 typically range from 4 to 750,000 Bqm^{-3} [5]. In this study, the RAD-7 was set to measure the mean radon concentrations of each spot for 1.5 h, with the readings recorded in printed copies and the software simultaneously every 30 min.

3 Results and Discussion

Figure 1a shows the presentation of radon levels at C21 and C22, which are the targeted old buildings at UTM and Fig. 1b indicates the total radon levels at the new building. The concentrations of radon varied from one location to another, thus exhibiting distinct readings at different levels of the buildings. A clustered column graph is appropriate to determine the locations with the highest or lowest levels of radon gas. On average, radon levels of the nuclear laboratory on ground floor (C22) were slightly higher than those of the meeting room on second floor by 3.8 Bqm^{-3}. On the other hand, the laboratory contained 9.7 Bqm^{-3} less radon gas than the lecturer room on second floor at C21 in the Faculty of Science. Of all the old buildings included in this study as shown in Fig. 1a, the radon contents of these locations did not exceed the WHO reference level of 100 Bqm^{-3}. It has been considered that the building occupants were experiencing low radon exposures, particularly at the nuclear laboratory and meeting room within C22, with concentrations below 20 Bqm^{-3}.

As proven by the previous research [6], radon gas largely comes from the soil, thus explaining higher concentrations of radon in the nuclear laboratory on the ground floor than inside the meeting room on the second floor in the old buildings. However, a different scenario was observed inside the lecturer room on the second floor in C21, where its radon level was unexpectedly 22% higher than that in the nuclear laboratory. This unusual situation could be due to the presence of natural aerosols, particularly dust particles <0.45 μm, arising from the carpet in the monitored lecturer room [7]. The radon produced daughter nuclei called ^{218}Po and ^{214}Po, which then

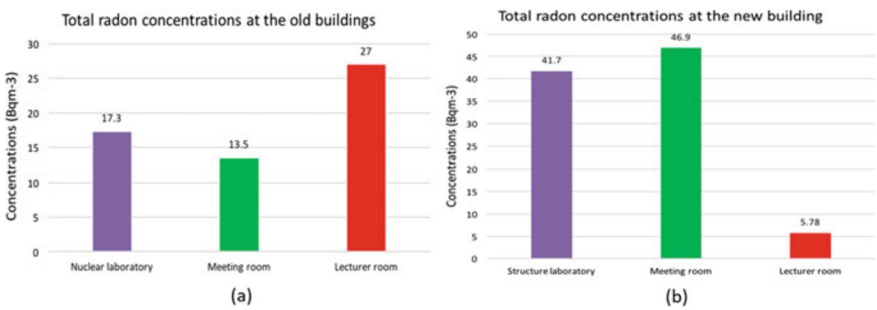


Fig. 1 **a** Overall levels of radon gas within the old buildings. **b** Overall levels of radon gas within the new building

attached to the dust particles of the uncleaned carpet and accumulated within the room.

Figure 1b indicates the total radon levels of the structure laboratory, meeting room and lecturer room within M50. By comparing the concentrations at these 3 locations, mitigation measures may be recommended to reduce exposures of those building occupants. It would be good to decrease the radon concentrations at M50 to lower levels as in C21 and C22. The overall radon levels at the structure laboratory on ground floor of M50 in Faculty of Civil Engineering were rather lower than those of the meeting room by 5.2 Bqm^{-3} but substantially higher than those of the lecturer room by 35.9 Bqm^{-3} as illustrated in Fig. 1b. Similarly, the radon contents of these locations inside the new building did not exceed the WHO reference radon levels of 100 Bqm^{-3}. Although indoor radon of the lecturer room does not pose a significant health threat to the building occupant, both the structure laboratory and meeting room demonstrate exceptionally higher readings despite newer construction materials and younger building age.

On the other hand, the structure laboratory on ground floor showed higher levels of radon than those inside the lecturer room, but lower levels than those of the meeting room at the new building. It has been anticipated that radon gas in regularly occupied space i.e. the lecturer room on second floor is often present at lower concentration. Nevertheless, the observation in the meeting room was contradictory to findings of the past research by Xie et al. [8], with 6% higher radon content than that of the structure laboratory. The slight increase in radon level of the meeting room was attributed to the formation of cracks and openings on its concrete walls through which radon gas seeps [2]. The lecturer room in M50 was found to have 75% less radon concentration than ground floor due to better appearance of material surfaces.

Figure 2a shows comparison of radon concentration between old and new buildings, meanwhile Fig. 2b illustrates the comparison of radon concentration between ground and second floor. Figure 2a illustrates whether the monitored old or new buildings of UTM contain higher radon levels. The indoor space of the new building would be assumed to have less emission of radon gas as compared to that of the old

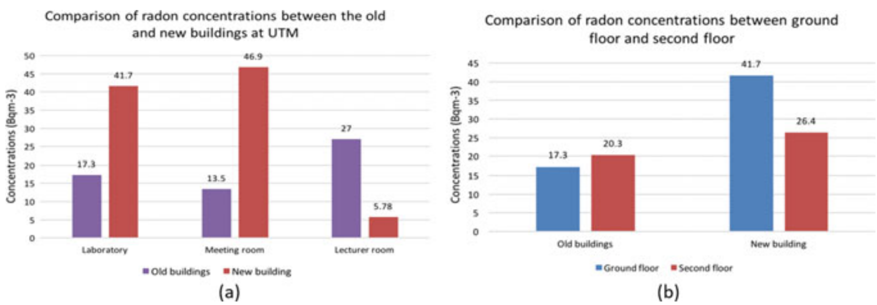


Fig. 2 **a** Differences of radon levels between new and old buildings. **b** Differences of radon level between ground and second floors

buildings. If the new building records higher readings, then physical conditions such as building materials and ventilation may be the contributing factors in this case.

Unexpectedly, radon levels of the laboratory and meeting room inside M50 as shown in Fig. 2a were substantially higher than those of C22 at UTM by 24.4 Bqm^{-3} and 33.4 Bqm^{-3}, respectively. Nevertheless, the lecturer room of M50 exhibited markedly lower radon content than that of C21, with a difference of 21.2 Bqm^{-3}. The new building had shown an average of 31.5 Bqm^{-3} indoor radon; whereas the mean concentrations of radon indoors within the old buildings were 19.3 Bqm^{-3}.

When comparing radon levels between the monitored old and new buildings at UTM, the new laboratory at M50 was shown to have 41.4% higher radon than the old laboratory at C22. Similarly, the new meeting room inside M50 manifested 55.2% more radon content than its counterpart at C22. However, the radon concentration inside the lecturer room at C21 was significantly greater than that at M50 by 65.2%. The observations coincided with findings of Koh [7] that the ventilation rate indoors plays a key role in variation of radon concentrations.

Contemporary and newly developed buildings are more energy efficient and airtight, thus preventing additional energy costs as well as the entry of air from outside if the indoor space is air conditioned. Nevertheless, the air exchange between outdoors and indoors is less likely to occur in modern buildings when air conditioners are turned off [7]. It thus justifies greater concentrations of radon within the indoor space of the new building in comparison with that of the old buildings at UTM. Conversely, the old buildings may have ventilation systems that allow the outside air to enter and leave efficiently after mixing with air indoors on a timely basis.

In comparison, radon levels on the ground floor of C22 were slightly lower than those of the second floor by 8% based on Fig. 2b. Meanwhile, the ground floor of M50 demonstrated 22.5% higher radon content than that of the second floor. In general, radon levels in both the old and new buildings were all below the WHO reference level (100 Bqm^{-3}). The health risks of students and staff from radon exposure in the monitored indoor environments were presumably low and insignificant. Although both types of the buildings demonstrated concentrations that were well within the limit value established by WHO, it was noteworthy to know that no threshold level has been set by any internationally recognisable organisation and even a small amount of radon may be associated with certain health issues, particularly lung cancer [9]. Therefore, it would be ideal to suggest some mitigation measures in this study to attain near-zero exposure to radon within interiors of the old and new buildings at UTM.

4 Conclusions

The radon concentrations inside the locations of the old buildings were all below 30 Bqm^{-3}; whereas those inside the new buildings were below 50 Bqm^{-3}. Hence, they did not exceed the WHO radon reference level of 100 Bqm^{-3}. At the old buildings, radon levels of the nuclear laboratory on ground floor were slightly higher than those of the meeting room on second floor. Nevertheless, the laboratory contained less radon gas than the lecturer room on second floor. This could be due to the presence of natural aerosols that attached to the dust particles of the uncleaned carpet and accumulated within the room. On contrary, the structure laboratory at the new building on ground floor had higher radon levels than those of the lecturer room but markedly lower readings than the meeting room on second floor. The slight increase in radon level of the meeting room was attributed to the formation of cracks and openings on its concrete walls through which radon gas seeps. The air exchange between outdoors and indoors is less likely to occur in modern buildings when air conditioners are turned off. Conversely, the old buildings may have ventilation systems that allow the outside air to enter and leave efficiently after mixing with air indoors on a timely basis.

Acknowledgements This work was supported/funded by the Ministry of Higher Education under Fundamental Research Grant Scheme (FRGS/1/2019/WAB05/UTM/02/7) and Universiti Teknologi Malaysia under UTMShine Signature Grant (Q.J130000.2451.07G91).

References

1. EPA (Environmental Protection Agency) (2020) Indoor air quality (IAQ). Retrieved from https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality. Accessed 7 May 2020
2. WHO (2008a) Indoor air pollution. Retrieved from https://www.who.int/ceh/capacity/Indoor_Air_Pollution.pdf?ua=1. Accessed 9 April 2020
3. Ahmad N, Khan IU, ur Rehman J, Nasir T (2017) An overview of radon concentration in Malaysia. J Radiat Res Appl Sci 10(4):327–330
4. Neidherr D, Audi G, Beck D, Blaum K, Böhm C, Breitenfeldt M, Herlert A (2009) Discovery of Rn 229 and the structure of the heaviest Rn and Ra isotopes from penning-trap mass measurements. Phys Rev Lett 102(11):112501
5. Mahdi KH, Al-Bakhat YM, Ishnayyin HG (2014) Indoor radon concentration in dwellings of Baghdad City and in dora refinery using Rad-7 detector. Adv Phys Theor Appl 35:58–63
6. WHO (2009) WHO handbook on indoor radon: a public health perspective. https://apps.who.int/iris/bitstream/handle/10665/44149/9789241547673_eng.pdf;jsessionid=B59EBC41EC31153131705D809C1F3DAA?sequence=1. Accessed 17 May 2020
7. Koh BKS (2019) Quantifying sources of indoor radon in office environments. Undergraduate thesis, National University of Singapore, Singapore
8. Xie D, Liao M, Kearfott KJ (2015) Influence of environmental factors on indoor radon concentration levels in the basement and ground floor of a building—a case study. Radiat Meas 82:52–58
9. Vimercati L, Fucilli F, Cavone D, De Maria L, Birtolo F, Ferri GM, Lovreglio P (2018) Radon levels in indoor environments of the university hospital in Bari-Apulia region southern Italy. Int J Environ Res Pub Health 15(4):694

Evaluating on Time Performance of Urban Bus Services in Southern States of Peninsular of Malaysia

Muhammad Fadhlullah Abu Bakar, Shuhairy Norhisham, Tengku Nor Azeruddin Tengku Nor Azman, Noorazizun Mohd Saad, Nor Najwa Irina Mohd Azlan, Nur Syafiqah Mohd Shkuri, Sotaro Yukawa, and Agusril Syamsir

Abstract Rapid urbanization had given a big impact on continuous development and major expansion of urban and population. As the number getting population getting increase caused the amount of traffic on the road. High number of traffic users in urban area were increase tremendously and caused a huge traffic impact particularly during weekday. Then, the bus services should be assessed on operation aspects on the punctuality which also known as on time performance of bus service in urban area. Therefore, this paper will present the study of evaluating the on-time performance of urban bus services in southern state Peninsular of Malaysia. The data of on time performance have been taken at main terminal at capital city of each states such as, Johor Bahru, Bandaraya Melaka and Seremban. Transit Capacity and Quality of Service Manual (TCRPM) has been stated as a specific guidelines and key indicators to determine and analysed the quality service of bus performance in selected area. There was one focused in this study specific areas would be focused on these studies namely on time performance factors attributes. The results shows that the total of departure in Johor Bahru, Bandaraya Melaka and Seremban were 652, 135 and 200 respectively. Meanwhile, percentage of on time departure daily in Johor Bahru, Bandaraya Melaka and Seremban were 66.17%, 56.15%, and 71.04% respectively.

M. F. A. Bakar · S. Norhisham (✉) · T. N. A. T. N. Azman · N. N. I. M. Azlan · A. Syamsir
College of Engineering, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia
e-mail: shuhairy@uniten.edu.my

N. M. Saad · A. Syamsir
College of Computing & Informatics, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

N. S. M. Shkuri
College of Energy Economics & Social Sciences, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

S. Norhisham · N. M. Saad · N. S. M. Shkuri
Institute of Energy Infrastructures (IEI), Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

S. Yukawa
Faculty of Economic, Osaka University of Commerce, 4-1-10 Mikuriya, Sakaemachi, Higashiosaka-shi, Osaka 577-8505, Japan

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_28

The average of percentage of on time departure daily for all routes were 71.04%. The mean of quality of service (QOS) of on time performance for Johor Bahru, Melaka and Seremban were classified as a QOS E, E and D respectively. Operators should monitor the on-time performance for bus services to ensure the passenger's trustworthiness and satisfaction towards bus services remined at the optimum level. Proper information should be installed at the bus terminal in order passenger and users always updated on routes information such as schedule, departure lane, and etc. The output of this studies can be used by operators and policy maker to improve bus services in other urban area as well.

Keywords Urban bus services · Quality of services · On time performance

1 Introduction

Rapid urbanization had given a big impact on continuous development and major expansion of urban and population. As the number getting population getting increase caused the amount of traffic on the road [4]. High number of traffic users in urban area were increase tremendously and caused a huge traffic impact particularly during weekday [2]. Thus, traffic congestion would occur daily especially during peak hour in the morning and late afternoon in order to cover a huge number of people movement [6]. According to World Bank, urban resident in this country specifically in Kuala Lumpur spend an average of 63 min in traffic congestion every day, resulting in productivity loss of RM 5.5 billion per year and Malaysia is ranked 95th (out of 100 cities) in Arcadis Sustainability Mobility Index [19]. Developing countries like Malaysia have urban areas that are densely populated and highly rely on public transportation [14]. Researchers in developing countries had addresses the significant concerns about improving public transportation especially bus services [12]. Public transport model Malaysia Smart City Framework Initiatives launched by Government of Malaysia through Ministry of Housing and Local Government in 2016 as developing smart mobility indicator to reducing traffic congestion, increasing first and last mile connectivity and accessibility and improving service quality and facility provision in public transportation [10]. Hence, it is important to identified service quality for bus services in this country especially in urban area [1].

Government has started to improve bus service in urban area by central the operation through handing the concession to specific operators as the operators can control the quality of services [2]. Globalization and technology had leads towards industrial revolution (IR) 4.0 which leads every angle of daily life get connected with internet of thing (IOT) [21]. Government should assist the key player in bus industries to developed and implemented new technology in bus services to improve service quality for bus performance namely actual time bus services [21], On time performance of bus services is also known as punctuality on services according to the schedule. Normally, one time departure will be considered if the bus departs between 0–5 min, as stated in the schedule [13]. Besides, one performance is defined as the number of on-time bus trips divided by all bus trips for the study systems [8]. Many people refused to take bus services as their primary transport option because the service is not available at the time when needed, especially during off peak hours [6]. Some researchers suggested that, small and medium cities have very little resources and less monitoring on the level of service as on time performance.

Southern Peninsular of Malaysia consists of three states namely Johor Bahru, Melaka and Negeri Sembilan. Each state plays a significant role for growth domestic product (GDP) of Malaysia. Some researcher had address that, certain transport policies in this country did not focused on the current issues and problem faced by bus operators as such the insufficient of implementing of public transport connection between interstate and local bus services [9]. A good service quality is defined as a development key for economic growth as quality not only contributes to give less environmental impact, but also supports the capacity of population growth of places [16, 17]. Currently, less than 25% of people in Malaysia are using public transport [11]. A study found that, passenger had emphasized the similar problem for almost a decade such as punctuality of bus drivers, lack of schedule information and there no continuous supervision by authorities [3, 15]. Authorities and government should improve bus services coordination, rectified the organization of bus services, improving terminal facility draw [5, 7] and specific services quality standard for bus service [9]. On the other note, passenger perception plays a significant impact on service quality for bus performance because passenger would be acts as customers demand the good services [20]. Thus, this paper will present the study of evaluating the on-time performance of urban bus services in Southern Peninsular of Malaysia.

2 Methodology

This section was explained all necessary procedure taken to evaluate the on-time performance of urban bus services in southern region Peninsular of Malaysia. Three state have been classified as a southern state in Peninsular of Malaysia namely Johor, Melaka and Negeri Sembilan. Capital city of each states have been selected in this study as such to evaluate the on-time performance of urban bus services, Johor Bahru (Johor), Bandaraya Melaka (Melaka) and Seremban (Negeri Sembilan). Main bus terminal for local bus services have been selected as a study area such as JB Sentral (Johor Bahru), Melaka Sentral (Bandaraya Melaka) and Terminal One (Seremban). These terminals were considered as a transportation hub terminal for local bus services and located at specifically at downtown for each city. The attribute data had been collected in January 2020.

There were 29 (JB Sentral), 15 (Melaka Sentral) and 15 (Terminal One) routes departing for various location in Johor Bahru, Melaka and Seremban respectively. All bus in these routes have used a several types of buses based on demand on designated routes. Bus operator were departed from JB Sentral were Causeway Link (111, 505, 7B, 5B, 10B, 777B, KSL, Senai Airport, BET3, MV2, CT1, JPO1, LM1, TD1, & P101), Maju Bus (208, 227, P102, & Larkin), City Bus (15, 39, 123, 133, 188, &

Table 1 Quality of Services (QOS) for on time performance percentage (Sources: Transit capacity and quality of service manual [18])

Service quality	A	B	C	D	E
On time performance (%)	95–100	90–94	80–89	70–79	<70

33) and S&S International (1, 2, 7, & Larkin/Skudai). Bus operator were departed from Melaka Sentral was Panorama Melaka (1A, 1B, 3, 6A, 8, 9A, 11, 14, 17, 21(A), 23, 24(A), 24 (B), 25 & 34). Meanwhile, bus operator was departed from Terminal One was MyBus (T10A, T10B, T30A, T30B, T31, T50, T52, T53, T54, T56, T60A, T60B, T70, F505 & F508). This study is only limited to local bus services which comprising bus services in Johor Bahru, Bandaraya Melaka and Seremban area only.

Transit Capacity and Quality of Service Manual (TCQSM) had selected as a standards and reference as to evaluate the service quality for bus performance in this study. One attributes would be focused on this study namely on time performance. On time performance percentage is aimed to determine the punctuality of bus departure based on existing schedule provided by operators. The data would be collected at departure lane at selected location each city. Punctuality of bus departure would be divided by four type namely on time, late departure, early departure and no show. The punctuality of departure time would determine the trustworthiness by passenger and users towards bus services. Passenger and users insist a short waiting time for bus services. In some cases, early departure also results no shows passenger as well. Table 1 shows the category of service quality for on time performance percentage.

3 Results

This section was explained the outcome of this study as to evaluate the quality of services of urban bus services in southern Peninsular of Malaysia. The results of on time performance attributes of bus services has been collected in the three capital cities of southern region of Peninsular of Malaysia namely Johor Bahru, Bandaraya Melaka and Seremban. On time performance results for all routes in Johor Bahru have been presented in Fig. 1. The total of 652 departure for 29 routes have been recorded at JB Sentral, Johor Bahru which 66.17% of it have depart according to the schedule. On the other hand, the results shows that only routes 10B and Larkin/Skudai have achieves of 91.43% and 92.86% of on time departure percentage respectively and classified as quality of services A. Most of the routes in Johor Bahru managed to depart less than 50% of on time departure daily.

On the other hand, on time performance results for all routes in Bandaraya Melaka have been presented in Fig. 2. The total of 135 of bus departure were recorded for 15 different destination at Melaka Sentral. The average of percentage of on time departure daily for all routes were 56.15%. The highest number of departures daily was routes 17 but these routes recorded only 30% of on time departure. The highest

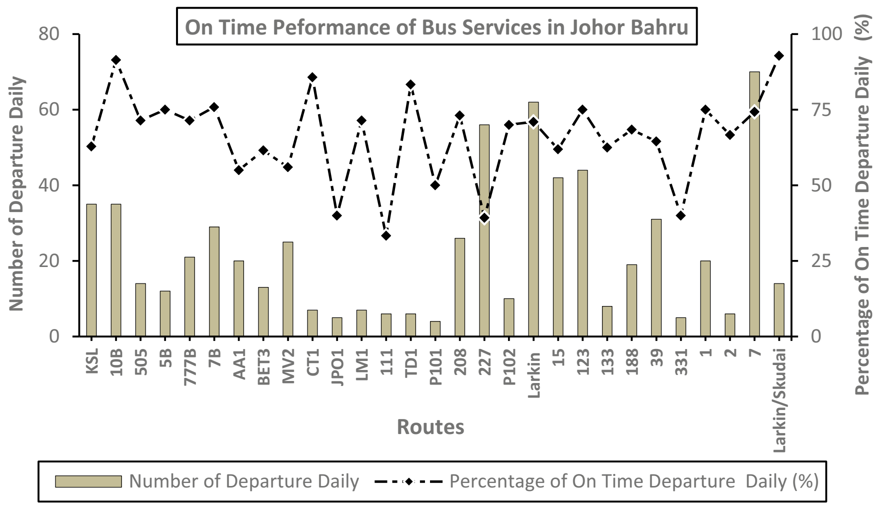


Fig. 1 On time performance of bus services in Johor Bahru, Johor

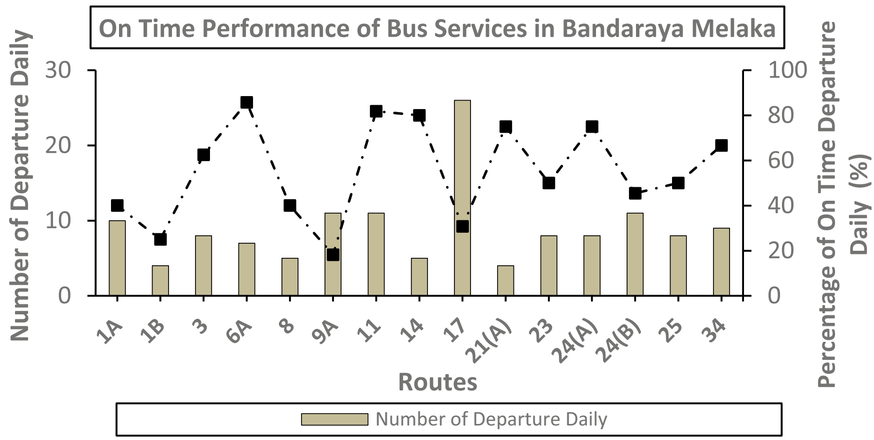


Fig. 2 On time performance of bus services in Bandaraya Melaka, Melaka

percentage of time departure daily was routes 6A which 85.17%. Based on the guidelines on previous section, it shows that only three routes were classified as quality of services (QOS) C namely routes 6A, 11 and 14 represented by 85.71%, 81.82% and 80.00% respectively.

Next, on time performance results for all routes in Seremban have been presented in Fig. 3. The total of 200 of bus departure were recorded for 15 different destination in at Terminal One. The average of percentage of on time departure daily for all routes were 71.04%. The highest number of departures daily was routes T10B, and these routes managed to depart with 88.00% of on time departure. Based on the

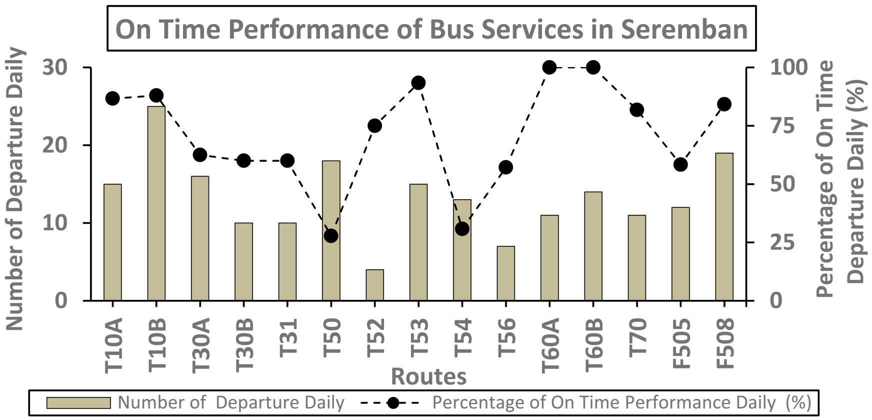


Fig. 3 On time performance of bus services in Seremban, Negeri Sembilan

Table 2 The mean of quality of service (QOS) of on time performance of urban bus services in Southern Peninsular of Malaysia

Location	Quality of Services (QOS)					Mean QOS
	A	B	C	D	E	
Johor Bahru	2	–	2	11	14	E
Melaka	–	–	3	2	10	E
Seremban	2	1	4	2	6	D

guidelines, it shows that only two routes were classified as quality of services (QOS) A namely routes T60A and T60B and both routes managed to record 100% of on time departure daily respectively.

As explained pervious section, on time performance is one of quality of service (QOS) attributes for bus services. Hence, Table 2 shows the mean of quality of service (QOS) of on time performance of urban bus services in Southern Peninsular of Malaysia. The mean of quality of service (QOS) of on time performance for Johor Bahru, Melaka and Seremban were classified as a QOS E, E and D respectively. Most of routes in these cities were classified as QOS E and only few routes were managed to be classified as QOS A & B in these studies. There are lot of factor that should be considered that should be identify by operators as such to improve the quality of services (QOS) of on time performance in these cities.

4 Conclusion

Peninsular of Malaysia. Southern States of Peninsular of Malaysia consist of Johor, Melaka and Negeri Sembilan. Capital city of each southern region of Peninsular of Malaysia have selected in this study. This study was conducted used by Transit Capacity and Quality of Service of Manual (TCPRM) as guidelines and reference to conduct this study. Capital city of each of southern state were selected in this study. All departure for every route were recorded in this study. The main terminal of each capital was selected namely JB Sentral (Johor Bahru), Melaka Sentral (Bandaraya Melaka) and Terminal One (Seremban). As explained in methodology section, this study was focusing the data collection of on time performance of urban bus services. The result shows that the total of 652 departure for 29 routes have been recorded at JB Sentral, Johor Bahru which 66.17% of it have depart according to the schedule. In Bandaraya Melaka, the total of 135 of bus departure were recorded for 15 different destination and the average of percentage of on time departure daily for all routes were 56.15%. The total of 200 of bus departure were recorded for 15 different destination in at Terminal One. The average of percentage of on time departure daily for all routes were 71.04%. The mean of quality of service (QOS) of on time performance for Johor Bahru, Melaka and Seremban were classified as a QOS E, E and D respectively. Operators should monitor the on-time performance for bus services to ensure the passenger's trustworthiness and satisfaction towards bus services remined at the optimum level. On the other hand, on time performance during peak hours should addressed by authority and operators as the delay always occurred due to high number of passenger and the traffic congestion on the journey to the designated destinations. Proper information should be installed at the bus terminal in order passenger and users always updated on routes information such as schedule, departure lane, and etc. The output of this studies can be used by operators and policy maker to improve bus services in other urban area as well. Authorities and government should monitor the effectiveness of performance bus services continuously as the quality of bus services considered as important issues risen in urban area since many years ago. This study should be repeated for both weekend and weekdays as the comparison data of bus services in weekend and weekday also can be made. Future studies in this topic by others researcher is highly recommended.

Acknowledgements Authors would like to thank Yayasan Canselor Universiti Tenaga Nasional for providing research grant for this study (202101012YCU) and Innovation Research Management Centre (IRMC), Universiti Tenaga Nasional.

References

1. Adebola O, Samuel O, Feyisola A, Eno O (2014) An Assessment of public transport security and safety: an examination of Lagos Bus Rapid Transit (BRT) Nigeria. J Civ Environ Res 6(4):105–117
2. Aziz A, Mohamad J (2013) Urban public transport in Penang: some public considerations. Conf East Asia Soc Transp Stud 9:1–9
3. Bekhet HA, Ivy YLL (2014) Highlighting energy policies and strategies for the residential sector in Malaysia. Int J Energy Econ Policy 4(3):448–456

4. Chow MF, Bakar MFA (2019) Environmental benefits of green roof to the sustainable urban development: a review. Lect Notes Civ Eng 9:1525–1541
5. Ensor JD (2004) Malaysia transport pricing strategies, measures and policies inception report. Malaysia Transport Research Group Massachusetts Institute of Technology
6. Esmailpour J, Aghabayk K, Vajari MA, Gruyter CD (2020) Importance—performance analysis (IPA) of bus services attributes: a case study in a developing country. Transp Res Part A 142(2020):129–150
7. Mazzulla G, Eboli L (2006) A service quality experimental measure for public transport Gabriella. Eur Trans 34:42–53
8. Liu Y, Chien S, Hu D, Wang N, Zhang R (2020) Developing an extenics-based for evaluting bus transit system. J Adv Transp 2020:1–13
9. Minhas A, Chatterjee A, Popli S (2020) Public perceptions: an important determinant of transport users' travel behaviour. J Stud Res Hum Geogr 14(2):177–196
10. Ministry of Housing and Local Council (2018) Final report of Malaysia smart cities framework
11. Ministry of Transport, Malaysia (2019) National transport policy 2019–2030, 29 March 2020. https://rb.gy/bo7avg
12. Ngadiman NI, Roslan NF, Rahman AF, Ahmad F, Daud MMS, Abdullah R (2020) Survey on quality of service (QoS) at Larkin Central Terminal (LCT) Johor Bahru. Int J Adv Trends Comp Sci Eng 9(1):229–232
13. Norhisham S, Bakar MFA, Tajri AA, Mohamed D, Yatuka S, Masjuki SA, Shukri NSM, Zaini N (2019) Statistical overview on quality bus service in Klang Valley. Int J Adv Sci Technol 28(10):370–380
14. Saleh SM, Sugiarto S, Anggraini R (2019) Analysis on public's response towards bus reform policy in Indonesia considering latent variable. Open Transp J 13:17–24
15. Soh KL, Chong CL, Wong WP, Hiew YH (2014) Proclivity of university students to use public bus transport service. Compr Res J Educ Gen Stud 2(2):24–34
16. Shukri MNS, Ponrahono Z, Sunoto NY, Ghazali WWNW (2020) Evaluation of Level of Service (LOS) on routes of smart bus in Kajang, Selangor. J Malays Inst Plan 18(3):241–250
17. Suman KH, Bolia NB, Tiwari G (2017) Comparing public bus transport service attributies in Delhi and Mumbai: policy implications for improving bus service in Delhi. Transp Policy 56(2017):63–74
18. Transit Capacity and Quality of Service Manual (TCQSM) (2013) TCRP Report 165 3rd edition, Transportation Research Board (3rd ed), Transit Cooperative Research Program, The Federal Transit Administration, Washington D. C.
19. World Bank (2018) The world bank annual report, 2018. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/30326 License: CC BY-NC-ND 3.0 IGO
20. Yaakub N, Napiah M (2011) Public transport: punctuality index for bus operation. World Acad Sci, Eng Technol 60:857–862
21. Zhang S, Yuan Z, Cao Z (2017) A frequency-based assignment model under day-to-day information evolution of oversaturated condition on a feeder bus. Information 8(19):1–19

Assessing the Passenger Load of Urban Bus Services in Southern States Peninsular of Malaysia

Muhammad Fadhlullah Abu Bakar, Shuhairy Norhisham, Muhammad Izzat Azhar Khebir, Noorazizun Mohd Saad, Nor Najwa Irina Mohd Azlan, Nur Syafiqah Mohd Shkuri, Sotaro Yukawa, and Agusril Syamsir

Abstract Urbanization process represents the increase in the proportion people living in towns and cities as a results of people movement from rural areas to urban areas. As the growing population in urban area increase tremendously and the high amount of traffic volume on the road would cause a huge traffic congestion in city area as well as suburb area. Moreover, the bus services should be assessed on operation aspects on the number of passengers had been used bus service recently and expectation of passenger and users towards bus services. Therefore, this paper will present the study of assessing the passenger load of urban bus services in southern state Peninsular of Malaysia. Passenger load data have been taken at main terminal at capital city of each states such as, Johor Bahru, Bandaraya Melaka and Seremban. Transit Capacity and Quality of Service Manual (TCRPM) has been stated as a specific guidelines and key indicators to determine and analyzed the quality service of bus performance in selected area. There was one focused in this study specific areas would be focused on these studies namely passenger load factors attributes. The results show that mean of quality of service (QOS) of on time performance for Johor Bahru, Melaka and Seremban were classified as a QOS B, A and A respectively. Most of the routes in these cities were classified as QOS A, two routes were

M. F. A. Bakar · S. Norhisham (✉) · M. I. A. Khebir · N. N. I. M. Azlan · A. Syamsir
College of Engineering, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia
e-mail: shuhairy@uniten.edu.my

N. M. Saad · A. Syamsir
College of Computing & Informatics, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

N. S. M. Shkuri
College of Energy Economics & Social Sciences, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

S. Norhisham · N. M. Saad · N. S. M. Shkuri
Institute of Energy Infrastructures (IEI), Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia

S. Yukawa
Faculty of Economic, Osaka University of Commerce, 4-1-10 Mikuriya, Sakaemachi, Higashiosaka-shi, Osaka 577-8505, Japan

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_29

classified as QOS B and two routes were classified as QOS C. Some improvement on these three attributes should be made to increase the quality of service. The outcome of these studies should be used as an indication by operators to measure their bus services. Since this city is capital city in southern state in Malaysia, authorities and government can used this outcome as their inputs to measure the effectiveness of public transportation in urban area.

Keywords Urban bus services · Quality of Services · Passenger load

1 Introduction

Urbanization process represents the increase in the proportion people living in towns and cities as a results of people movement from rural areas to urban areas. This process also called as a process that leads to the growth of cities due to industrialization and economic development, that leads to urban specific changes in specifically labor division and human behaviors [11]. Demand of daily movement from one place to another also getting increase as part of an economic development purpose [5, 6]. As the growing population in urban area increase tremendously and the high amount of traffic volume on the road would cause a huge traffic congestion in city area as well as suburb area [4]. Thus, traffic congestion would occur daily especially during peak hour in the morning and late afternoon in order to cover a huge number of people movement [8]. Report released by Ministry Housing and Local Council reported that public transport modal share in Malaysia in 2017 is only 20%, compared to 66% recorded in Singapore, while 82% of Malaysia households owns a car. Currently in Malaysia, there more than 28 billion vehicles on the road [10]. With the recent initiative launched by Government of Malaysia on implementing Malaysia Smart City Framework public transportation mode in Malaysia would be expected to increase to 40% by 2030 [9].

Passenger load is an attribute that refer to passengers who have the opportunities to get a seat when riding the bus and to identify the overall crowding level on the vehicle [15, 17]. Passenger load analysis is suggested to be conducted during peak hours, non-peak hours, weekdays and weekends to analyze the number of passenger load, as well as the service provided by operators [14, 17]. Previous studies suggested that operators should try to utilize the maximum bus capacity while taking into account the constraints in number of seats and available buses [2]. Several researchers addressed that modern public transportation system model should be developed including passenger demands, bus capacity and transportation network. The capacity demand should be continuously assessed as demand reached the maximum, especially during peak hours [21, 23]. Therefore, operators are highly recommended to increase the frequency number because lack of bus capacity will increase passenger waiting time at stations and bus stops [12, 24]. Service provider to identify and addressed all customer perceptions and their demand according and tried their best to rectify all weakness accordingly [3, 20]. Operators should also implement level of services (LOS) assessment plays as a standard measurement for determine an acceptable level of quality of services for each attribute [17, 22]. Authority and operators should establish an attractive, safe and highly sophisticated public bus service [13].

Southern Peninsular of Malaysia consists of three states namely Johor Bahru, Melaka and Negeri Sembilan. Each state plays a significant role for economic growth in Malaysia. Instead of using private vehicles, public transportation should be a connector between people from one point to another point. Bus services should be assessed regularly on its operation aspects provided by operators and the understanding on passenger perceptions and expectation of passenger and users towards bus services [14]. Passenger and user in this country facing a continuous problem daily such as limited of area covered by bus services and excess number of passengers during peak hours in weekdays (passenger load) in urban area [1]. Generally, customers would express good perception if the service given reach their expectation and reached a minimum acceptable standard of service [13, 14]. Previous studies also justified that overall satisfaction and behavioral intentions would an important factor to analysis service quality of bus services on qualitative aspects [16, 19]. A better understanding of bus services is required as to rectify the quality of services and the increasing of passenger and user used bus services [8]. Quantitative measurement on service quality would include hours of services, service frequency passenger load factors and on time performance, as this attribute should be measured according to transportation engineering knowledge [7]. Therefore, this paper will present the study of assessing the passenger load of urban bus services in southern state Peninsular of Malaysia.

2 Methodology

In this section, the method and procedure would be explained in detail as such to assessing the passenger load of urban bus services in southern region in Peninsular of Malaysia. There are three stated have been identified as southern region in Peninsular of Malaysia such as Johor, Melaka and Negeri Sembilan. Capital city of each state have been selected in this study as these cities were considered as the most urbanized and center of administration and economy in these states. Capital states for each state comprises of Johor Bahru (Johor), Bandaraya Melaka (Melaka) and Seremban (Negeri Sembilan). Main bus terminal for local bus services have been selected as a study area such as JB Sentral (Johor Bahru), Melaka Sentral (Bandaraya Melaka) and Terminal One (Seremban). These terminals were considered as a transportation hub terminal for local bus services and located at specifically at downtown for each city. The attribute data had been collected in January 2020.

There were 29 (JB Sentral), 15 (Melaka Sentral) and 15 (Terminal One) routes departing for various location in Johor Bahru, Melaka and Seremban respectively. All bus in these routes have used a several types of buses based on demand on designated routes. Bus operator were departed from JB Sentral were Causeway Link (111, 505,

Table 1 Quality of Services (QOS) for passenger load factor (Sources: Transit capacity and quality of service manual [18])

Quality of service	A	B	C	D	E	F
Passenger load (passenger/seat)	0.00–0.50	0.51–0.75	0.76–1.00	1.01–1.25	1.26–1.50	>1.50

7B, 5B, 10B, 777B, KSL, Senai Airport, BET3, MV2, CT1, JPO1, LM1, TD1, & P101), Maju Bus (208, 227, P102, & Larkin), City Bus (15, 39, 123, 133, 188, & 33) and S&S International (1, 2, 7, & Larkin/Skudai). Bus operator were departed from Melaka Sentral was Panorama Melaka (1A, 1B, 3, 6A, 8, 9A, 11, 14, 17, 21(A), 23, 24(A), 24 (B), 25 & 34). Meanwhile, bus operator was departed from Terminal One was MyBus (T10A, T10B, T30A, T30B, T31, T50, T52, T53, T54, T56, T60A, T60B, T70, F505 & F508). This study is only limited to local bus services which comprising bus services in Johor Bahru, Bandaraya Melaka and Seremban area only.

Transit Capacity and Quality of Service Manual (TCQSM) had selected as a standards and reference as to assessing the service quality passenger load in this study. Passenger load factor would be focused on this study. The data of passenger would be taken for roundtrip. Hence, five different routes would be chosen in this study as it should represent different destination in Johor Bahru, Melaka and Seremban. Data of passenger load were collected on weekdays only as the number of passengers on weekday were expected to be higher than weekends. The average of passenger for the roundtrip journey would be calculated divided by total of seat provided in the bus as shown in Eq. 1 and the number of seats provided might be different based type and bus model used by operators. As per journey, the average of passenger load will be counted. The passenger load would be calculated for both return journey. Lastly, the quality of services (QOS) for passenger load attributes will be classified to determined level of quality of service in this study. The quality of service (QOS) would be determined based on the passenger load for each route. Table 1 shows quality of services based on load passenger factor.

$$\text{Passenger Load} = \text{Load Factors} = \frac{\text{No.of Passernger}}{\text{No.of seats provided}} \tag{1}$$

3 Results

In this section, the results of the passenger load of bus services in southern region of Peninsular of Malaysia namely Johor Bahru, Bandaraya Melaka and Seremban would be explained in detail. The total of five routes have been selected as such to determine the passenger load factors for bus services in Johor Bahru. Figure 1 shows the summarization of passenger load factors for Johor Bahru. The result shows that the highest number of passengers on these routes was routes 10B which recorded 82

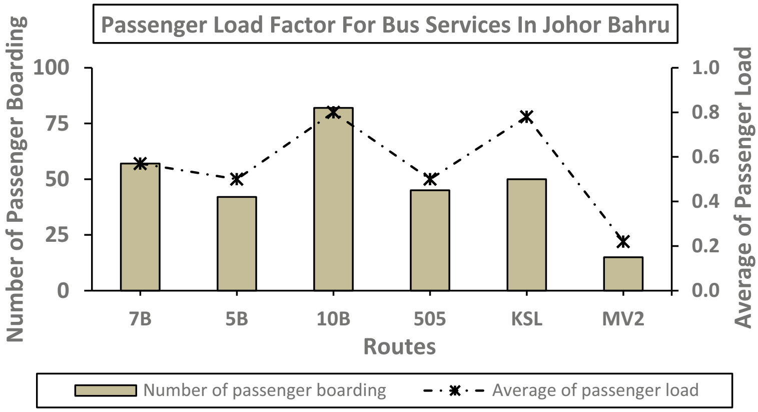


Fig. 1 Passenger load for bus services in Johor Bahru, Johor

passengers boarding in this trip and the average of passenger was 0.80. Meanwhile, the lowest number of passengers on these routes was routes MV2 which recorded only 14 passengers boarding in these trips and the average of passenger was 0.22. The average of passenger load of these five routes in Johor Bahru were 0.56.

On the other hand, the total of six routes have been selected as such to determine the passenger load factors for bus services in Bandar. Figure 2 shows the summarization of passenger load factors for bus services in Bandaraya Melaka. Only routes 14 and 17 have been recorded the number of passengers more than 30 passenger and each route recorded the average of passenger load of 0.26 and 0.23 respectively. While there were two routes were recorded the number of passengers less than 10 passenger in this trip namely routes 3 and 17 and each route recorded the average of passenger

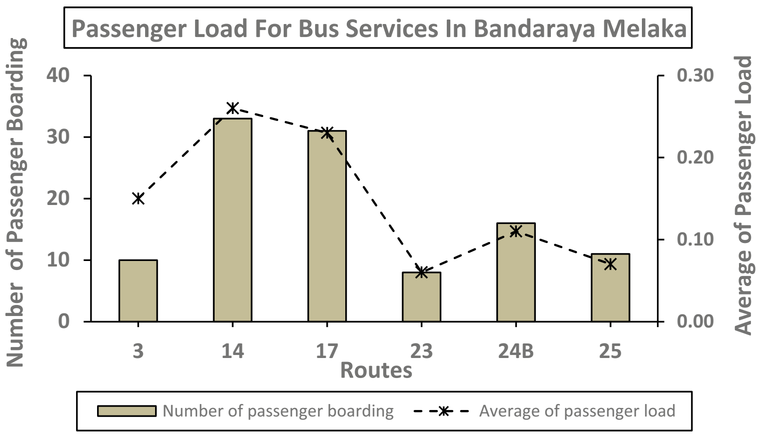


Fig. 2 Passenger load for bus services in Bandaraya Melaka, Melaka

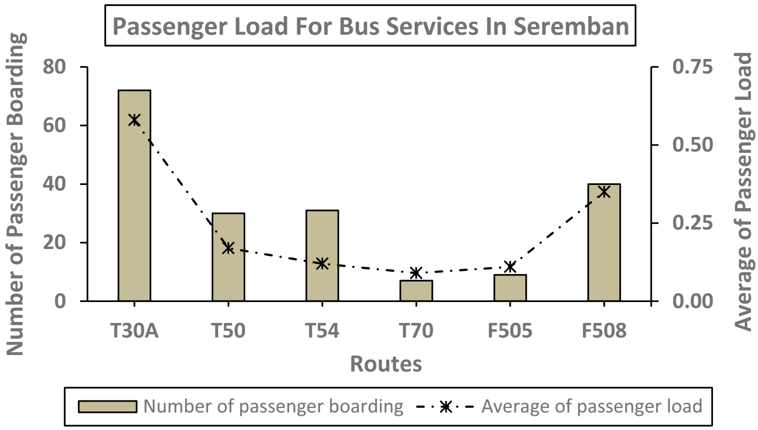


Fig. 3 Passenger load for bus services in Seremban, Negeri Sembilan

load of 0.15 and 0.06 respectively. The average of passenger load of these six routes in Bandaraya Melaka were 015.

In Seremban, Negeri Sembilan, there were also six routes have been selected to determine the passenger load for bus services. Figure 3 shows the summarization of passenger load factors for bus services in Seremban. The results show that routes have recorded the highest passenger boarding in designated trip was routes T30A which recorded the total of 72 passenger boarding. Thus, the average of passenger load for these routes was 0.58. There were two routes were recorded the number of passengers less than 10 passenger in this trip namely routes T70 and F505 and each route recorded the average of passenger load of 7 and 9 respectively. The average of passenger load of these six routes in Seremban were 0.24.

Passenger load is one of quality of service (QOS) attributes in determine quality of services for bus services as explained in pervious section. Therefore, Table 2 shows the mean of services quality (QOS) of passenger load for urban bus services in Southern Peninsular of Malaysia. The mean of quality of service (QOS) of on time performance for Johor Bahru, Melaka and Seremban were classified as a QOS B, A and A respectively. Most of the routes in these cities were classified as QOS A, two routes were classified as QOS B and two routes were classified as QOS C. The

Table 2 The mean of quality of service (QOS) of passenger load for urban bus services in Southern Peninsular of Malaysia

Location	Quality of Services (QOS)					Mean QOS
	A	B	C	D	E	
Johor Bahru	2	1	2	–	–	B
Melaka	5	–	–	–	–	A
Seremban	4	1	–	–	–	A

passenger load attributes were representing the volume of passenger were boarding from one destination to other destination using bus services. Yet, The number of passengers still low for the most of destination in these cities especially in Melaka.

4 Conclusion

This study is focusing on assessing the passenger load of urban bus services in southern states Peninsular of Malaysia. Southern region of Peninsular of Malaysia consists of Johor, Melaka and Negeri Sembilan. Capital city of each southern states in Peninsular of Malaysia have selected in this study. This study was conducted using procedure and approach that been proposed by Transit Capacity and Quality of Service of Manual (TCPRM). Five and six routes have been selected for each location depends on suitability and bus availability. The highest number of passenger boarding was route 10B in Johor Bahru recorded 82 passenger and the lowest passenger boarding was route T70 recorded with only 7 passengers. Johor Bahru recorded the highest number of passenger boarding followed by Seremban and Melaka. Johor Bahru recorded the highest number of passengers used bus services as such Johor Bahru is the only land entrance to Singapore. The average of quality of services for Johor Bahru was QOS B and for Melaka and Seremban the quality of service was QOS A. On the other hand, authority should play a significant role to increase the number of passengers in Bandaraya Melaka since this state in one of the smaller states in Malaysia which face high number of traffic volume in peak hours period. Besides, this state also a main historical tourism attraction in this country. The output of this studies can be used by operators and policy maker to improve bus services in other urban area as well. Since these cities in Malaysia were capital city for each states, authorities and government can used this outcome as their inputs to measure the effectiveness of public transportation in urban area. Future studies in this topic by others researcher is highly recommended.

Acknowledgements Authors would like to thank Yayasan Canselor Universiti Tenaga Nasional for providing research grant for this study (202101015YCU) and Innovation Research Management Centre (IRMC), Universiti Tenaga Nasional.

References

1. Abdullah AA (2013) Rapidkl bus service in city center, Kuala Lumpur, Malaysia: an epitome of good service? Int J Acad Res Bus Soc Sci 3(4):333–349
2. Al-Hawari F, Al-Sammarraie M, Al-Khaffaf T (2020) Design, validation, and comparative analysis of a private bus location tracking information system. J Adv Transp 2020:1–18

3. Azadi M, Shabani A, Khodakarami M, Farzipoor SR (2015) Reprint of planning in feasible region by two-stage target-setting DEA methods: an application in green supply chain management of public transportation service providers. Transp Res Part E: Logist Transp Rev, Elsevier 74:22–36
4. Aziz A, Mohamad J (2013) Urban public transport in Penang: some public considerations. Conf of Eastern Asia Soc Transp Stud 9:1–9
5. Chow MF, Bakar MFA (2019) Environmental benefits of green roof to the sustainable urban development: areview. Lect Notes Civ Eng 9:1525–1541
6. Cui J, Gao Y, Cheng J, Shi L (2020) Study on the selection model of staying adjustment bus lines along rail transit. J Adv Transp 2020:1–12
7. Eboli L, Forciniti C, Mazzulla G (2018) Spatial variations of the perceived transit service quality at rail stations. Transp Res Part a Policy Pract 114:67–83
8. Esmailpour J, Aghabayk K, Vajari MA, Gruyter CD (2020) Importance—performance analysis (IPA) of bus services attributes: a case study in a developing country. Transp Res Part A 142(2020):129–150
9. Ministry of Housing and Local Council (2018) Final report of Malaysia smart cities framework
10. Ministry of Transport, Malaysia (2019) National transport policy 2019–2030, 29 March 2020. https://rb.gy/bo7avg
11. Molla MB (2015) Urbanization process in developing countries: a review on urban ecosystems degradation and public health effect. Res J Agric Environ Manage 4(7):291–298
12. Mou Z, Zhang H, Liang S (2020) Reliability optimization model of stop-skipping bus operation with capacity constraints. J Adv Transp 2020:1–11
13. Ngadiman NI, Roslan NF, Rahman AF, Ahmad F, Daud MMS, Abdullah R (2020) Survey on Quality of Service (QoS) at Larkin Central Terminal (LCT). Johor Bahru, Int J Adv Trends Comput Sci Eng 9(1):229–232
14. Norhisham S, Bakar MFA, Tajri AA, Mohamed D, Yatuka S, Masjuki SA, Shukri NSM, Zaini N (2019) Statistical overview on quality bus service in Klang Valley. Int J Adv Sci Technol 28(10):370–380
15. Ponrahono Z, Bachok S, Osman MM, Ibrahim M, Abdullah MF (2017) Public bus level of service performance in Peninsular Malaysia: correlation analyses on level of service (LOS) and passenger's satisfaction level. J Malays Inst Plan 15(1):229–234
16. Purba A (2015) A study on evaluating urban bus service performance in developing countries: case study of medium—sized cities in Indonesia. PhD dissertation. Yokohama National University
17. Shukri MNS, Ponrahono Z, Sunoto NY, Ghazali WWNW (2020) Evaluation of Level of Service (LOS) on routes of smart bus in Kajang. Selangor. J Malays Inst Plan 18(3):241–250
18. Transit Capacity and Quality of Service Manual (TCQSM) (2013) TCRP Report 165 3rd edition, Transportation Research Board (3rd ed), Transit Cooperative Research Program, The Federal Transit Administration, Washington D.C.
19. Vien LL, Bagheri Y, Sadullah AFBM (2010) Analysis of headways on passenger loads for public bus services: case study of Penang Island, Malaysia. J Eur Sci Res 45(3):476–483. http://www.eurojournals.com/ejsr.htm
20. Wahjono IS, Bachok KYM, Marina A, Mochklas M (2017) The importance of MPIS on RK for futher ITS implementation in Malaysia. Int J Adv Appl Sci 4(9):53–56
21. Wang J, Cao Y (2017) Operating time division for a bus route based on the recovery of GPS data. J Sens 2017:1–8
22. Yaakub N, Napiah M (2011) Public transport: punctuality index for bus operation. World. Acad Sci, Eng Technol 60:857–862
23. Zhang S, Yuan Z, Cao Z (2017) A frequency-based assignment model under day-to-day information evolution of oversaturated condition on a feeder bus. Information 8(19):1–19
24. Zhao S, Wang D, Sun J, Liu H (2017) Optimization model for multiple-vehicle-type structure in urban bus systems. Math Probl Eng 2017:1–6

Observation on Landslide Occurrence by the Rise of Groundwater After Prolong Rainfall Event

Nor Hazwani Nor Khalid, Fathoni Usman, Rohayu Che Omar, Shuhairy Norhisham, and Azwin Zailti Abdul Razad

Abstract Landslide is one of the natural disasters that gained attention worldwide these days. The effects are not only limited to changes in topography but also cause fatality. Rainfall and groundwater are among the factors that contribute to landslide occurrence. This study focused on finding the possibility of groundwater increment after prolong rainfall events that might lead to landslide occurrence. Thus, slopes that have a landslide history located at three different locations were selected for rainfall and groundwater monitoring. After a year of observation, the longest time of prolonged rainfall was selected for further analysis. The study found that prolonged rainfall does not cause an increment to the groundwater level.

Keywords Prolong rainfall · Groundwater · Landslide · Sandy-SILT

1 Introduction

Malaysia has received an average of 2400 mm rainfall annually [1, 2]. The rainfall pattern in Malaysia is influenced by two Monsoon seasons, which are Southwest and Northeast Monsoon. Study conducted by [3–5] found that the rainfall trend in Malaysia is increasing [6]. Stated that landslides disaster in Malaysia normally occur during the monsoon season, which usually affected hilly topography areas. The impact of rainfall that leads to landslide incidence in Malaysia was also studied by [2, 4, 7–9], using various techniques and approaches. However, all studies have agreed that rainfall is the main factor in triggering the occurrence of slope failure.

Rainfall increases the groundwater level which eventually contributes to slope failure [10–15]. Nevertheless, the groundwater level is highly depending on the ability of the soil to absorb water, especially during water penetration into the ground [12, 13, 16–22]. As water seeps through the ground, the pore water pressure will increase and lower the matric suction. The increment of water content consequently reduces the shear strength between soil particles and this phenomenon will lead to slope

N. H. N. Khalid (✉) · F. Usman · R. C. Omar · S. Norhisham · A. Z. A. Razad
Universiti Tenaga Nasional, Jalan Ikram-Uniten, 43000 Kajang, Selangor, Malaysia
e-mail: Hazwani@uniten.edu.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_30

displacement. A study conducted by [10] through site monitoring and laboratory simulation of pore-water pressure stated that rainfall infiltration has initiate landslide by a decrement in soil suction and increment of the groundwater level, especially for unsaturated slope. However, not all unsaturated slopes will fail due to the increment of the groundwater level, since it is depending on the permeability in the unsaturated zone above the phreatic surface. Low permeability above the phreatic surface will cause a delay in groundwater level increment [23]. In other studies on the effect of rainfall infiltration on the increment of groundwater, it was found that the increment is depending on the flux boundary condition of the ground surface (wetting front), infiltration rate, matric suction reduction depth, and evapotranspiration [24–26].

This paper presents a result on the observation of groundwater level increment during prolonged rainfall events for sandy-SILT type of soil in hilly areas.

2 Study Area

The study was conducted at three different slopes located within hilly area in two different states in Peninsular Malaysia, which are Terengganu and Kelantan. Slope A and B are in Terengganu, while, slope C is in Kelantan. The distance between A and B is 850 m apart, while location C is 124 km away from A and B. The study areas are in hilly topography, near fault lines that makes the areas prone to landslides (Fig. 1). The locations were chosen based on their historical landslide and crack signed appear on the surface of the concrete cover, as in Fig. 2.

3 Methodology

This study was a continuity from the previous studies in [27, 28], where this study will focus on the rise of groundwater during a prolonged rainfall event. A set of instruments to monitor landslide occurrence were installed at three locations and two of them are rain gauge and piezometer. A soil sample from the borehole was used to determine the types of soil, while the borehole itself was used to place the piezometer. The soil type at locations A, B, and C are Sandy-SILT. The piezometers are installed at a depth between 18–20 m on the slope, depending on the hard layer of the slope. The initial reading was recorded and was used as a reference in the analysis stage. After the installation work was done, the rain gauge and the piezometer were connected to the data logger. The data collection process was started after the instruments were smoothly sent the data into the data logger. Those slopes are monitored for a year and the longest prolong rainfall event for each slope was chosen to be further analyzed.

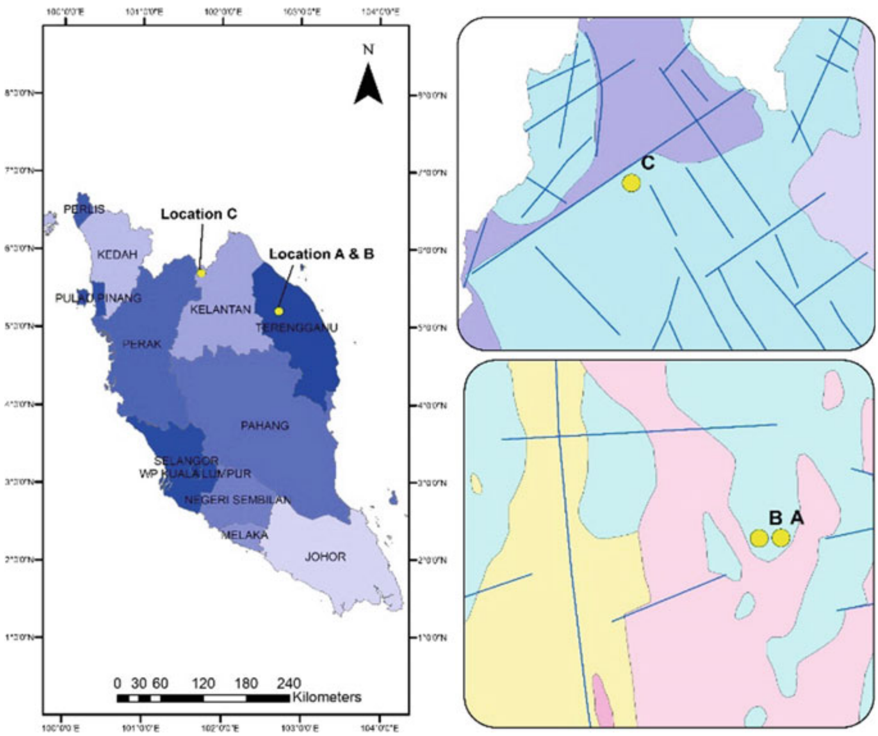


Fig. 1 The study areas

Fig. 2 Crack and settlement indicate active landslide occurs at the slope

4 Discussion and Analysis

To determine the response of groundwater to the received rainfall for locations A, B, and C, the cumulative rainfall, rainfall duration, and groundwater level data from each location were plotted and shown in Fig. 3. The groundwater for location A is at 18 m, location B is at 19 m and location C is at 19 m underground. The study discovered that the changes in groundwater are insignificant to the increment of rainfall. [23]

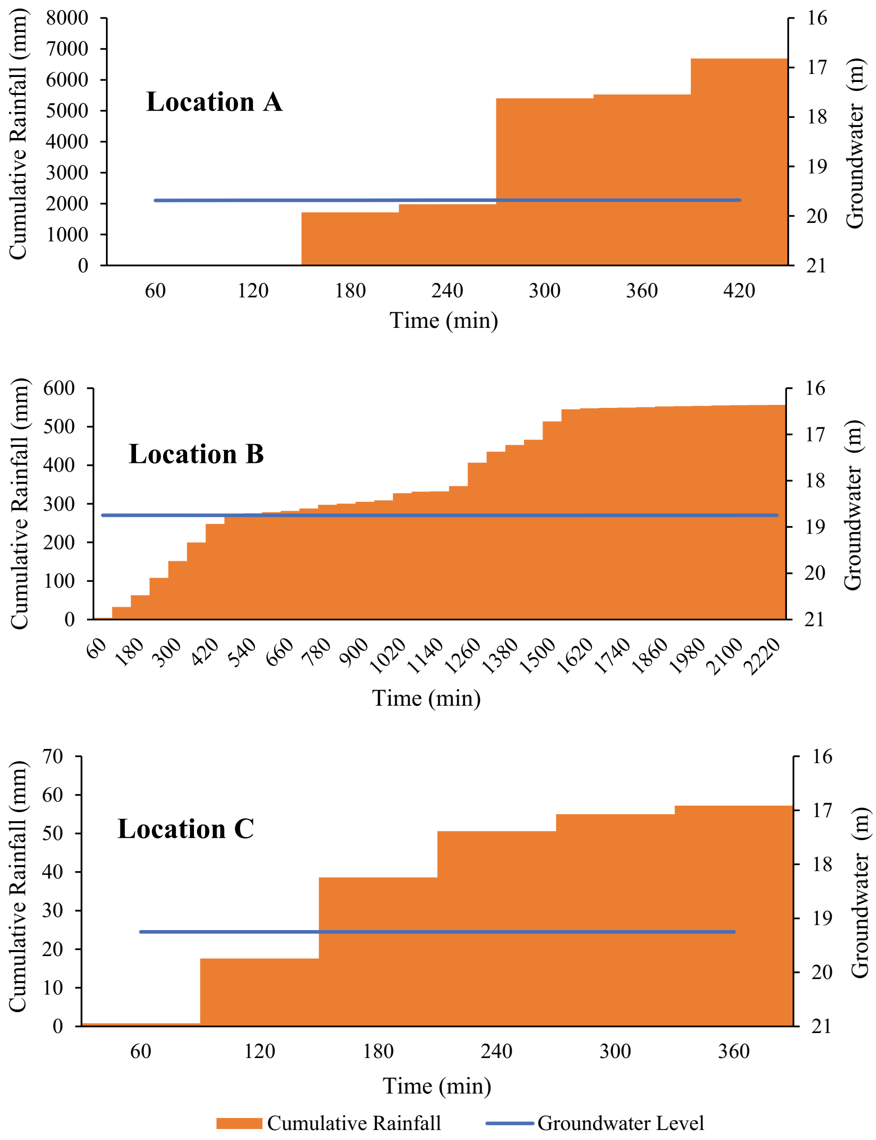
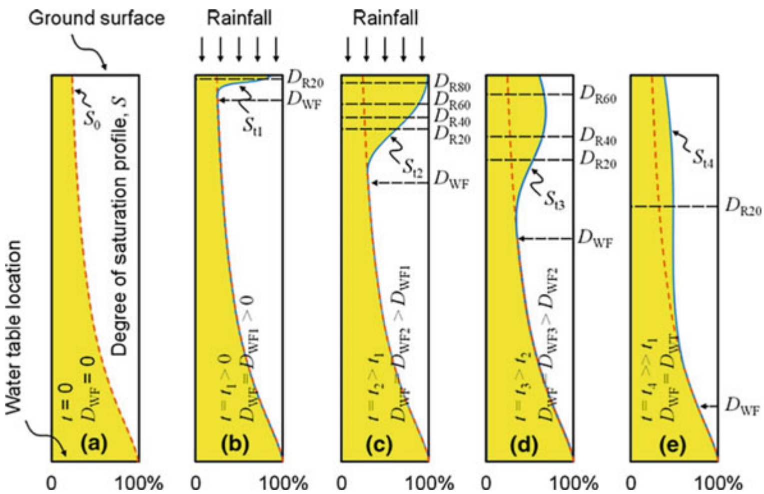


Fig. 3 Cummulative rainfall and groundwater level for the studies slopes

stated that unsaturated soil with low permeability might delay the rising of the water table. This is due to the longer time taken for pore-water pressure to be equalized.

According to [20], landslide might not occur during or immediately after prolonged rainfall for fine-grained soil such as the one found at all the studied slope locations (sandy silt), but the landslide occurrence might happen few hours or even days after the rainfall event. This is due to the suction redistribution pattern, where the infiltration rate is greatest at the crest of a slope, followed by the face, and finally at the toe of the slope. A study on a phase of infiltration and wetting front conducted by Rahardjo et al. [24] found that matric suction was reduced as the depth increased. The findings as illustrated in Fig. 4, which was involving depth of wetting front (DWF) and matric suction reduction depth (DRn). In addition, the same findings were also discovered by another study conducted by Lee et al. [8] where the study focused on comparing four types of soil which were sand gravel, silty gravel, sandy silt, and silt (kaolin). Based on the extreme rainfall and soil hydraulic properties as input data for the numerical simulation, a suction envelop was determined. For sandy silt, the critical suction envelops (maximum depth) was at six meters to seven meters, as shown in Fig. 5. A study on groundwater fluctuation conditions during 15 h of prolonged heavy rainfall found that rainfall has cause increment of the groundwater about 25 mm. The fluctuation is highly affected by evaporation and transpiration activities caused by its surroundings [28]. Moreover, no research proved that water tables rise significantly and trigger slope failure. Most of the landslide occurs above the groundwater table that is usually one to three meters below the surface [29]. In this study, since the groundwater level is very deep and does not increase even to one meter during heavy rainfall, the possibility of a landslide occurrence due to the rising of the water table is almost impossible. The crack sign found on the slope surface might be cause by the increment in perched water that exist near the surface.



(a) Initial condition
(b) Immediate after start of rainfall
(c) Immediate before the cessation of rainfall
(d) Immediate after cessation of rainfall
(e) Long after rainfall ended

Fig. 4 Dept of wetting front and matric suction reduction depth by [24]

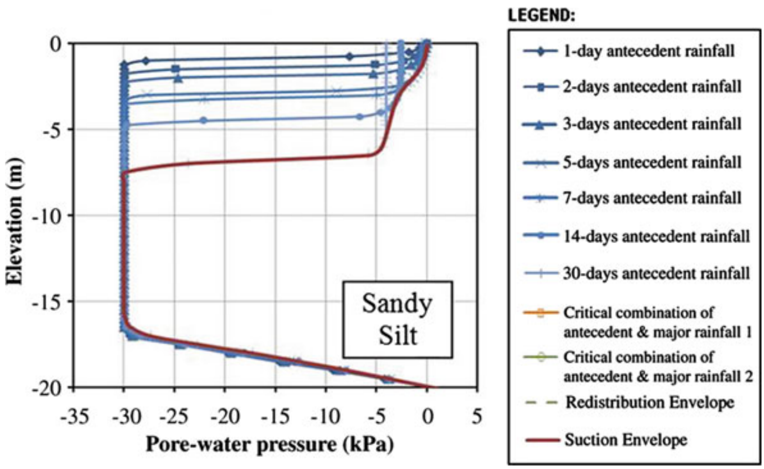


Fig. 5 Suction envelope by Lee et al. [8]

5 Conclusion

Observation on the groundwater level and the received rainfall at three different slopes discovered that the groundwater level does not rise and is impossible to cause the landslide occurrence. It was suspected that the landslide had occurred due to the volume increment in a perched water table formed by antecedent rainfall.

Acknowledgements The authors would like to thank Tenaga Nasional Berhad (TNB) for the funding and support in making this study successfully achieve the objective.

References

1. Hashim M, Ismail WR, Rahaman ZA et al (2016) Accelerated development and changes in rainfall trends and variations in Malaysia: a case study of the Kinta River basin 1960–2006. Geogr Malays J Soc Sp 12:126–141
2. Mukhlisin M, Matlan SJ, Ahlan MJ, Taha MR (2015) Analysis of rainfall effect to slope stability in Ulu Klang, Malaysia. J Teknol 72:15–21
3. Wong CL, Venneker R, Uhlenbrook S et al (2009) Variability of rainfall in Peninsular Malaysia. Hydrol Earth Syst Sci Discuss 6:5471–5503
4. Mayowa OO, Pour SH, Shahid S (2015) Trends in rainfall and rainfall-related extremes in the east coast of peninsular Malaysia Trends in rainfall and rainfall-related extremes in the east coast of peninsular Malaysia. J Earth Syst Sci 1609–1622
5. Chin RJ, Lai SH, Chang KB, Othman F (2011) Analysis of rainfall events over Peninsular Malaysia
6. Abdul H, Mapjabil J (2017) Landslides disaster in Malaysia: an overview. Heal Environ J 8:71
7. Tajudin N, Ya'Acob N, Ali DM, et al (2018) Rainfall—landslide potential mapping using remote sensing and GIS at Ulu Kelang, Selangor. IOP Conf Ser Earth Environ Sci, Malaysia, p 169

8. Lee LM, Gofar N, Rahardjo H (2009) A simple model for preliminary evaluation of rainfall-induced slope instability. Eng Geol 108:272–285
9. Lee ML, Ng KY, Huang YF, Li WC (2014) Rainfall-induced landslides in Hulu Kelang area, Malaysia. Nat Hazards 70:353–375
10. Chen H, Lee CF, Law KT (2004) Causative mechanisms of rainfall-induced fill slope failures. J Geotech Geoenviron Eng 130:593–602
11. Novotný J, Kobr M (2009) Hydrogeological pattern of groundwater flow of landslides in Cretaceous claystones based on long-term groundwater monitoring and hydrologging measurement. Environ Geol 58:25–32
12. Sapari N, Sati I, Harahap H, Adlan MN (2008) The influence of rising groundwater on slope stability and engineering properties. In: 2nd engineering conference on sustainable engineering infrastructures development management, pp 1–7
13. Abdullahi MG, Garba I (2016) Effect of rainfall on groundwater level fluctuation in terengganu. J Remote Sens GIS, Malaysia, p 4
14. Conte E, Donato A, Troncone A (2017) A simplified method for predicting rainfall-induced mobility of active landslides. Landslides 14:35–45
15. Liu Q, Jian W, Nie W (2021) Rainstorm-induced landslides early warning system in mountainous cities based on groundwater level change fast prediction. Sustain Cities Soc 69:102817
16. Kim J, Jeong S, Park S, Sharma J (2004) Influence of rainfall-induced wetting on the stability of slopes in weathered soils. Eng Geol 75:251–262
17. Larson CL (1973) rainfall intensity is initially less than the infiltration capacity of the soil in this paper a. Water Resour Res 9:384–394
18. Kovalevsky VS (2016) Infiltration and groundwater formation Sa Ne M Sc Pl O E–C Eo Ap Ls Te S M Sc Pl O E—III
19. Gofar N, Lee LM, Kassim A (2008) Response of suction distribution to rainfall infiltration in soil slope. Electron J Geotech Eng 13 E
20. Gasmo JM, Rahardjo H, Leong EC (2000) Infiltration effects on stability of a residual soil slope. Comput Geotech 26:145–165
21. Nygren M, Giese M, Kløve B et al (2020) Changes in seasonality of groundwater level fluctuations in a temperate-cold climate transition zone. J Hydrol X 8:100062
22. Mcfarlane D, George R, Ruprecht J et al (2020) Runoff and groundwater responses to climate change in South West Australia. J R Soc West Aust 103:9–27
23. Schnellmann R, Busslinger M, Schneider HR, Rahardjo H (2010) Effect of rising water table in an unsaturated slope. Eng Geol 114:71–83
24. Rahardjo H, Ong TH, Rezaur RB et al (2010) Response parameters for characterization of infiltration. Environ Earth Sci 60:1369–1380
25. Chien-Yuan C, Tien-Chien C, Fan-Chieh Y, Sheng-Chi L (2005) Analysis of time-varying rainfall infiltration induced landslide. Environ Geol 48:466–479
26. Kristo C, Rahardjo H, Satyanaga A (2017) Effect of variations in rainfall intensity on slope stability in Singapore. Int Soil Water Conserv Res 5:258–264
27. Hazwani NK, Rohayu CO, Fathoni U et al (2016) Integration of multi-sensors data in detecting slope movement based on threshold values. ARPN J Eng Appl Sci 11:2592–2596
28. Hazwani NK (2018) Effect of rainfall to the groundwater and soil displacement. Int J Eng Res Technol 11:439–450
29. Hakro MR, Harahap ISH, (2015) Laboratory experiments on rainfall-induced flowslide from pore pressure and moisture content measurements. Nat Hazards Earth Syst Sci Discuss 3:1575–1613

Architectural Spaces of Comics: Social and Visual Representations

Lim Poh Im and Yap Wei Tyng

Abstract Comics is used to communicate messages in a fun story-telling manner, while architectural visuals are commonly appreciated through drawings. This paper discusses the potentials of comics as an important communication medium. It explores how comics aid in showcasing architectural ideas with unique visual representations. Besides this, comics is a tool to communicate nuances of social phenomena. Our study employed content analysis on selected comics; supported by interviews with comic artists and architects. Findings suggest that comics project architectural spaces in easy comprehension as it breaks the formality of architecture presentations and translate them into laymen's terms. The uniqueness in the visual representations allow artists to express art and convey intended messages in lively manners. Referring to selected comics from Malaysia, our study demonstrates how the local comic contents are very much ingrained in the local context, and how they have manifested contemporary social, cultural, and political scenarios with symbolic visual representations. The study suggests that comics should be further explored to be used as a useful alternative medium in architecture communications.

Keywords Comics and architecture · Architecture spaces in comics · Social representations of comics · Malaysian comics

1 Introduction

Comics is a graphic medium to deliver an artist's messages through sequential art. Comic art has been used as a medium in spreading information, as well as entertainment reading materials especially in mainland Europe, America and Japan [1]. Besides, comics were used in communicating architecture utopian ideals and in highlighting issues affecting society in different historical periods. This paper aims to discuss the relationships between comics and architecture, focussing on imaginary spaces and spatial experiences of comics, and it's roles and potentials as social

L. P. Im (✉) · Y. W. Tyng
Universiti Tunku Abdul Rahman, Selangor, Malaysia
e-mail: limpi@utar.edu.my

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_31

representations. Referring to selected comics from Malaysia, our study explores how these comics had manifested local social, cultural, and political scenarios with vivid symbolic representations.

2 Literature Review

Comics are mediums of expressions combining images with text, it provides readers with easily comprehensible messages, which goes beyond literacy levels. Reading comics can heighten human cognition and perception, as the images are accompanied with text, rather than only relying on text alone [2]. Instead of demanding a reader to assemble their own movement through a series of spaces, comics control how spatial information is presented to the reader. By doing so comics emphasise the nature of a space or series of spaces, and therefore assist in communicating architectural intent to the reader [1].

Traditionally, architecture is mostly presented in static form, depicting spaces or forms of a particular time. Some of the earliest use of comics in communicating design ideas can be found in Le Corbusier's 'Ville Radieuse' (Radiant City) and Frank Lloyd Right's Broadacre City. In *Lettre a Madame Meyer* (1925), Corbusier applied a cartoon/comic strips style of presentation where he drew spaces of building in separate panels, accompanied by narratives to explain the expected experience of the building. Rather than using a typical orthographic drawing, the comic-like graphics were able to communicate the ideas in an easily comprehensible manner to his layman client [3].

In the present time, architectural drawings are aided by advanced software technology, they may be lacking in terms of narratives to interpret the meanings of design. Human figures may appear lifeless as they are just attachment to the buildings. Indeed, comics have abilities to mimic elements of the real world. The non-repetitive frames arouse the curiosity to continue to uncover the stories. For example, the perspectives of the Superheroes allow the readers to immerse in the architecture wonders of the city. Besides this, comics can highlight societal conditions in its representations. Moscovici defined social representation as social understanding that deferred with cultures [4]. For instance, the character of *Wonder Woman* created by William Moulton Marston, was a symbol of feminism. As the first female superhero, she depicted women taking over typical male occupied important positions in World-War II. The character represented the feminist's empowerment, countering the masculine-dominated world [5].

3 Methodology

This research is based on qualitative approach. Content analysis was carried out on selected Malaysian comics with support from purposive interviews. The selected comics were screened and categorised based on the research aims, analysis was carried out on the technique and style, along with relevant messages and visual graphics that represented the themes. Interviews were conducted with comic artists who were involved in producing architecture related comics and artists who successfully published their comic works. Triangulation was done on both interviews and content analysis to derive critical insights on the topic.

4 Findings and Discussion

Comics have been in existence since the British colonial period. Initially, they were used as a tool for political propaganda. Through time, they evolved into graphic novels or comic books for educational purposes, recording historical culture and entertainment for children and adults [6]. Local comics frequently showcase rich fabrics of our multi-ethnic society and its' associated socio-political nuances. This section is based on our analysis on six selected comics: 1. *Ipoh Mali: 80s as we were* by Kumar Nagalingam; 2. *Ge Mei Liang* or *Kokko & May by* Eddie See Yew Lee*;* 3. *Kampung Boy* series by Lat; 4. *TwitTwit Cincin* by Zulkiflee Anwar Haque or Zunar; 5. Cartoon series by Reggie Lee and 6. *The Blue Mansion* by Lim Eu Jin.

Ipoh Mali painted the scenarios of Ipoh in the eighties through the eyes of a local boy. The artist described Buntong then as 'the wild west of Ipoh' and the Buntong Market a place he would cycle with his dad for breakfast. Here, the urban elements and street characters of a secondary towns in Malaysia were projected vividly. In one example, the liveliness of the marketplace frequented by the multi-ethnic locals was showcased from the speech bubbles in three languages (Fig. 1).

In *Ge Mei Liang* series, using the core family, school and environment surrounded the upbring of a pair of siblings, KoKo and Mei, the comics impart life lessons, moral and societal values to young readers. The stories painted unique facets of typical Malaysian culture from their spoken language, food, festivals, pastimes, etc. For example, in a scene of a wedding (Fig. 2), local Chinese customs and values were vividly seen from the hall decorations, nags of the parents to their children emphasised the virtues of punctuality, greeting relatives and table manners.

Another example of how comics are used to illustrate local customs is the ever-popular *Kampung Boy series.* The series were Lat's autobiography, portraying himself as the main character, reminisced his simple life as a child who grew up in a village, his adventures in the jungles and tin mines, his circumcision, family and school life. In one example (Fig. 3), *Lat was* dressed in traditional costumes, seated on floor mat having a big feast with families and friends in a 'berkhatan' ritual.[1] Indirectly, Lat used his art to help educate the young about his faith. Besides this, Lat helped painted the harmonious sides of Malaysians, with his drawings of

[1] 'Majlis Berkhatan' (circumcision ceremony) is celebrated by the Malay Muslim to commemorate the coming-of-age of a boy when they turn ten years old.

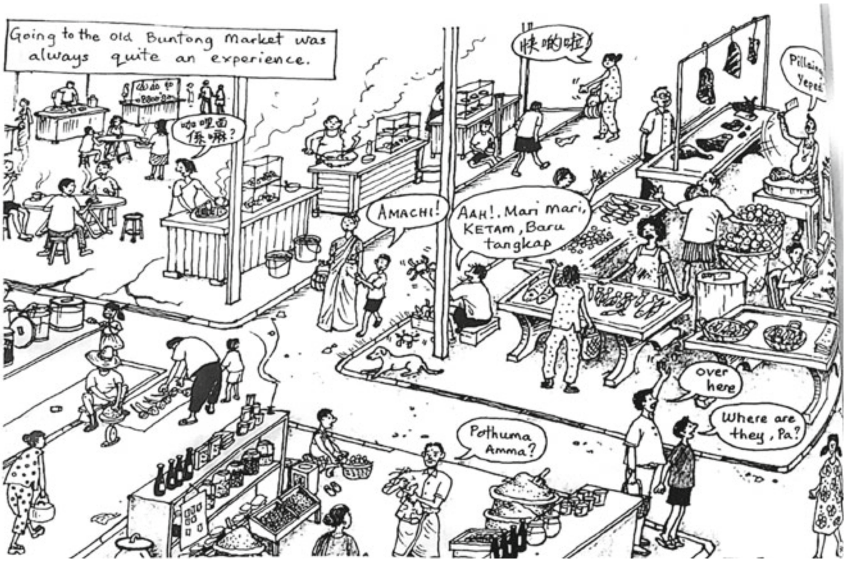


Fig. 1 Scenario of a wet market, "*Ipoh Mali*"

Fig. 2 A wedding ceremony, *GeMeiLiang*

Fig. 3 Scenes of a village kid at a circumcision ceremony, *Kampung Boy*

crowd scenes and interactions. Muliyadi described Lat's style as "subtle, indirect, and symbolic" in portraying the Malaysian humour [7].

Besides the day-to-day lives and social circumstances, comics are frequently used as political satire to voice the grouses and frustrations of the common folks, such as misuse of power of the rich ruling elites. During the 1MDB episodes, comics were used by whistle blowers to either inform, alert, or highlight politcal situations using funny caricatures. This includes comics such as *TwitTwit Cincin* by Zulkiflee Anwar Haque or Zunar; and cartoon series by Reggie Lee.

In *The Blue Mansion*, the social fabrics and architecture of colonial era were depicted by detailing the activities, building elements and courtyard interior. The plot was based on the romanticised daily life of a Chinese tycoon Cheong Fatt Tze. Readers experienced the immediate context of the wondrous architecture and magical spaces of Straits Chinese mansion. For example, in Fig. 4, the roofscape and the aesthetic mansion were brought to life through the birds' eye view. The intricate details of roof tile patterns, tea drinking culture and fine ornaments of the interior were magnified through the backdrop of the rain drops.

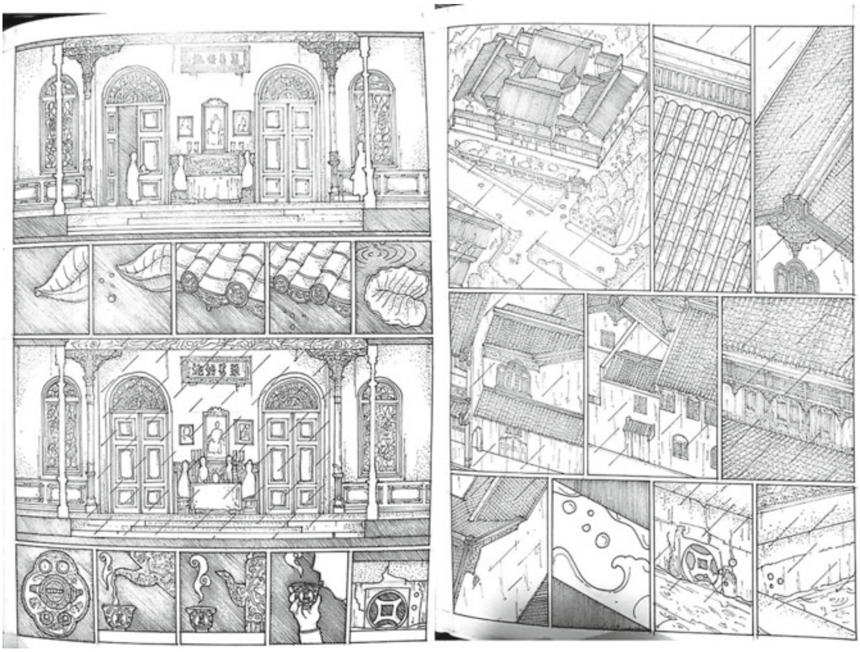


Fig. 4 Architecture detailing in *The Blue Mansion*

5 Conclusion

As shown in our examples, comics has been a fascinating medium with its unique capacity to integrate communication, space, and movement to provide readers with a wholesome enjoyable reading experience, through the combinations of human character, narratives, and vivid physical setting; using multiple angles and techniques to convey messages. The selected comics referred in this research are just some examples. They highlight the essence of the Malaysian society reflecting the local lifestyles and living culture, at times they are used as means to raise awareness on social unjust and oppression of the state. The choice of metaphors and use of common themes, developed in simple strokes and vivid colours appeal to the mass. The lesson to learn is that visual representations of architecture could emulate the techniques, strategies, and aesthetics of the graphic narrative, as this would break the formality of formal presentations so that it is more appealing and result in better comprehension to the lay person.

References

1. Brown MR (2014) A way of looking—an exploration into representation of architecture. Unitec Institute of Technology. https://www.researchbank.ac.nz/bitstream/handle/10652/2537/Matthew%20Brown_2014-11-05.pdf?sequence=1&isAllowed=y
2. Tilley C, Weiner R (2016) Teaching and learning with comics. In: Routledge guide to comics and graphic novels. Routledge
3. Arana KL (2013) Comics and architecture, comics in architecture. https://www.mascontext.com/issues/20-narrative-winter-13/comics-and-architecture-comics-in-architecture-a-not-so-short-recount-of-the-interactions-between-architecture-and-graphic-narrative-1
4. Moscovici S (2000) Social representations. Explorations in social psychology. Polity Press, Cambridge, UK
5. Marshall WSC (2018) Wonder woman and the nine ladies worthy: the male gaze and what it takes to be a 'worthy woman'. In: Medievalism to early-modernism. Routledge
6. PACCM (2016) Penang asia comic cultural museum. http://paccm.com.my/our-story/
7. Muliyadi M (2003) An overview of Malaysian contemporary cartoons. Int J Comic Art 5(1):292–304

European Union's Role in Handling Overtourism (Case Study in Venice, Barcelona, and Santorini)

Najmah Azzahra and Henny Saptatia Drajati Nugrahani

Abstract The tourism industry in Europe is growing rapidly especially from 2017 to 2019. The increasing number of tourist arrivals has negative impacts on tourism, such as overtourism. The phenomenon occurs when there are too many visitors in certain tourism destinations and impacted the quality of life in the area. Overtourism has negative impacts such as environmental damage, damage to cultural sites, economic inequality, and damage to life quality of the local community. This paper aims to analyze the phenomenon that currently raising in European Union member states. The focus of this paper is EU's role in handling overtourism that occurring in Venice, Barcelona, and Santorini as the cities mentioned are located in EU's member states. This research is a qualitative study, with case study of overtourism occuring in Venice, Barcelona, and Santorini. The theme is analyzed using formal intergovernmental organization and compliance theories. It is found that European Union's role in handling overtourism in Venice, Barcelona, and Santorini is by applying their regulations in environmental, tourism, and sustainability fields to the mentioned countries because EU is a supranational intergovernmental institution and their member states have to comply every regulations made by EU.

Keywords European Union · Overtoursim · Formal intergovernmental organization · Compliance

1 Introduction

Tourism is one of the fastest growing industries. The tourism industry in Europe, is growing rapidly because European countries have the most popular and most visited tourist destinations. The international tourist arrivals in Europe in 2018 reached 713 million [16]. This number increased by 6% from 2017. In 2019, data on international tourists coming to Europe shows an increase of 4% from 2018 [16]. The UNWTO predicts that this number will reach 1.8 billion by 2030 [16].

N. Azzahra (✉) · H. S. D. Nugrahani
School of Strategic and Global Studies, University of Indonesia, Depok City, Indonesia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_32

The increasing number of tourist arrivals gave negative impacts on tourism, such as overtourism. This phenomenon occurs when there are so many tourists come to a certain tourism destination that it exceeds the capacity [16]. Moreover, some tourists do not protect the environment of the tourist destinations they visit [16]. The phenomenon created several damages to environmental, cultural sites, economic inequality, and the quality of life of local communities [16].

One of the overtourism locations is Venice in Italy. Data in 2017 shows that the number of tourists visiting and staying in Venice reached 10.2 million, while the number of tourists visiting without staying overnight reached 35 million [12]. The number of tourists in Venice is much greater than the number of local residents. The total local population in 2019 is around 270,000 [7]. This number is decreasing as the arrival of tourists in Venice is increasing, causing local residents to feel like they are losing their city and decide to move to another city [7].

The phenomenon of overtourism in Venice has caused damage to the environment like lagoons and cultural sites. The Italian government did not immediately address this phenomenon because tourism is one of the main sectors that contributed a lot to Italy's per capita income amid its economic crisis [15]. In 2017, the contribution of the tourism sector to Italy's GDP was 223.2 billion Euros, 13% of Italy's total GDP in 2017 [15]. This number has increased in 2018, with a total GDP of the tourism sector of 227.3 billion Euros [15].

Another city, Barcelona in Spain, is one of the most visited tourist destinations. In 2018, the total number of tourists visiting Barcelona was 32 million, far more than the number of Barcelona residents who were only 5.5 million [18]. Spain's revenue from the tourism sector in 2018 was 176 billion euros, 16% of the total Spanish GDP [18].

Tourism is a main sector in Spain, but many problems arise as a result of overtourism. Based on Barcelona Barometer, in June 2017 local residents consider tourism to be one of the most important issues [2]. In December 2017, tourism was considered the fourth biggest problem [2]. The explosion of visiting tourists as well as the unstable political conditions in Barcelona caused the quality of life of the local population to suffer, resulting in negative views on tourism and several demonstrations protesting against tourism policy in Barcelona [2].

The tourism sector in Greece is one of the main sectors for the country's economic income. In 2017, the World Travel & Tourism Council reported that out of 185 countries, Greece was ranked 25th in tourism sector contribution to GDP, 40th in contribution to employment, 40th in investment contribution, and 21st in total foreign tourists who come to tour [18]. The number of tourists who came to Greece in 2018 reached 32 million, a drastic increase from 15 million in 2010 [1].

Tourist arrivals to Santorini, Greece, reached more than two million in 2018, up from 1.7 million in 2017 [10]. The locals in Santorini are aware of the impact of overtourism [14]. Living costs are getting more expensive and many migrants work and become permanent residents in Santorini but have difficulty paying the rent [14]. Local residents also complain that the development of the tourism sector has caused nature to be damaged by the continuous construction of construction, both legally and illegally [14].

This study focuses on Venice, Barcelona and Santorini because they are located in Italy, Spain and Greece, which are located in Southern Europe. The three countries experienced an economic crisis from 2009 to 2019, so that tourism has become one of the sectors that are relied on for their country's income. Even though the three countries experienced a crisis, the tourism sector continued to run smoothly, even causing overtourism.

Based on Table 1, it can be seen that the number of tourists who come to those cities is much larger than the local residents. The large number of tourists has caused various negative impacts in those cities. However, the governments of Italy, Spain and Greece did not immediately take action to deal with overtourism.

The phenomenon that occurred in Venice, Barcelona and Santorini is interesting to study because it has several similarities. It is located in three countries in Southern Europe with economic crisis and their governments do not immediately take action to deal with the phenomenon of overtourism in their countries. The cities are located in Italy, Spain and Greece, which are member states of the European Union. As member states of the European Union, the three countries must comply with EU policies in the field of environment and tourism. This study will discuss the extent of the European Union's role in dealing with the phenomenon of overtourism that occurred in Venice, Barcelona and Santorini.

Table 1 Overtourism comparison table in Venice, Barcelona and Santorini Year 2018 15

No	City name	Number of tourists	Total population	Impacts
1	Venice	36,500,000 [15]	260,897 [15]	Damage to canals, environmental pollution, disrupting the activities of local residents, increasing the cost of living [7]
2	Barcelona	32,000,000 [1]	5,541,127 [18]	Disturbing the activities of local residents, increasing living costs, damage to cultural sites and environmental pollution [18]
3	Santorini	2,500,000 [10]	15,545 [10]	Damage to cultural sites, many tourists who later become permanent residents so that local residents are disturbed, tourists who later become local residents cannot afford the cost of renting houses and increasing living costs [14]

2 Methods

This study uses a qualitative method that presents data in a descriptive-explanatory form. It aims to find an explanation of a phenomenon, problem or behavior that is the core of research. The data were obtained using the literature study method by collecting relevant information and data from previous research, such as journals, books and reports, as well as mass media and online media.

The theory used in this research is the formal theory of intergovernmental organization proposed by Keohane and Martin and the concept of compliance from Beth A. Simmons. Keohane and Martin stated that international institutions are classified as institutional neoliberal if they fulfill one of the following forms [17]. First, a formal intergovernmental organization. As an organization that has a specific purpose, this organization can oversee activities and respond to these activities. This organization is formed by the state (formal intergovernmental) and non-state (cross national nongovernmental). They have a bureaucratic organization with clear rules and regulations and specific tasks for the individuals and groups that belong to it [17].

Second, the international regime which is an institution that has explicit regulations approved by the state, linked to international relations issues [17]. Third, conventions which are informal institutions that have implicit rules and understandings that shape the expectations of the actors involved [17].

The above descriptions help to identify the European Union as a neoliberal institution. In the grouping of neoliberal institutions, EU is included in the formal intergovernmental group. The EU is called a supranational organization because its member countries remain sovereign and independent states [6], but they combine their sovereignty with a view to gain greater collective power and influence [6]. EU member states are bound by a series of treaties that have been signed and must be agreed upon by each member state, then ratified either by the national parliament or by means of a referendum [6].

There are three categories to form a formal intergovernmental organization [9]. The first category is purpose [9]. EU had clear objectives when it came to form such an organization. The second category is bureaucratic organizations [9]. EU has various bureaucratic organizations, meaning that EU is eligible to form a formal governmental organization. The last category is explicit rules and missions [9]. A formal intergovernmental organization will make various regulations and explicit missions [9]. EU is known as an organization that has a series of regulations that are binding on its member countries. In this research, explicit rules and missions are series of rules to handle overtourism in EU member countries.

The formal theory of intergovernmental organization is used to analyze the role of EU in dealing with the phenomenon of overtourism that occurs in its member countries because EU is a neoliberal international institution in the formal intergovernmental category. EU has a set of rules and policies that its member states must comply. This theory is used to analyze how the regulations owned by EU are able to deal with overtourism in Venice, Barcelona and Santorini.

The concept of compliance discusses to which extent regional organizational regulations are applied by the state [13]. Simmons defines compliance as a form of compliance from member countries to the international institutions that support them. International law plays an important role in ensuring state compliance with international institutions [13]. Institutions force states to make various legal commitments that are divided into different policy areas [13]. This effort refers to the management role played by institutions in using existing legal instruments to ensure state behavior [13]. Compliance is closely related to explicit rules possessed by formal intergovernmental organizations [13]. In an intergovernmental organization, especially one that is supranational, member countries must comply with the explicit rules that apply in their institutions [13].

In this study, the concept of compliance is used to describe the relationship between member countries (Italy, Spain, and Greece) and international institution (EU). The supranationalism characteristic of an international institution, in this case the EU, will be reflected in the implementation of the regulations set by the governments of member countries. EU regulations in the field of tourism and the environment must be fulfilled by member countries because they are binding.

3 Discussions

As member states of EU, Italy, Spain and Greece governments must comply with the regulations made by EU. The phenomenon of overtourism which causes negative impacts, one of which is damaging the environment, has caused EU to step in. Laws related to policies on environmental protection in the European Union are made by the European Parliament. Environmental protection policies in Europe were first created in 1972 [4]. This policy is found under Articles 191–193 on Treaty on the Functioning of the European Union [4]. Policies can be divided into several groups, namely protection of air, chemicals, weather, nature, waste management, and water [4]. The negative impact of overtourism which damages the environment can pollute the entire group [4].

In protecting nature in tourist destinations, EU has a Nature Directive policy [5]. In 2017, the European Commission released an action plan to increase its contribution to nature protection [5]. The European Parliament strongly supports nature directives and asks the Commission and member countries to increase their priority in protecting nature, especially in tourist destinations [5].

Tourism policy in the EU was originally set up by the European Commission [3]. Then, the integration of the principles of sustainable development into European treaties then gave rise to a framework for tourism policy making [3]. The Lisbon Treaty in 2017, Articles 6 and 195 to be precise, gave birth to an EU policy that focuses on tourism [3].

In this policy, EU takes an integrated approach. All impacts of tourism must be considered when planning and development. Tourism must be balanced and integrated with various activities that have an impact on society and the environment

[5]. It is also necessary to make long-term plans so that they do not have a negative impact on future generations [5]. There must be commitment from all participants involved in decision making as well as all participants involved in implementation [5].

Furthermore, there must be a full evaluation and preventive action to prevent damage to the environment or society [16]. The government needs to limit tourism-related development so as not to disturb local residents and damage the environment, as well as limit tourist arrival [16]. It is necessary to carry out continuous monitoring because the impact of tourism is always changing, so that when new problems arise in tourism, action can be taken to overcome them [16].

EU states the need to distribute tourists to other tourist destinations with attractive offers so that they do not overflow in tourist destinations that experience overtourism [8]. Then, increasing the capacity in tourist destinations is needed so that they can accommodate tourists without damaging these destinations [8]. Financial regulation is also needed, such as increasing prices (in a certain time and place) through taxes [8].

Furthermore, real time information about tourist destinations is needed for tourists [11]. The government also needs to take "green measures" on tourist destinations [11]. Then, local residents must benefit economically from visiting tourists [11]. Finally, a tourist destination must feel comfortable and safe for both tourists and local residents [11].

4 Conclusions

The conclusion of this study is that the European Union deals with the phenomenon of overtourism that occurs in Venice, Barcelona and Santorini by using regulations. EU applied regulations in tourism, environment, and other fields because EU member states must comply with regulations that have been issued by the EU. The negative impacts of overtourism have been decreasing since EU applied above regulations to these countries.

References

1. Almazan I (2018, July 20) Greece: new European destination victim of overtourism? https://www.tourismdashboard.org/greece-new-european-destination-victim-of-overtourism/. Accessed 13 Nov 2019
2. Eliasson E, Velasco K (2018) Coping with overtourism: redirecting tourism consumption through social media and the internet. University of Gothenburg
3. Estol J (2017) European Union tourism policy. University of Barcelona Publication
4. European Parliament (2018) Environmental protection. EU Policies
5. European Parliament (2018) Research for TRAN committee-overtourism: impact and possible policy responses. Policy Department for Structural and Cohesion Policies

6. Folsom RH (2017) European Union Law in a nutshell. West Academic Publishing
7. Hospers G-J (2019) Overtourism in European cities: from challenges to coping strategies. CESifo Forum
8. Jordan P, Pastras P, Psarros M (2018) Managing tourism growth in Europe. The ECM Toolbox
9. Keohane, Martin L (1995) The promise of institutionalist theory. International Security
10. Krinis N (2018, Oct 29) Thira Mayor: Santorini is a 365-day tourism destination. GTP News. https://news.gtp.gr/2018/10/29/thira-mayor-santorini-365-day-tourism-destination/. Accessed 13 Nov 2019
11. McKinsey and Company (2017) Managing overcrowding in tourism destinations. World Travel and Tourism Council
12. Nolan E, Seraphin H (2019) Venice: capacity and tourism. Overtourisim Issues Realit Solut 139–151
13. Simmons BA (2009) Treaty compliance and violation. Faculty Scholarship University of Pennsylvania Law School
14. Stanchev R (2018) The most affected European destinations by over-tourism. Universitat de les Illes Balears
15. Statista (2019, Nov 7) Total contribution of travel and tourisim to GDP in Italy from 2012 to 2028. Statista. https://www.statista.com/statistics/627988/tourism-total-contribution-to-gdp-italy/. Accessed 8 Dec 2019
16. UNWTO (2018) Overtourism? Understanding and managing urban tourism growth beyond perceptions. World Tourism Organization
17. Viotti, Kauppi (2012) International relations theory, 5th edn. Pearson Education, Inc
18. WTTC (2018) Economic impact of tourism: Greece and Spain. World Travel and Tourism Council

Mechanical Properties of Concrete with Activated Sugarcane Bagasse Ashes as Cement Replacement

Noor Aina Misnon, Faridah Hanim Khairuddin, Siti Zubaidah Mohd Asri, Nur Liza Rahim, Rijalul Fikri, and Siti Khadijah Che Osmi

Abstract Sugarcane bagasse waste is one of the biomass wastes generated in Malaysia. This study investigates the potential of the sugarcane bagasse waste to replace cement content in concrete mixtures by converting the bagasse waste into activated carbon ashes using physical activation method. The mechanical properties of sugarcane bagasse activated carbon concrete was carried out to determine the effectiveness of activated sugarcane bagasse ash (SBA) in the concrete mix by performing concrete hardened test i.e., compressive test, splitting tensile test and flexural test. The SBA replacement in concrete mixture showed a promising result and has a great potential to be pozzolan materials.

Keywords Cement replacement · Concrete properties · Pozzolanic material · Sugarcane bagasse ash · Sustainability

1 Introduction

Sugarcane or scientific name is '*Saccharum officanarum*' is one of the largest agricultural exports of Malaysia with annual sugar export valued approximately between US$200 to 300 million [1]. With great production of sugar in Malaysia, the sugarcane waste (i.e., raw bagasse and ashes) is a common issue being highlighted as one of the pollutants. Towards environmental and sustainability, wastes have been converted to useful products to be used as alternative to the existing conventional method such as the use of natural fibre waste in bulletproof jacket [2] and also as construction

N. A. Misnon (✉) · F. H. Khairuddin · S. Z. M. Asri · S. K. C. Osmi
Department of Civil Engineering, Faculty of Engineering, Universiti Pertahanan Nasional Malaysia, Kem Sungai Besi, Sungai Besi, 57000 Kuala Lumpur, Malaysia
e-mail: nooraina@upnm.edu.my

N. L. Rahim
School of Environmental Engineering, Universiti Malaysia Perlis, Kompleks Pusat Pengajian Jejawi 3, 02600 Arau, Perlis, Malaysia

R. Fikri
Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_33

materials [3–5]. Thus, to minimise the waste abundance issue, research has been conducted to investigate and fully utilize the sugarcane waste as one of the substitute materials to the existing technology.

For pavement material, sugarcane bagasse ash was found effectively used as a filler in a production of hot mix asphalt (HMA) with an increment of the Marshall stability, flow and Resilient Modulus by 0.6%, 4.9% and 17.4% respectively in comparison with ordinary HMA [6]. The powdered sugarcane bagasse activated carbon was reported as a good absorber and potential to be used for treatment when the removal of organic content, contaminant, metal and others pollutant in groundwater achieved more than 90% efficiency in relative to granular [7]. Due to a high content of sucrose, the sugarcane bagasse waste was found as a good economical-natural concrete retarder which required longer setting time by several hours [8]. In [9] manufactured clay bricks made of sugarcane bagasse waste with a final performance of the products satisfied the building code of practice. In [10] reported with the limitations of the use of raw sugarcane bagasse less than 10% weight since it caused a decrement on mechanical strength. The sugarcane bagasse ash used as fine sand in concrete showed promising results when 20% and 30% replacement increased the compressive strength relative to normal mortar mix and suitable for design strength up to 30 MPa [11].

The use of pozzolan in concrete mixture aids for high strength concrete production in relative with the one with ordinary Portland cement only. It can be found in natural form or artificially made. The pozzolana can be defined as siliceous or siliceous and aluminous material which alone possess little or no cementitious value which will, in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature or form compounds possessing cementitious properties [12]. Good pozzolanic materials contain a high content of amorphous silica and high specific surfaces to generate a pozzolanic reaction [13]. Silica fume, ground granulated blast furnace slag (GGBS) and fly ash are the common pozzolan used in concrete that available in market with high price. Research has been conducted on the performance of concrete with such pozzolan and showed great improvement to the concrete properties [14–17]. Additional of 25–35% fly ash was found as a practical way to utilize a high percentage of recycled aggregate in concrete [16]. GGBS offered a great protection to corrosion of steel embedded in concrete when used as cement replacement to high performance concrete mixture [17]. With a finding that ground sugarcane bagasse ash contains high percentage of silicon dioxide (SiO_2) [18] makes this material as one of the potential economical pozzolan. The pozzolanic activities can be activated for sugarcane bagasse ash (SBA) using activated carbon process. The activated carbon can be summarized as a form of the carbon processed to produce a small and low volume pore that increases the surface area available for chemical reaction.

This study aims to produce SBA activated carbon using sugarcane bagasse waste to replace cement content in the concrete mix. To investigate the effectiveness of SBA replacement, mechanical properties of the sugarcane bagasse ash concrete (SBAC) including compressive strength, splitting tensile strength and flexural strength tests

Table 1 Mix proportion of 0.001 m^3 concrete

Specimens	Cement	Fine aggregate	Coarse aggregate	SBA
Control (0%)	3.40	6.40	11.90	0.00
5% SBA	3.23	6.40	11.90	0.17
10% SBA	3.06	6.40	11.90	0.34
15% SBA	2.89	6.40	11.90	0.51

Note All units in kg

were carried out. The collected data was analysed and used to identify the optimum percentage of SBA replacement in the concrete mixture.

2 Materials Characterisation and Experimental Setup

2.1 Raw Material and Mix Design

The SBAC contents were Ordinary Portland Cement, fine aggregate, coarse aggregate, water and activated SBA. The maximum size of fine and coarse aggregate used was less than 5 mm and 20 mm respectively. The concrete grade 30 was adopted with design mix ratio of 1:1.8:3.5 (cement: sand: aggregate) and the water-cement ratio (w/c) used was 0.5. The amount of cement was replaced by three different percentage of SBA: 5, 10 and 15%. Table 1 shows the mix proportion of 0.01 m^3 concrete mix. The specimens were demolded after 24 h and were immersed in water for 7 and 28 days for curing purpose.

2.2 Physical Activation

The raw sugarcane bagasse waste was collected from wider Kuala Lumpur, Malaysia area. The collected sugarcane bagasse waste was washed thoroughly with distilled water to remove unnecessary substance which might be affected by the strength of the concrete. Subsequently, the waste was sun-dried for three days and being cut into approximately 5 mm long of the fibre. The fibre was ground until becoming small particles and was burned in a furnace with temperatures up to 600 °C for two hours. The final step involved the sieving process of activated SBA and only size less than 0.15 mm was collected which to be used as cement replacement.

(a) (b) (c)

Fig. 1 Laboratory test. **a** Slump test measurement. **b** UTM machine for compressive strength and splitting tensile test. **c** Flexural testing setup using two points loading test

2.3 Laboratory Test

Slump test was carried out in accordance with BS EN 12350 [19] for each batch of concrete mixture to check the workability of the mix which can affect the degree of compaction yet excessive water result in bleeding and reduce the concrete strength. Figure 1a shows slump test measurement one of the specimens.

Compression test was conducted on 24 cube specimens with a dimension of 100 mm × 100 mm × 100 mm according to BS EN 12390 [20] to determine compressive strength of the specimens. The test was carried out at 7 days (12 cubes) and 28 days (12 cubes) of curing time. Prior to the test, the specimens were weighted on balance to determine the density of the specimens. Figure 1b shows compression test was conducted on a cube specimen. A total of 12 cylinders with diameter 150 mm and 300 mm height were tested under splitting tensile test in accordance with BS EN 12390-6 [21]. This test was conducted at 28 days to determine the tensile strength of the specimens. 12 beamlets with dimension of 100 mm × 100 mm × 500 mm were tested at 28 days to determine the flexural strength of the specimen using two points loading test. The test was conducted to measure the ability of the beamlets to resist failure in bending. The two points loading (see Fig. 1c) was arranged according to BS EN 12390-5 [22].

3 Results and Discussion

3.1 Slump and Density

All specimens showed a true slump type with the height value ranging from 60 to 65 mm. From Fig. 2a, the slump value gradually increased with an increment of the SBA replacement in the concrete mix. Specimens with 15% SBA replacement showed the maximum height of slump with slump value of 65 mm. This is an indicator concrete mixture containing SBA requires more water to remain the workability. It might be due to the higher specific surface area of the SBA particle [23]. The density

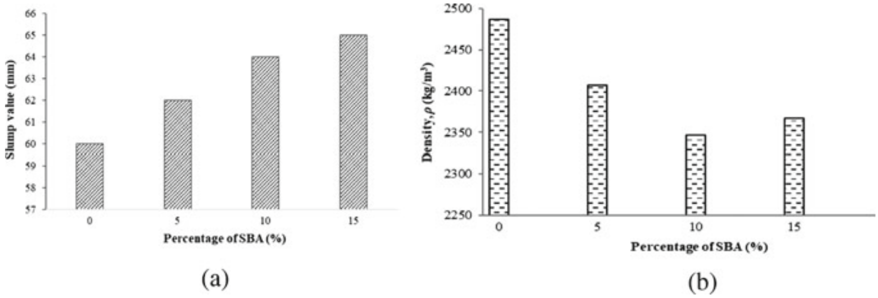


Fig. 2 **a** Slump value and **b** density of SBA concrete with different percentage of replacement

of the specimens is as shown in Fig. 2b. SBA concrete density decreased with an increment amount of SBA. The density of the specimens was reduced to 3.2%, 5.6% and 4.85% for 5%, 10% and 15% amount of SBA replacement respectively in comparison to control specimen. 10% of SBA replacement produced the lightest specimen with the density of 2346.67 kg/m^3. The reduction of concrete density is beneficial in reducing the self-weight of the concrete structures and resulting in less inertia force under dynamic loading such as impact loading [24].

3.2 Mechanical Properties of SBAC

Compressive strength, f_c of the specimens for 7 and 28 days were recorded and plotted as shown in Fig. 3. Additional SBA replacement increased the f_c value up to 10% SBA replacement with f_c value were 27.13 MPa at 7 days and 43.25 MPa at 28 days which can be categorized as high strength concrete (f_c more than 40 MPa).

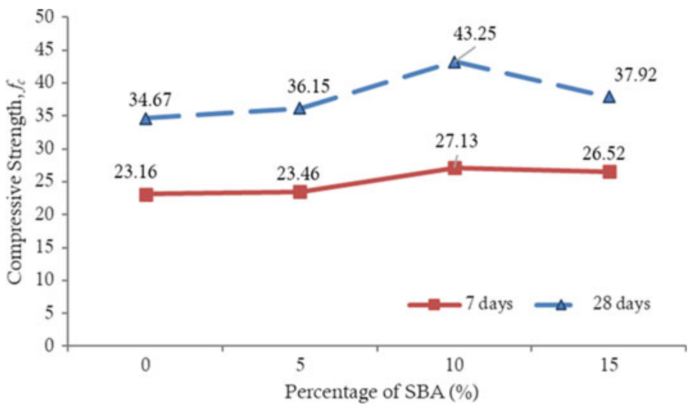


Fig. 3 Compressive strength of SBA concrete specimens at 7 and 28 days

Further increment SBA percentage decreased the *fc* of the specimens and yet still higher than the control specimen. At this stage, the reduction of the hydration reaction since high cement content was being replaced by the SBA. The presence of cement is necessary to produce calcium silicate hydrate (CSH) which contributes to the strength of the concrete [23]. Figure 4 shows the split tensile strength (STS) of the specimens at 28 days. All the specimens with SBA replacement showed higher STS value in comparison to the control specimens. Increment SBA replacement in the concrete mixture improved the STS value of the specimens up to 10% amount of SBA replacement and started to reduce the STS when 15% of SBA replaced cement content in the concrete mixture. This result was expected since the STS has a close relationship with f_c value [25]. The flexural strength, f_{cf} of the specimens at 28 days is as illustrated in Fig. 5. Increasing the percentage of SBA replacement

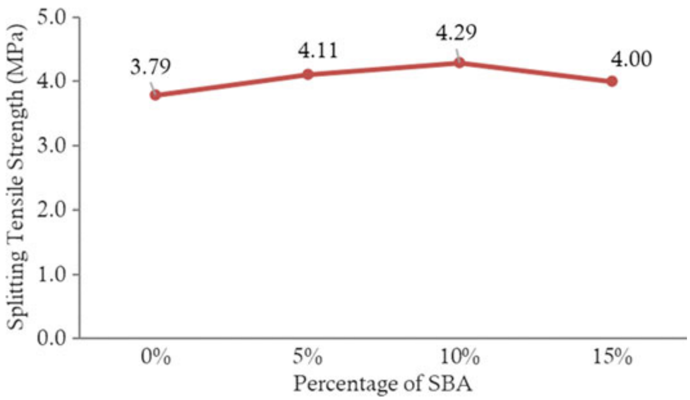


Fig. 4 STS value of the specimens with different percentage of SBA replacement

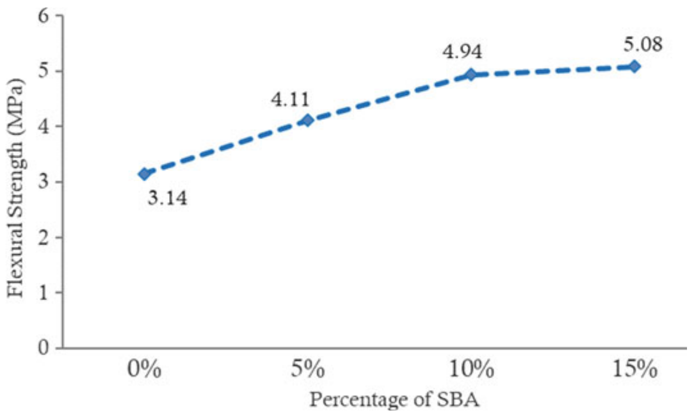


Fig. 5 Flexural strength of the specimens with different percentage of SBA

gradually increased the f_{cf}. 15% SBA replacement showed the highest value of f_{cf} with approximately 62% higher than control specimens.

4 Conclusions

In this study, the sugarcane waste had been activated using physical activation to produce pozzolan materials in the concrete mixture. The used of activated SBA as cement replacement showed the promising result on the mechanical properties of concrete. The results revealed that the reduction in density of concrete was obtained for the specimens with SBA replacement. This gives benefit in decreasing the dead load of the concrete structures and inertia force when subjected to dynamic loading. The compressive strength, f_c of the specimens with SBA replacement increased with the additional percentage of SBA replacement up to 10%. Further addition SBA amount in concrete mixture resulted in decreasing the f_c value. Less production of CSH was expected for the specimens with SBA replacement more than 10%. Increasing the SBA replacement amount improved the splitting tensile strength and with 10% SBA replacement showed the highest STS value. With growing SBA amount as a cement replacement, gradually increased the flexural strength of the specimens. 10% SBA replacement was found as the optimum amount for cement replacement in the concrete mixture.

Acknowledgements This project was funded by Universiti Pertahanan Malaysia under grant number UPNM/2019/GPJP/TK/15. The authors gratefully acknowledge the assistance of technical staff of structural and heavy material laboratory. This is publication number JP002 of the grant.

References

1. Food and Agriculture Organization (1996) Part I—theoretical outlook, framework analysis and background documentation background studies. In: Proceedings of the international sugar conference, pp 1–40
2. Yahaya R, Sapuan SM, Jawaid M et al (2016) Investigating ballistic impact properties of woven kenaf-aramid hybrid composites. Fibers Polym 17(2):275–281
3. Ali M, Liu A, Sou H et al (2012) Mechanical and dynamic properties of coconut fibre reinforced concrete. Constr Build Mater 30:814–825
4. Aziz MA, Paramasivam P, Lee SL (1981) Prospects for natural fibre reinforced concretes in construction. Int J Cem Compos Lightweight Concrete 3(2):123–132
5. Abdullah A, Jamaludin SB, Mazlee MN et al (2011) Composite cement reinforced coconut fiber: physical and mechanical properties and fracture behavior. Aust J Basic Appl Sci 5(7):1228–1240
6. Zainudin MZM, Khairuddin FH, Ng CP et al (2016) Effect of sugarcane bagasse ash as filler in hot mix asphalt. Mater Sci Forum 846:683–689
7. Che Osmi SK, Che Osmi SF, Misnon NA et al (2012) Utilization of sugarcane bagasse in the production of activated carbon for groundwater treatment. Int J Eng Appl Sci 1(2):76–85

8. Yahya MA, Yusof MA, Abu Hassan Z et al (2013) Usage of sugarcane bagasse as concrete retarder. Int J Bus Technopreneursh 3(3):495–503
9. Kazmi SMS, Abbas SMA et al (2016) Manufacturing of sustainable clay bricks S.: Utilization of waste sugarcane bagasse and rice husk ashes. Constr Build Mater 120:29–41
10. Faria KCP, Gurgel RF, Holanda JNF (2012) Recycling of sugarcane bagasse ash waste in the production of clay bricks. J Environ Manage 101:7–12
11. Sales A, Lima SA (2010) Use of Brazilian sugarcane bagasse ash in concrete as sand replacement. Waste Manag 30(6):1114
12. ASTM (2010) Standard specification for coal fly ash and raw or calcined natural Pozzolan for use. ASTM Int
13. Neville A (1995) Properties of concrete. Pearson Education
14. Siddique R (2004) Performance characteristics of high-volume class F fly ash concrete. Cem Concr Res 34(3):487–493
15. Mazloom M, Ramezanianpour AA, Brooks JJ (2004) Effect of silica fume on mechanical properties of high-strength concrete. Cem Concr Compos 26(4):347–357
16. Kou SC, Poon CS, Chan D (2007) Influence of fly ash as cement replacement on the properties of recycled aggregate concrete. J Mater Civ Eng 19(9):709–717
17. Siddique R, Kaur D (2012) Properties of concrete containing ground granulated blast furnace slag (GGBFS) at elevated temperatures. J Adv Res 3(1):45–51
18. Chusilp N, Jaturapitakkul C, Kiattikomol K (2009) Utilization of bagasse ash as a pozzolanic material in concrete. Constr Build Mater 23(11):3352–3358
19. BS EN 12350-2 (2000) Testing fresh concrete Part 2: slump-test
20. BS EN 12390-3 (2009) Testing hardened concrete Part 3: compressive strength of test specimens
21. BS EN 12390-6 (2009) Testing hardened concrete Part 6: tensile splitting strength
22. BS EN 12390-5 (2009) Testing hardened concrete Part 5: flexural strength of test specimens
23. Hailu B, Dinku A (2012) Application of sugarcane bagasse ash as a partial cement replacement material. J EEA 29:1–12
24. Misnon NA, Osmi SKC, Chouw N et al (2017) Influence of coir random fibre length on concrete: mechanical properties. Malaysian Constr Res J 22(2):47–58
25. Yan K, Xu H, Shen G et al (2013) Prediction of splitting tensile strength from cylinder compressive strength of concrete by support vector machine. Adv Mater Sci Eng 2013:1–13

Life Cycle Assessment on Alternatives Concretes and Cementitious Materials

Sarah Laila Mohd Jan, Norelyza Hussien, Nor Hasanah Abdul Shukor Lim, Che Hafizan Che Haasan, and Nur Syamimi Zaidi

Abstract The utilization of industrial and agricultural waste materials can be an alternative as cementitious material to reduce the carbon dioxide (CO_2) emission from cement production and will lower other environmental impact. In recent years, more research has been done using life cycle assessment (LCA) on construction material production to understand the energy usage and its environmental impacts to find the possible low energy usage and green building alternatives. Several LCA studies have been reviewed in this paper that mainly are the concretes and cementitious material. Hence, this study will provide new perspectives of the methodology used in the environmental assessment by researchers in the world that compare to the International Organization for Standardization (ISO) LCA standards (ISO 14040:2006 and ISO 14044:2006). Comparing LCA studies to ISO guidelines ensures that all of the important factors in LCA are achieved, and the lack of use of these guidelines will impair the qualities of life cycle interpretation and data assessment.

Keywords Secondary cementitious material · Environmental impact · ISO guidelines

1 Introduction

The spike in the human population globally contributes to industrialization, urbanization, and economic development, which subsequently increased demand for housing and infrastructure. There are increment in global cement manufacture from 2.284 billion tons in 2005 to 4.1 billion tons in 2018 and soon 45% more cement will be

S. L. M. Jan (✉) · N. Hussien · N. H. A. S. Lim · N. S. Zaidi
Faculty of Civil Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

C. H. C. Haasan
Centre for Environmental Sustainability and Water Security (IPASA), Universiti Teknologi Malaysia, Johor Bahru, Malaysia

N. S. Zaidi
Faculty of Applied Sciences, Universiti Teknologi MARA, Cawangan Pahang, Kampus Jengka, Jengka, Malaysia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_34

produced by 2050 than current production [1]. Estimation about 50% of the world's carbon dioxide (CO_2) gas emissions come from the cement industrial which the manufacture of one ton of ordinary Portland cement (OPC) produces around half tons of CO_2 gas and involved other 0.39 tons of CO_2 gas in fuel emissions for raw materials processes [2]. However, despite the release of CO_2 gas as main criteria used in the assessment of environmental impacts, there are also further environmental impacts were assessed such as fresh water and marine ecotoxicity, photochemical oxidation, ozone depletion, eutrophication, acidification, and human toxicity [3–5].

To reduce the utilization of natural resources and environmental impacts in cement manufacture, any use of waste materials from other industries could be a potential alternative to cement. Some of these waste materials will display a compliant characteristic due to their chemical composition could be used in building materials manufacture [1]. Due to the huge quantity of biomass ash produced, the rising use of biomass for sustainable energy production has encouraged research into the substitution of traditional Portland cement with biomass ash by-products [6]. Some useful waste will be utilized as supplementary cementitious material (SCM) for example by recycling industrial wastes such as fly ashes (FA), blast furnace slag, and some agricultural wastes. In years, there has been extensive interest in finding to solve the difficulties of managing the industrial waste dump, construction waste, and land pollution and there are more research groups working on the application of green building materials (GBMs) in engineering construction [7]. Comparing the conventional building materials (CBMs) with the GBMs, it is more ecological, healthy, recyclable, and also high performance. Therefore, throughout its life cycle analysis including the resource used, manufacturing, operation, disposal, and recycling, the type of material that low influences towards the environment and human health can be determined [8].

Life cycle assessment (LCA) has been an important methodology and is widely used to facilitate the transition towards sustainable development by considering entirely various other potential environmental impacts related with the stages of a product life cycle respectively [9]. Basic of LCA contains three mainly phase which are the identification and evaluation of system boundary, functional unit and analysis timelines.

2 Methodology

The LCA was performed in accordance with standardization by the International Organization for Standardization (ISO), ISO 14040 and ISO 14044, which refer to the LCA of any product, whereas EN 15978:2011 is specific to construction products. Validation of data and analysis for LCA on various secondary cementitious materials can be accomplished using a variety of software and life cycle impact assessment methods. SimaPro is a software extensively used among researcher and it also uses different kind of impact assessment methods such as Eco-Indicator 99 method, ReCiPe v1.12 (H) and the Centrum voor Milieukunde Leiden (CML) methods that was recommended by EN 15978:2011. The Eco-Indicator 99 studies the 11 impact categories in three main endpoint categories; human health, ecosystem quality, and depletion of resources, and meanwhile because of to a non-specific method for the Chilean context and its global scope, ReCiPe was chose [10–13].

Another commercial LCA modelling was completed using GaBi software and the impact assessment was done using the CML 2016 method; it provides information on the environmental issues connected with the contributions and productions of any product [14]. Besides commercial software, other LCA modelling software used is EASETECH which was developed at the Technical University of Denmark (DTU) in Denmark, and the impact assessment incorporated by the European Commission's suggested the midpoint impact categories in the International Reference Life Cycle Data System (ILCD) Handbook [6].

The process of conducting an LCA consists of few steps and the initially step is the goal of study; objectives of the study (intended application) and targeted audiences. Then, the scope of study consists of functional unit, system boundary, the justification of the system boundary, and distribution procedures. Next, life cycle inventory includes data assessment such as location coverage, raw material sources, relation data to functional unit, data quality, data uncertainty, and data disaggregation. Then, life cycle impact assessment and lastly life cycle interpretation provides restriction and recommendation of the study [15, 16]

3 Comparison Results and Analysis

Table 1 shown an overview of origin and research product that has been reviewed and the research papers selected mainly are concrete and cementitious related materials.

The checklist of LCA procedure according to the ISO standard has been retrieved from previous research paper [15]. Table 2 shown the results comparison of all these ten LCA for cement and concrete to ISO standard guidelines.

3.1 Goal

Definition of the goal of study must be defined in early stage of the study and clearly state. A research without clear definition goal of study will influence the methods and its impact assessment [16]. All of the research paper reviewed clearly state the goal of study and the main goal of LCA study is to evaluate the potential environmental benefits and material sustainability due to alteration or substitution materials in the cement mixture. The impact of biomass secondary cementitious material or ecological aggregates added in the cement mixture to produce concrete were caught the researcher's interest besides the impact of waste management (resource) and human health.

Table 1 Overview of LCA studies

Origin	Product	References
Campania, South Italy	Concrete mixtures using recycle aggregate i.e., marble sludge, incinerator ashes, blast furnace slag, and construction and demolition waste (CDW)	[11]
Qatar	Cement mortar (waste carbon black, WCB)	[14]
Western Europe	Portland cement	[10]
Chile	Supplementary cementitious material (copper treated tailings, TT)	[17]
Brazil	Wood bio-concrete	[12]
Ontario, Canada	Concrete mixture, supplementary cementitious materials (i.e., slag, silica fume and metakaolin)	[18]
Netherlands	Cement mortars, secondary cementitious material (biomass fly ash)	[6]
Malaysia	Concrete (Mixture of Granulated Blast-Furnace Slag, GBFS and fly ash, FA)	[19]
United State (11 western state)	Mixed mortar (containing the 13 different blended binders)	[20]
United Kingdom	Concrete mix designs: 100% PC and various ratio of CEM II and CEM III with FA and GBFS	[21]

Intended audiences was neglected by most of researchers, only few papers clearly address the intended audiences that will provide them new insights from these environment assessment reports. The targeted audiences included are policymakers, concrete manufacturers, the construction industry and academics, future developer and building designer will benefits on the environmental implications of replacing conventional material [12, 18].

3.2 Scope

Generally, the scope of study consists of functional unit, system boundaries and assumption or scenario to rationale the system boundaries. Functional unit and system boundaries have been identified in all paper research, but the rationale for the system boundary is not clearly stated in most papers. The functional unit is known as the reference to which inputs and outputs are related and ensure the reliability of LCA results for alternative projects. Meanwhile, the system boundaries limits which unit processes should be included within the LCA, cut-off criteria, application reliability and the hypothesis made [5]. LCA is increasingly being used to analyse the potential implications of various waste and residue treatment methods [22].

Table 2 Results comparison between 10 LCA research papers to ISO standard guidelines

ISO standard guidelines	10 LCA research papers		
	State unambiguously	State but not clear	Not defined
Goal			
Objectives of the study	10		
Targeted audiences	2		8
Scope			
Functional unit	7		3
System boundary	8	1	1
Rationale of system boundaries	5	4	1
Explicit allocation procedures	2		8
Life cycle inventory			
Time-related, technology coverage, geographical	6	4	
Sources of data inventory; *Primary sources* *Secondary sources*	8 6	4	2
Uncertainty of data/information	4		6
Relation of data—functional unit	3	2	5
Quality data assessment; *Completeness analysis* *Consistency analysis* *Sensitivity analysis*	3	1 1	9 10 6
Data disaggregation	1	9	
Life cycle impact assessment			
Impact models (indicators, categories, and characterization)	9	1	
Classification of LCI results	8	1	1
Characterization of category indicator results (calculation)	9	1	
Life cycle interpretation			
Identification of the significant issues (LCI or LCA results)	7	2	1
Conclusion	9	1	
Limitation	5	3	2
Recommendation	6	2	2

3.2.1 Functional Unit

Functional unit quantifies the primary function by providing a basis of comparison to the input and output data. This reference is particularly important when comparing different systems to approve that such evaluations are made on a constant basis [16].

In cement and concrete studies, the functional units are commonly compared on a volume basis as 1 cubic meter (1 m^3) and material properties such as compressive strength, mechanical strength, workability, and durability [18]. There are some hypothesis or assumption being made to ensure the comparisons unit valid such as the cement content and the functional performance of the concrete were constant [11], biomass enter to the systems with zero burden assumption [6] and concretes were sold in volumetric basis [21].

3.2.2 System Boundaries

The system boundaries is the interface between the product and the environment system and also define the processes and life cycle stages [23]. It defines which activities will be included in the product system and is usually clearly illustrated. For concrete and cement production, the processes in the system boundary include energy, environmental discharges, and flows of material (inputs and outputs) [10]. Commonly researcher choose cradle-to-gate model system [17]. Six of the research papers illustrated the system boundaries and one research paper refer system boundaries as reference scenario.

3.3 Life-Cycle Inventory (LCI)

The LCI step includes producing an inventory of flows from and to nature for a product system and all system boundary's unit processes are quantified [16]. Inventory tables usually are extensive and it begin with the contributions and productions throughout the life cycle will be compiled and quantify, and then feed data into the software. This should include all of the materials and processes that were defined in the system boundary. Finally, after the various processes, the calculation of tabulated numerical values of the inputs and outputs will be displayed related to the concern of the environmental impact [21].

LCI information generally derived from two sources: primary data and secondary data and researcher can be used one or two sources for LCA and must be related to functional unit [15]. Most of researcher conducted the LCI primary data in laboratory, Environmental Product Declaration (EPD), during inspection to the manufacturing and recycling sites. If the primary data unavailable, the researcher were opted to use database such as Ecoinvent from SimaPro and database of GaBi software.

Sensitivity analysis has been done for data quality assessment because several assumptions were made during research. To assess the influence of these assumption, the most sensitive parameter must be identified. Four of the research papers completed the sensitivity analysis including of these parameters; transportation distance [17], constrained SCMs [18], leaching from second life, density leaching from landfill, infiltration rate, layer, production of additional OPC [6], various fuels used in the calcination and allocation processes of biomass [12]. Another data quality assessments are consistency analysis and completeness analysis, none of researchers done the consistency analysis and only one researcher done completeness analysis which provide information is sufficient to reach conclusions. A good quality of dataset should provide all three types analysis for data quality assessment.

3.4 Life-Cycle Impact Assessment (LCIA)

The LCIA assesses the impact of operations on the environment, resources, and human health by categorization and characterization of LCI results. The significance of the potential impacts can be understood and evaluated throughout its life cycle and completed in four steps; classification, characterization, normalization and weighting [11]. This will aid in determining the significance of data and its association with various impact categories. The impact mostly considered by researcher are on environmental categories such as Global Warming Potential (GWP_{100}), Potential of Photochemical Oxidation (POCP), Ozone Depletion Potential (ODP), Eutrophication Potential (EP), Acidification Potential (AP), Abiotic Depletion of Elements (ADP-e), and Abiotic Depletion of Fossil Fuels (ADP-ff) [12]. Some researchers were evaluated the impact of greenhouse gas (GhG) emission, cost and energy saving but the most popular impact is Global Warming Potential (GWP_{100}) with 7 out of 10 research papers. The impact assessment categories by all research papers were responded to the goal of the studies which related to environmental impacts.

3.5 Life Cycle Interpretation

Life cycle interpretation conclude the understanding of result accuracy and ensure the goal of the study achieved. This systematic technique can be accomplished by categorising the data elements that contribute significantly to each impact category, assessing the sensitivity of these significant data, evaluating the completeness and consistency of the study, drawing conclusions and recommendations based on the LCIA results were developed [16].

Identification of LCIA results in accordance with the goal and scope definition determine the significant issues raised in the study. There are few issues that being state in the research papers such as lack information on region context [17], uncertainty of leaching data from uncontaminated biomass ash [6], technical and economical aspect [11]. Next, the researchers will evaluate the issue, conclude the LCA findings and released the recommendation for the intended audiences. The research on LCA has a great implication into concretes and cementitious materials studies since majority agreed with the LCIA results showed low environmental impacts with alteration/ substitution materials on OPC.

4 Conclusions

In this article, the LCA studies on cementitious material and concrete have been comparing to ISO guidelines to ensure the information obtained for the LCA study is appropriate. In all studies, the waste used on construction materials has been shown promising potential and proven to reduce environmental consequences. Although the target audience has been disregarding in their studies, most researchers are clear about the goal of the LCA study since it is critical to set the objectives before starting the analyses. All the potential findings will be impractical in the real world due to the lack of a targeted audience indicated in the research papers. Global warming and other environmental impacts can also be reduced if the potential results and solutions can reach the right audience. Another incomplete issue by researchers is data quality assessment; the researchers failed to disclose the completeness, consistency, and sensitivity analyses in their studies. In the future, researchers are advising to complete these analyses to improve the data assessment quality and fulfilled all the ISO guidelines.

Acknowledgements This work was supported and funded by the Ministry of Higher Education (MOHE) under Fundamental Research Grant Scheme (FRGS/1/2019/WAB05/UTM/02/7) and Universiti Teknologi Malaysia under UTMShine Signature Grant (Q.J130000.2451.07G91).

References

1. Nwankwo CO, Bamigboye GO, Davies IEE et al (2020) High volume Portland cement replacement: a review. Constr Build Mater 260
2. Singh N, Bhardwaj A (2019) Reviewing the role of coal bottom ash as an alternative of cement. Constr Build Mater 233:117276
3. Zain H, Abdullah MMAB, Hussin K et al (2017) Review on various types of geopolymer materials with the environmental impact assessment. MATEC Web Conf 97
4. Huber F, Laner D, Fellner J (2018) Comparative life cycle assessment of MSWI fly ash treatment and disposal. Waste Manag 73:392–403
5. Li J, Xiao F, Zhang L, Amirkhanian SN (2019) Life cycle assessment and life cycle cost analysis of recycled solid waste materials in highway pavement: a review. J Clean Prod 233:1182–1206
6. Tosti L, van Zomeren A, Pels JR et al (2020) Life cycle assessment of the reuse of fly ash from biomass combustion as secondary cementitious material in cement products. J Clean Prod 245(118937):1–10
7. Zhao Y, Yu M, Xiang Y (2020) A sustainability comparison between green concretes and traditional concrete using an energy ternary diagram. J Clean Prod 256
8. Khoshnava SM, Rostami R, Zin RM et al (2020) The role of green building materials in reducing environmental and human health impacts. Int J Environ Res Public Health 17(7)
9. Balaguera A, Carvajal GI, Albertí J et al (2018) Life cycle assessment of road construction alternative materials: a literature review. Resour Conserv Recycl 132:37–48
10. Morsali S (2017) Emissions from Portland cement production using life cycle assessment inventory and method. Environ Energy Econ 1(1):1–8
11. Colangelo F, Forcina A, Farina I et al (2018) Life cycle assessment (LCA) of different kinds of concrete containing waste for sustainable construction. Buildings 8(5):1–12

12. Caldas LR, Da Gloria MYR, Pittau F et al (2021) Environmental impact assessment of wood bio-concretes: Evaluation of the influence of different supplementary cementitious materials. Constr Build Mater 268:121146
13. Vargas F, Lopez M, Rigamonti L (2020) Environmental impacts evaluation of treated copper tailings as supplementary cementitious materials. Resour Conserv Recycl 160:104890.
14. Irshidat MR, Al-nuaimi N, Ahmed W et al (2021) Feasibility of recycling waste carbon black in cement mortar production: environmental life cycle assessment and performance evaluation. Constr Build Mater 296:123740
15. Lu H, Masanet E, Price L (2009) Evaluation of life-cycle assessment studies of Chinese cement production. Challenges and Opportunities. California
16. Hernandez P, Oregi X, Longo S et al (2018) Life-cycle assessment of buildings. In: Handbook of energy efficiency in buildings: a life cycle approach. Elsevier Inc., 207–261 pp.
17. Vargas F, Rigamonti L (2020) Environmental evaluation of treated tailing as supplementary cementitious material. Proc CIRP 90:280–284
18. Arrigoni A, Panesar DK, Duhamel M et al (2020) Life cycle greenhouse gas emissions of concrete containing supplementary cementitious materials: cut-off vs. substitution. J Clean Prod 263:121465
19. Huseien GF, Shah KW (2020) Durability and life cycle evaluation of self-compacting concrete containing fly ash as GBFS replacement with alkali activation. Constr Build Mater 235:117458
20. Li J, Zhang W, Li C, Monteiro PJM (2020) Eco-friendly mortar with high-volume diatomite and fly ash: performance and life-cycle assessment with regional variability. J Clean Prod 261:121224
21. Tait MW, Cheung WM (2016) A comparative cradle-to-gate life cycle assessment of three concrete mix designs. Int J Life Cycle Assess 847–860
22. Tosti L, van Zomeren A, Pels JR et al (2020) Life cycle assessment of the reuse of fly ash from biomass combustion as secondary cementitious material in cement products. J Clean Prod 245
23. Crossin E (2012) Comparative life cycle assessment of concrete blends

A GIS-Based Seismic Hazard and Building Vulnerability Assessment for an Earthquake Scenario in Chennai Utilizing a Structural Approach

Ahamed Ibrahim Mohammed Ikhlas, Achuthan Geetha Ishwrya, Pulipakkam Sridhar Balaji, and K.P. Jaya

Abstract A city's hazard mitigation plan requires an assessment of building susceptibility and a thorough seismic analysis. To contribute to the seismic analysis of the Chennai city, this study is done as an attempt to evaluate the vulnerability of every building prone to earthquakes. The design base shear was compared with the base shear calculated from peak ground acceleration to understand the effectiveness of the design base shear. The base shear for the buildings was predicted with the help of support vector regression, accuracy of the predictions with respect to the design base shear is found which was further used in the evaluation of modelled buildings' base shears. Support Vector Regression was primarily used as it considers all data for fitting, giving an apt relationship between the variables considered, whereas interpolation will consider only the nearest two values. The structures closer to the ocean are safer than those further inland in Chennai. The approach of prediction was shown to be more effective for structures with less storeys, and it may be applied to future buildings in Chennai as well as other cities with comparable soil characteristics, allowing the city to adjust to future changes.

Keywords Seismic hazard analysis · Geographic information system · Support vector regression · ETABS

1 Introduction

Earthquakes are low probability-high consequence events which can potentially cause extensive damage, particularly in large cities with areas of complex infrastructure and high population density. Due to the injuries, fatalities and financial damages that earthquakes cause in prone regions, the estimation of seismic activity in urban areas is important. Recent advancements in digital communication and seismic sensor technology make it possible to build reliable seismic hazard analysis

A. I. Mohammed Ikhlas · A. G. Ishwrya · P. S. Balaji (✉) · K.P. Jaya
Division of Structural Engineering, Department of Civil Engineering, Anna University, Chennai, Chennai 600025, Tamil Nadu, India

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_35

systems. However, development of seismic engineering technologies will never get rid of earthquake disasters [1, 2].

2 Design and Methodology

The significant parameters of a building such as number of storeys, area, length, width and the height of the buildings required for the study have been concluded from an intensive study of the literature and publicly available datasets. Collection of datasets of the identified parameters is done by utilizing the government maintained websites, open source web pages providing building and geographic data and literature [3, 4]. ArcGIS software is used as the base for extraction. Seismic analysis (static and dynamic) is carried out after the collection of data and compared.

2.1 Seismic Analysis

2.1.1 Static Analysis

The initial step in static analysis involves calculating design seismic base shear by following IS 1893 [5]. The formula for calculating Seismic Base Shear is given as,

$$V_b = A_h W \tag{1}$$

$$A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)} \tag{2}$$

$$Sa = 2.65 \times \text{Peak Ground Acceleration} \tag{3}$$

where

V_b—Seismic base shear, A_h—Design horizontal acceleration coefficient, W—Seismic weight of the building, Z—Zone factor, I—Importance factor, R—Response reduction factor, S_a/g—Average response acceleration coefficient.

After the design base shear has been calculated using IS recommended procedure, the base shear calculation using peak ground acceleration was found by replacing the Average Response acceleration coefficient with the value obtained from the empirical relationship [6].

2.1.2 Dynamic Analysis

An initial data set of 120 buildings with areas ranging from 40 to 5000 m^2 with various aspect ratios were created and analyzed dynamically using the structural analysis software, ETABS. The variables maximum displacement, maximum stiffness, maximum overturning moment, maximum story drift along with the base shear of the structure have been calculated. The maximum seismic base shear is noted at the completion. The parametric values for all the buildings in the entire study area are calculated using support vector regression and is compared with the parametric data obtained from static analysis.

3 Prediction of Seismic Base Shear Using Support Vector Regression (SVR)

Base shear, V_b values are predicted by machine learning technique, support vector regression [7], which is a type of Support Vector Machine. The SVM formulated for this study is a quadratic programming problem with linear constraints as opposed to traditional Neural Networks. The generic support vector regression estimating function is in the form of [8]

$$f(x) = (w \cdot \varphi(x)) + b \tag{4}$$

$$R_{reg}(f) = C\sum_{i=0}^{i} \mathrm{r}(f(x_i) - y_i) + \frac{1}{2}||w||^2 \tag{5}$$

where r() is a cost function, C is a constant, and vector w with the objective of reducing the regression risk. The cost function used is the ε-insensitive loss function. The effectiveness of a support vector regression model is determined based on the R-squared value. The values which were tested are C values from 1 to 100 and Epsilon values from 0.05 to 1 in intervals of 0.05. After fitting the optimal curve, the seismic base shear for the buildings of the study area were predicted.

The various parameters from the modelled buildings and study area buildings which were of easy access are Area and Aspect Ratio. We have tried to also incorporate no. of storeys from 1 to 5 storeys. From the hyper-tuning, the parameters were taken as, C = 74 and epsilon = 0.05; The R-squared value or coefficient of Determination was 0.71 for the training data even though it is near the optimal fit value of 0.85, it still can be improved with more data. From this model, the Base shear values for the buildings were predicted.

4 Results and Discussion

The three base shears have been computed and correlated by performing seismic analyses, following the above mentioned methodology.

4.1 Static Analysis

4.1.1 $\mathbf{V_{bdesign}}$ Versus $\mathbf{V_{bpga}}$ Map Analysis

The design seismic base shear ($\mathbf{V_{bdesign}}$) and PGA based seismic base shear ($\mathbf{V_{bpga}}$) are compared in Fig. 1, by finding the percentage deviation from PGA based seismic shear to the design base shear. Closer the $\mathbf{V_{bpga}}$ is to the $\mathbf{V_{bdesign}}$, more vulnerable that building is considered to be, as $\mathbf{V_{bpga}}$ is the base shear which is likely to occur in the event of an earthquake. Hence a greater $\mathbf{V_{bdesign}}$ would mean the buildings designed are safer. Since an accurate building height data of the city was not available, 5 situations have been considered where each building in the study area is from 1 to 5 storeys.

A similarity amongst the maps can be noticed, as the fundamental period of vibration for the buildings tends to lie between 0.10 and 0.67 whereas the IS code recommends a constant value for the average response acceleration coefficient of

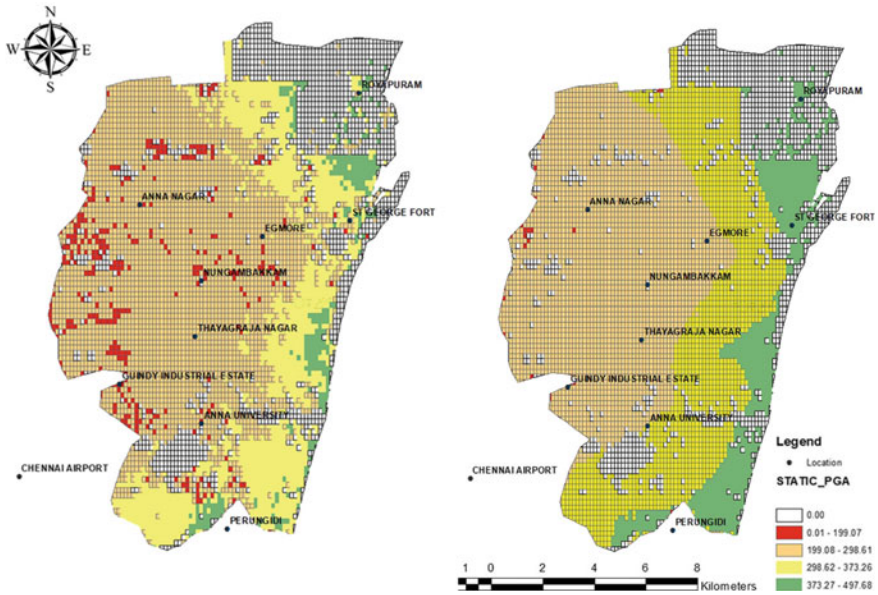


Fig.1 $\mathrm{V_{bdesign}}$ versus $\mathrm{V_{bpga}}$ for 1 storey buildings (left) and 5 storey buildings (right)

2.50. The average of the percentages in each grid area are taken into consideration. The regions which are red in color, have $\mathbf{V_{bpga}}$ closer to the $\mathbf{V_{bdesign}}$, and have buildings which are more prone to earthquake damage as their design base shear itself is very close to the actual $\mathbf{V_{bpga}}$. These are densely in the western parts of the study, and are recommended to be further analysed for seismic behaviour as they are the most prone of the available data.

4.2 Dynamic Analysis

The predicted base shear value from the support vector regression and the design Base shear are compared in Fig. 2, to understand the accuracy of the regression model. The percentage deviation of the predicted base shear from the design base shear is taken and averaged for the grid location. From Fig. 2, it can be observed the error occurring in the 4 story and 5 story maps are very much similar with a slight increase in 5 story as the Static analysis tends to produce similar values of horizontal acceleration coefficient (A_h). These maps depict the accuracy of the model, the range of buildings which are around 65% similar to the design base shear has been considered accurate.

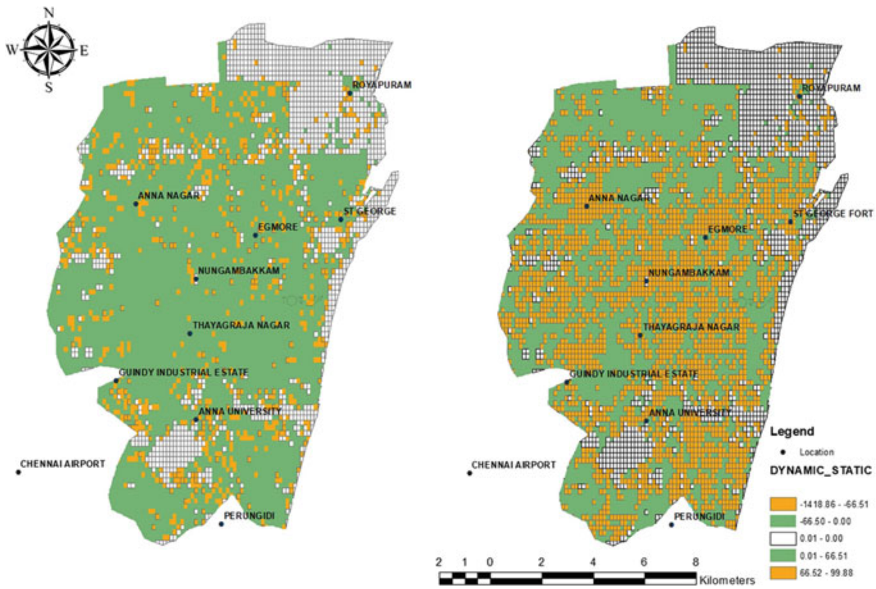


Fig. 2 Comparative maps of predicted and design base shears—1 storey (left) and 5 storey (right)

5 Conclusion

The model has been created in order to predict the base shear of buildings more rapidly and was trained using modelled buildings. This predicted base shear was compared to the design base shear to understand the accuracy of the predictions with respect to the design base shear. From the maps, it can be inferred that the buildings in Chennai are relatively safer closer to the coast than inland. The method of prediction was found more effective for buildings with less number of storeys and can be utilized for other cities with similar soil conditions as well as future buildings in Chennai itself and hence can adapt to future changes to the city.

In continuation with the work, the support vector regression model performs better by feeding more data and can further be extended to various regions of study. Various shapes and aspect ratios for existing storeys can be included while calculating the design base shear and the PGA based base shear. Soil type can be considered as one of the parameters for support vector regression.

References

1. Takagi J, Wada A (2019) Recent earthquakes and the need for a new philosophy for earthquake-resistant design. Soil Dyn Earthq Eng 119:499–507
2. Karimzadeh S, Miyajima M, Hassanzadeh R, Amiraslanzadeh R, Kamel B (2014) A GIS-based seismic hazard, building vulnerability and human loss assessment for the earthquake scenario in Tabriz. Soil Dyn Earthq Eng 66:263–280. https://doi.org/10.1016/j.soildyn.2014.06.026
3. Boominathan A, Dodagoudar G, Suganthi A, Uma Maheswari R (2008) Seismic hazard assessment of Chennai city considering local site effects. J Earth Syst Sci 117(S2):853–863. https://doi.org/10.1007/s12040-008-0072-4
4. Ganapathy G, Rajawat A (2012) Evaluation of liquefaction potential hazard of Chennai city, India: using geological and geomorphological characteristics. Nat Hazards 64(2):1717–1729. https://doi.org/10.1007/s11069-012-0331-1
5. IS 1893: criteria for earthquake resistant design of structures
6. Booth E (2007) The estimation of peak ground-motion parameters from spectral ordinates. J Earthquake Eng 11(1):13–32. https://doi.org/10.1080/13632460601123156
7. Smola A, Schölkopf B (2004) A tutorial on support vector regression. Stat Comput 14(3):199–222. https://doi.org/10.1023/b:stco.0000035301.49549.88
8. Drucker H, Burges CJC, Kaufman L et al (1997) Support vector regression machines. In: Advances in neural information processing systems, vol. 9, NIPS 1996, MIT Press, pp 155–161

Boutique Hotels Within Heritage Shophouses in George Town: Understanding Adaptive Reuse Through Existing Interior Layouts

Muhammad Firzan, Rani Prihatmanti, Shafiq Falil Johari, Tan Sin Ning, and A. Ghafar Ahmad

Abstract Adaptive reuse has been an emerging means of conservation and commodification of built heritage worldwide. Its implementation is associable with the thrive in tourism industry for UNESCO World Heritage Site (WHS) localities. As seen in George Town WHS of Malaysia, conversion of heritage shophouses to function as boutique hotels is one of the common trends. However, observation and documentation on the physical impact of such cases are in sparse mode, thus compels the execution of this exploratory study. A preliminary inventory to identify heritage shophouses that legitimately met the meaning and criteria of a boutique hotel was performed, prior to conducting field observation to record the physical changes and modifications. Consequently, five buildings were identified and further scrutinised through field observation that gave special emphasis on their new interior layout. It is found that spatial provisions such as reception and lobby area, guest rooms, and *en suite* bathroom are inevitable for repurposing heritage shophouses into boutique hotels. Besides, integration of swimming pool was uncommon while setting up a rooftop garden was unlikely, implying from the collective cases.

Keywords Adaptive reuse and retrofit · Boutique hotels · Building interiors · City cultural heritage · Heritage shophouses

1 Introduction

Adaptive reuse intervention has been an emerging means of conservation and commodification of built heritage worldwide. It became favourable for reviving physical, functional, and financial aspects of underutilised or physically worn buildings. It is fair to claim that the thrive in tourism industry for localities revered as UNESCO World Heritage Site (WHS) can be associated with adaptive reuse implementation.

M. Firzan (✉) · R. Prihatmanti · S. F. Johari · T. S. Ning · A. Ghafar Ahmad
School of Housing, Building and Planning, Universiti Sains Malaysia, George Town, Malaysia
e-mail: firzan@usm.my

R. Prihatmanti
School of Creative Industry, Universitas Ciputra Surabaya, Surabaya, Indonesia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_36

In the WHS of Malaysia, heritage shophouses in George Town and Melaka carry profound significance in relation to the Outstanding Universal Values (OUVs). One of the common trends of adaptive reuse seen, particularly in George Town WHS, is the conversion of heritage shophouses to function as boutique hotels. However, the arduous meaning and legitimate criteria of a boutique hotel have been much debated previously. Besides, it is of very little evidence available currently on the observation and documentation of physical impact committed to heritage shophouses that have undergone adaptive reuse to boutique hotels. Acknowledging so, this exploratory study is purposed to identify the heritage shophouses that legitimately met the meaning and criteria of a boutique hotel. Subsequently, it records on the physical changes and modifications occurred to heritage shophouses in functioning as a boutique hotel, with special emphasis on their new interior layouts. Anticipatedly, the study will update on the legitimate boutique hotels that are still operational in George Town WHS despite the recent struck of unprecedented COVID-19 pandemic to the tourism sector. Moreover, it will shed lights on the physical impact on heritage shophouses resulting from their adaptive reuse to boutique hotels. The subsequent section dissects and synthesises past literature concerning the baseline design of heritage shophouse mainly within the context of the research locale namely George Town WHS, followed with comprehending boutique hotel legitimately, as well as matters on repurposing heritage shophouses to serve the functions associated with boutique hotel.

2 Literature Review

Traditionally, shophouses in George Town were urban building built with mixed use functions—commercial and residential. The ground floor serves as the business premise (usually a family business) and dwellings on the upper floor. This spatial arrangement not only provides shelter, but also convenience and security [1, 2]. Shophouses were built in rows with shared party walls and interconnecting five-foot walkway in the front with narrow façade (6–7 m width). It has a deep rear that reach 30 m and it could extend up to 60 m [3]. Due to the length, air well is presence to control the ventilation as well as to illuminate the interior space (Fig. 1). Heritage shophouse possessed a historical urban building typology which formed and developed over 200 years ago. These heritage shophouses were connected along the veranda namely five-foot way facing the main road. Generally, it claimed to have business premise at the ground floor area while the accommodation chambers are located at the upper level [4].

A shophouse commonly built as a single, double or triple storey building which depends on the architectural style of the construction period. In George Town, there are main six architectural styles as illustrated in Fig. 2. The first four styles (Early Penang style, Southern Chinese Eclectic style, Early Straits Eclectic style, and Late Straits Eclectic style) were constructed before the Second World War, hence it is

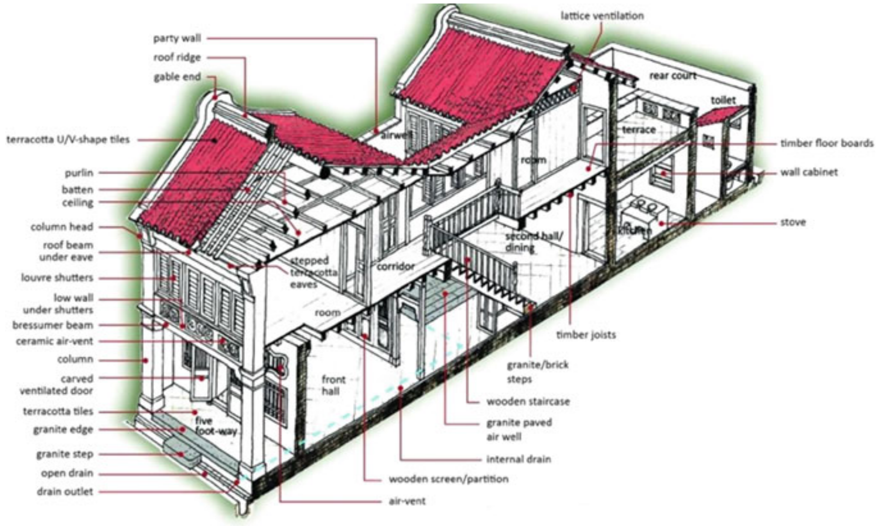


Fig. 1 Typical features of a Southern Chinese eclectic style shophouse [5]

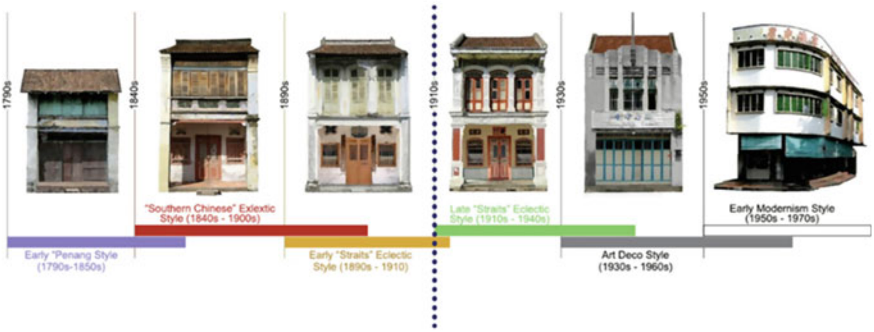


Fig. 2 Architectural styles of shophouses in George Town [2]

commonly known as the pre-war shophouse. After the Second World War, shophouses with Art Deco style and Early Modern style were built based on the socioeconomic changes and technology development that grew in Penang [1]. The dominating styles that are applied on the shophouse boutique hotels in this research are the 'Southern Chinese' Eclectic Style (1840s–1900s) and the 'Early Straits' Eclectic Style (1890s–1910s). During the pre-war era, the shophouses were constructed based on the local knowledge and the building construction method was brought by the immigrants from the southern coastal province of China which then adapted to the shophouses in Penang. Therefore, it is a combination of vernacular, European as well as Chinese cultural influences. These cultural influences create a unique yet exceptional building styles which reflects in the OUV criteria (iv) [2].

Since the inscription of the UNESCO World Heritage Site in 2008, Penang is struggling to maintain the authenticity of these shophouses. The Penang State Government (Majlis Bandaraya Pulau Pinang/MBPP) together with the George Town World Heritage Incorporated (GTWHI) and local NGO such as Penang Heritage Trust (PHT) are closely monitoring any alteration on the building fabrics as well as the interior layout of the shophouses. Any protection, preservation and conservation works, including adaptive reuse, must comply to the standard, i.e. Special Area Plan (SAP) of George Town. This guideline provides a full statement of the government's policy for protection of heritage buildings, conservation areas and other historic elements within the George Town WHS. It is a requirement for any adaptive reuse practice in commodifying the heritage shophouses into boutique hotels to issue HIA report. It is used to describe the compatible development and new use projects as well as for assessing the impact of OUVs of the site. According to the SAP of George Town, the shophouses within the WHS are categorised as Category II—"buildings, objects and sites of special interest that warrant every effort being made to preserve them" [2].

After being listed as the WHS, many pre-war buildings, such as traditional shophouses and heritage mansions, were adaptively reused into boutique hotels to accommodate the tourists. This commodification has emerged to increase the economic and tourism sector in WHS in the form of transforming goods, services or ideas into an extended economic value. Consequently, the number of boutique hotels was increasing due to the market demand since the year 2008 [6, 7]. An important aspect of concern when rehabilitating the shophouses into boutique hotels is to maintain its significant historical architecture characteristics and values held within the building fabrics. However, new facilities and space functions are necessary for the retrofit of heritage shophouse to boutique hotel as they served a different building purpose. Therefore, the proposal of new space requirements for the boutique hotel has to be based on their selection of services provided to meet the guest's activities. For facilities and public spaces wise, few accommodation quarters, bar counter, restaurant and dining area are the basic needs of interior space to serve as a hotel. Besides, there are some supportive facilities such as administration office, housekeeping room, security room and reception counter are required for management purpose [4].

Several previous studies have been conducted to determine the most suitable criteria of boutique hotels in George Town WHS. According to Khosravi, Malek and Ekiz [8], the most attractive attributes are special services, room features, convenience, and the hotel design. The guests prefer to receive individualised and personalised services from the friendly staff in a homely and comfortable environment. The uniqueness on the interior and architecture of boutique hotels creates a dramatic impression to the guests. As stated in earlier studies, layout and decorations of the hotel room, particularly the hotel lobby, are essential factor in creating customers' experience during their stay [8–10]. Although commonly situated in old buildings, high tech facilities in the room are required by the guests. Moreover, they also expect to engage in local activities offered by the hotel. In-house entertainment such as lounge and bar are considered as necessities. Price and location are also important attributes for the guests in selecting boutique hotels in George Town. Hence, easy access to the downtown and airport has always been a preference. To summarise, the characteristics of the boutique hotel in George Town are classified into the tangible and intangible values. The tangible values consist of the location, distinctiveness architecture design, premise size and number of rooms, uniqueness and dissimilarity of rooms, the features available in each room, and the hotel facilities offered. Meanwhile, image of the hotel as WHS branding, the historical origin and background, rare experience and facilities, specialised services provided, and the price are included as the intangible value of boutique hotel criteria.

It is imperative to cater guests' needs and fulfil hotel functional requirements while repurposing heritage shophouses to function as a boutique hotel. This is especially true when guest's satisfaction and their acceptance towards the boutique hotels are central for such business. Interestingly, boutique hotels are expected to provide a more personalised and distinguished experience as opposed to other type of hotels in the market [9, 11]. Thus, factors that contribute largely to guests' satisfaction and attraction towards boutique hotels as outlined by Khosravi, Malek and Ekiz [8] are deemed imperative which include convenience, room features, special services, and design element. To summarise, the criteria of boutique hotels in George Town is tabulated in Table 1 as follows:

3 Methodology

Initially, an inventory was performed to identify the actual number of boutique hotels located in the Core Zone of George Town WHS. The site inventory was conducted to list and identify converted heritage shophouses that qualify the legitimate meaning and function of a boutique hotel. Two days were taken to conduct the site inventory, covering the 109.38 ha of Core Zone of George Town WHS. Prior to the site inventory survey, the hotel names were searched earlier from their official websites as well as from the online travel agency for lodging reservations. As illustrated in Fig. 3, the hotels located in zone A and B were surveyed to validate the existence on the first day, followed by zone B and C on the second day. Unfortunately, some hotels were permanently closed due to the financial crisis caused by the COVID-19 global pandemic. First set of checklist which consists of name, address, building typology, and type of hotels was used when conducting the site survey. In total, there were 53 hotels surveyed within the Core Zone of the WHS.

Hotels which are categorised as a 'boutique hotel' and located in a pre-war shophouse were selected for this study, particularly the Southern Chinese Eclectic style. Table 1 presented earlier was used as the guidance to select the buildings for field observation. Based on that, there were six boutique hotels and only five were operating for business (Fig. 4). Field observation was then perfomed on each of the five buildings, involving three enumerators of built-environment background. Since archival documents and reports such as Heritage Impact Assessment (HIA) and copies of architectural drawings were not accessible due to confidentiality, informal interview with the hotel's proprietor and/or the staff in charge was also carried out to

Table 1 Key consideration aspects on the tangible values of a legitimate boutique hotel

Aspects			Author(s)
Tangible value	Location	Convenient to the airport	[8]
		Setting in the city centre	[6]
		Strategic location and nearby all attractions	
	Distinctiveness architecture design (heritage building)	Heritage building value (listed building)	
		Originally shophouse with an average of 3 storey premise	
		Uniqueness layout of heritage/pre-war premises	
		Restoration and re-adaptive reuse for contemporary uses	
		Architectural style	[7]
		Unique and distinctive concept and design	[12]
	Premise size and number of rooms	Small size of the premise	[6]
		Less than 50 rooms	
	Uniqueness and dissimilarity of rooms	Individualised	
		Every room offers different design	
		Different sets of furniture and decoration	
		Different theme in every boutique hotel	
		Antique collections and artwork inherited from the ancestors (furniture and interior décor)	[7]
	Room features	Availability of high-tech facilities in the room	[8]
	Hotel facilities	Library	[8]
		Gallery	
		Rooftop garden	
		Souvenir shop	
	Star rating	Three to five stars	[12]

probe historical background and physical interventions committed at those buildings. Basic measurements of the five buildings were also performed and the reproduction of the drawings of their new interior layouts followed suit. The field observation data is analysed based on intra-case (reporting changes and modifications observed at each of the building) and inter-case (cross-comparing spatial hierarchy, spatial zoning, and facilities provision of the five buildings) reviews.

1. You Le Yuen (Love Lane)
2. Seven Terraces (Argus Lane)
3. Mclane Boutique Hotel (Market Lane)
4. The Boutique Residence Hotel (Pitt Street)
5. Sweet Cili Boutique Hotel (Malay Street Ghaut)

Fig. 3 Location of boutique hotels involved in field observation. *Source* Modified from Penang Global Tourism [13]

Fig. 4 From left to right namely You Le Yuen (visited on May 1–2, 2021), Seven Terraces (visited on May 2–3, 2021), Mclane Boutique Hotel (visited on May 3–4, 2021), The Boutique Residence Hotel (visited on May 4–5, 2021), and Sweet Cili Boutique Hotel (visited on May 6–7, 2021)

4 Results and Discussion

Figure 4 shows the five boutique hotels in George Town shortlisted for field observation, found to be operational despite the unprecedented COVID-19 pandemic that has negatively affected the global tourism industry.

These buildings are similar in terms of their architectural style (Southern Chinese eclectic) as well as their number of floors (2 storeys height). Table 2 tabulates the changes and modifications observed at each boutique hotel. The floor plan of each site is attached in the Appendix 1 and the supporting figures are attached in

Table 2 Intra-case review on the changes and modifications observed

Case	Adaptive reuse remarks
You Le Yuen	• Made of one unit of shophouse building • Addition of reception area, souvenir shop, fitting room, and bar area at the front hall and the second hall of the first floor • Modification of the steepness and original position of the staircase (Fig. 5 in Appendix 2) • Addition of four guest rooms on the first floor and the mezzanine floor • Addition of *en suite* toilet on guest room 1, 2 and 3 on the first floor and guest room 4 on the mezzanine floor • Addition of new walls to segregate mini-kitchen and security room (Fig. 6 in Appendix 2) • Addition of security room and guest room 4 has occupied and enclosed the opening of the rear courtyard which is typically available in Straits Chinese eclectic style shophouse (Fig. 7 in Appendix 2)
Seven Terraces	• Made of nine units of shophouse building • The shophouses were 90% demolished when purchased, hence the central courtyard merged into one from 7 unit of shophouses (Figs. 8 and 9 in Appendix 2) • Addition of reception area, lobby, souvenir shop-cum-gallery, swimming pool, library at the poolside lounge, multi-purpose dining hall, Kebaya Restaurant, kitchen, staff area, office, exhibition area, furniture storage and workshop, garden, and swimming pool on the ground floor • Addition of 16 guest rooms (14 standard rooms and 2 apartments) and linen storage on the first floor • Each of the standard guest rooms are provided with semi outdoor balcony (Fig. 10 in Appendix 2) • Addition of mezzanine in each standard room, connected with wooden staircase (Fig. 11 in Appendix 2) and *en suite* toilet is provided in the mezzanine floor of the standard room (Fig. 12 in Appendix 2) • Addition of lift and spiral staircase for the hotel guests on the public area (Fig. 13 in Appendix 2) • Addition of 2 fire escape stairs on the left and right side of the building to comply the fire safety regulation • Addition of disabled restroom on the ground floor. However, the toilet failed to comply the standard • The rear part of the original building facing Argus Lane now become the main entrance of the hotel (Fig. 14 in Appendix 2). The original façades facing Lorong Stewart become the entrance of Kebaya restaurant and gallery-cum-souvenir shop

(continued)

Table 2 (continued)

Case	Adaptive reuse remarks
Mclane Boutique Hotel	• Made of four units of shophouse building • Addition of reception area at ground floor, guest room and storage rooms at the rear court (Figs. 15 and 16 in Appendix 2) • Addition of 8 guest rooms on the ground floor area and 14 guest rooms on the first floor area • Rear court have been newly constructed to accommodate storage rooms (Fig. 16 in Appendix 2) • The open courtyard of 4 row of shophouse is merged to create one open courtyard with a newly constructed guest room (Fig. 16 in Appendix 2) • Addition of *en suite* toilet in all guest rooms • Newly constructed concrete floor with finishes (terracotta/laminated wood floor) to accommodate new lounge, guest rooms on ground floor and first floor (Figs. 17 and 18 in Appendix 2) • Lounge is introduced as a public space on first floor on the fourth unit • Newly constructed partition wall to create guest rooms, storage rooms (Fig. 19 in Appendix 2) • Newly constructed staircases located at first and third unit of the shophouse as opposed to its original location (Fig. 20 in Appendix 2) • New staircase is constructed to access Room 22 (Fig. 21 in Appendix 2) • Walls are hacked to create continuous accessible corridor on both floors
The Boutique Residence Hotel	• Made of six units of shophouse building • Addition of lobby and reception area at ground floor (Figs. 22 and 23 in Appendix 2) • Now abandoned café with kitchen and bar at the ground floor (Fig. 24 in Appendix 2) • Swimming pool at the air well area (Fig. 25 in Appendix 2) • Air well on 4 unit of the shophouse (2 unit on the left and right side of the building row) has been closed to accommodate guest rooms (Room 2 and Room 9) and staircases • Newly constructed partition walls to accommodate the new spaces • Staircases are built anew and relocated at both left and right side at 2 unit of the shophouse (Fig. 26 in Appendix 2) • Concrete with terracotta tiles and laminated wood finishes corridor on the first floor (Fig. 27 in Appendix 2) • Polycarbonate roofing enclosure at the air well (Fig. 28 in Appendix 2) • Addition of toilet in each guest room (Fig. 29 in Appendix 2) • The addition of guest rooms (Room 1, 2, 9 and 10) on the first floor at the rear court space as well as the storage compartments

(continued)

Table 2 (continued)

Case	Adaptive reuse remarks
Sweet Cili Boutique Hotel	• Made of three units of shophouse building • Addition of reception area, lobby, pantry at ground floor and ample storage spaces for cleaning equipment and linen at first floor • Modification of staircase in terms of steepness, material, and type of staircase (Fig. 30 in Appendix 2) • Withdrawal of staircase for the second shophouse unit • Enclosure of air wells for the first and third shophouse unit to accommodate more guest room spaces • Addition of three guest rooms (1, 2, 3) at ground floor and five guest rooms (4, 5, 6, 7, 8) at first floor. All guest rooms are equipped with *en suite* toilet • Replacement of timber flooring into red-coloured seamless concrete floor for guest rooms at first floor (Fig. app 31) • Addition of polycarbonate overhang as roofing at the courtyard (Fig. 32 in Appendix 2) • Addition of glass panels at air vents and windows on the façade to insulate the interior space with exterior of hotel (Figs. 33 and 34 in Appendix 2) • Addition of single leaf glass door with electronic lock at the entrance for security purpose (Fig. 35 in Appendix 2) • Addition of new walls to segregate storage area (Fig. 36 in Appendix 2)

Appendix 2. Table 3 meanwhile presents the cross-comparison among the five buildings based on the spatial hierarchy, spatial zoning, and facilities provision.

5 Conclusions

Implying from the collective results, a certain degree of physical changes and modifications to the existing layout of heritage shophouses is necessitated in accommodating the new boutique hotel function. For such repurposing intervention, it is apparent that spatial alterations to cater guests' needs and fulfil a hotel functional requirement are inevitable. These, as seen in the new interior layouts, include:

- Revamping the front hall to accommodate reception and lobby area (for welcoming and facilitating guests in checking in and out of their stays),
- Erecting new walls mainly at the first floor to segregate the typical long and narrow shophouse interior (for creating guest rooms, which quantity is contributory to the revenue generation), and,
- Retrofitting additional sanitary and plumbing system (for equipping *en suite* toilet within each guest room, a paramount feature of a boutique hotel).

Table 3 Inter-case review on the cross-comparison of the five buildings

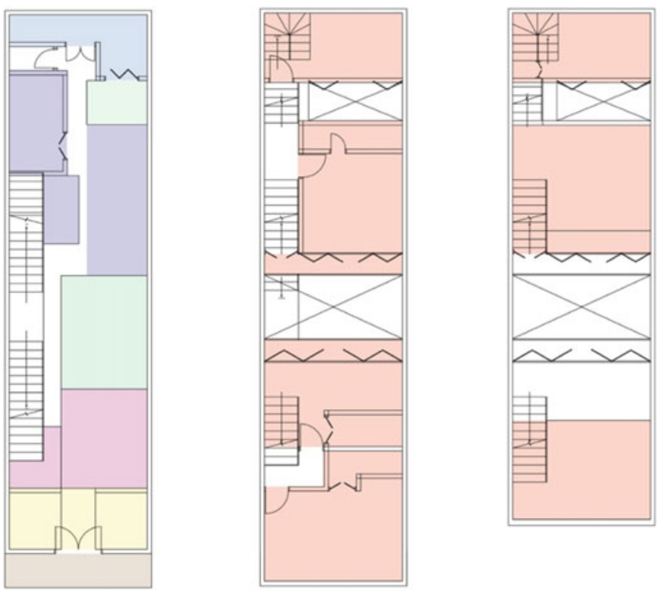
Aspect		You Le Yuen	Seven Terraces	Mclane Boutique Hotel	The Boutique Residence Hotel	Sweet Cili Boutique Hotel
Spatial hierarchy	Largest	Lounge and reading corner	Courtyard, Kebaya Restaurant	Open courtyard	Lobby, bar, swimming pool	Lobby
	Smallest	Kitchen	Linen storage	Guest Rooms (Room 6 and 7)	Toilet (ground floor)	Storage room
Spatial zoning	Public	Courtyard lounge, dining area, bar, rear courtyard	Lobby lounge, library/poolside lounge, Kebaya Restaurant, exhibition area, souvenir shop, courtyard	Lobby, open courtyard	Lobby, café, bar	Lobby
	Semi-public	Reception	Reception, swimming pool	Reception	Reception, swimming pool	Reception, courtyard
	Private	Guest rooms, security room	Guest rooms, staff area, furniture workshop, office	Guest rooms	Guest rooms, office, staff area	Guest rooms
	Service	Kitchen	Kitchen, store room (linen & furniture)	Storage rooms	Kitchen	Pantry, storage
Facilities provision	Library	Yes (Reading corner)	Yes (Reading corner)	None	None	None
	Gallery	None	Yes (Peranakan jewelleries, porcelain-ware, interior decors, and furniture)	None	None	None
	Rooftop garden	None	None	None	None	None
	Souvenir shop	Yes (Fashion boutique)	Yes (Peranakan jewelleries, porcelain-ware, interior decors, and furniture)	None	None	None
	Miscellaneous	Security room	Swimming pool, garden	None	Swimming pool	None

- Two out of the five buildings equipped their respective building with a swimming pool (one is within the internal space which is considerably an intrusive intervention to the existing cultural fabric).
- None of the buildings provided the facility of a rooftop garden, presumably unfeasible to be constructed and due to the importance to retain the original roof identity of heritage shophouse (identity of Southern Chinese eclectic style).

Inferably, both building owners and heritage consultants faced challenges in accomplishing the varying business and conservation needs while planning for such adaptive reuse implementation. It is suggested that this study is extended to other building typology other than heritage shophouses, besides expanded to cover beyond the Core Zone of George Town WHS to foster a better understanding on the physical impact of adaptive reuse on built heritage in a holistic manner.

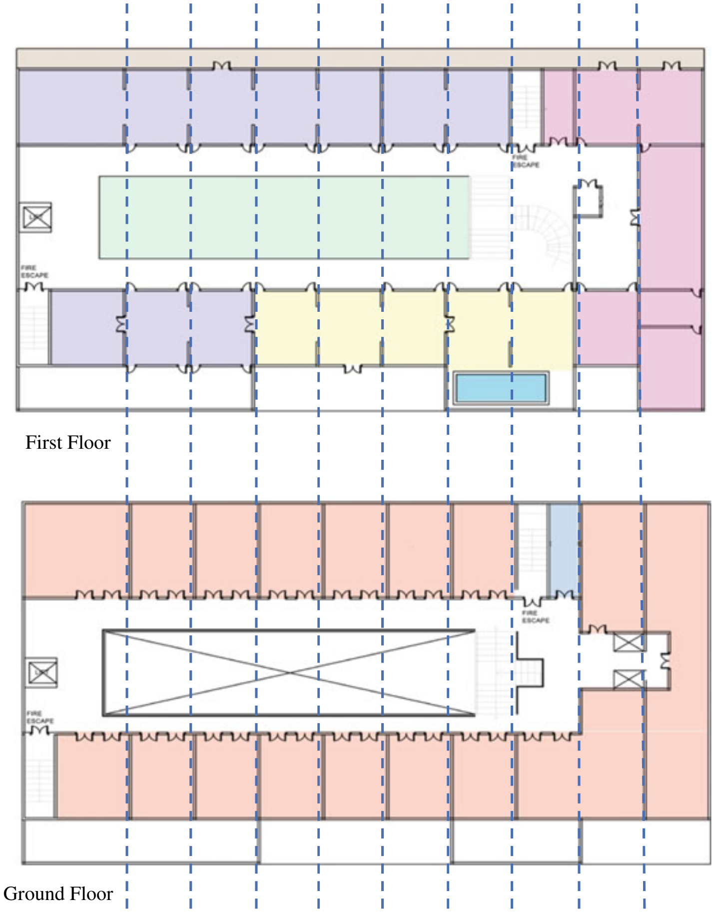
Acknowledgements The authors fully appreciate Universiti Sains Malaysia (USM) for funding this study under the Short-Term Grant (304/PPBGN/6315362) and the School of Housing, Building and Planning as well as other parties that have directly and indirectly contributed in this study.

Appendix 1

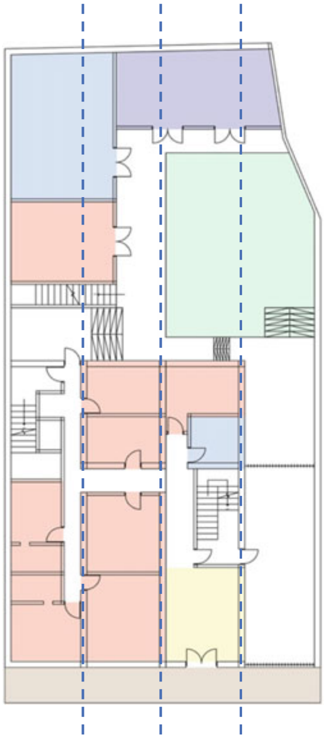


Ground Floor First Floor Mezzanine Floor

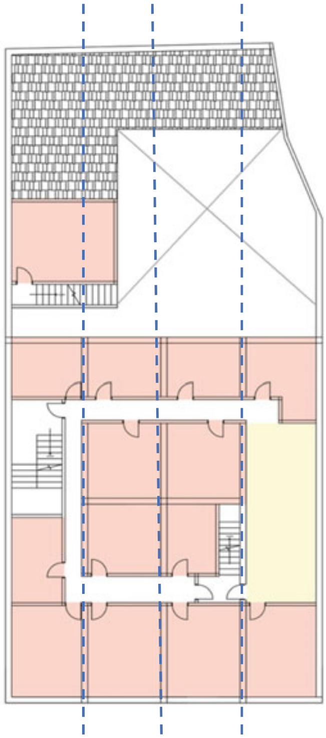
You Le Yuen



Seven Terraces

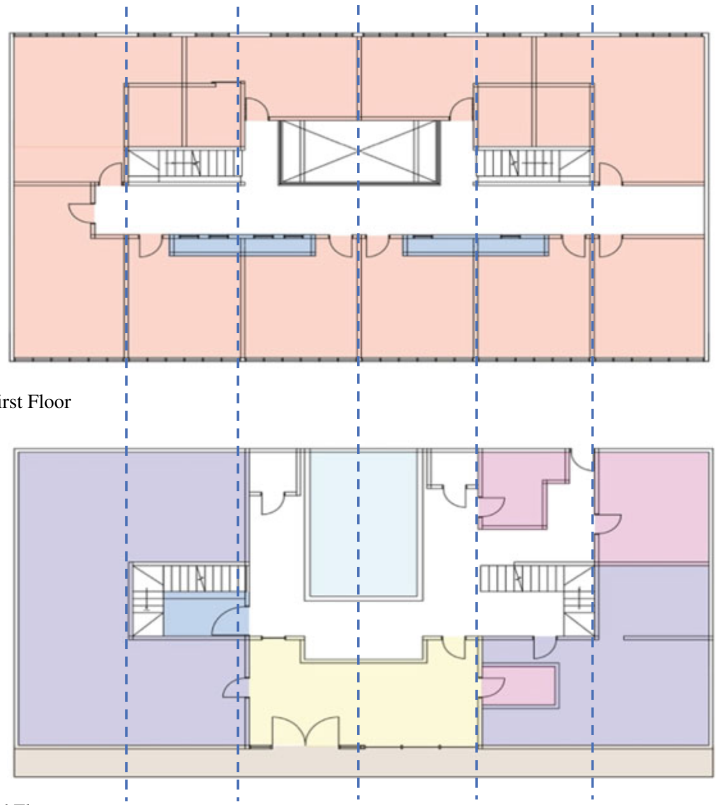


Ground Floor

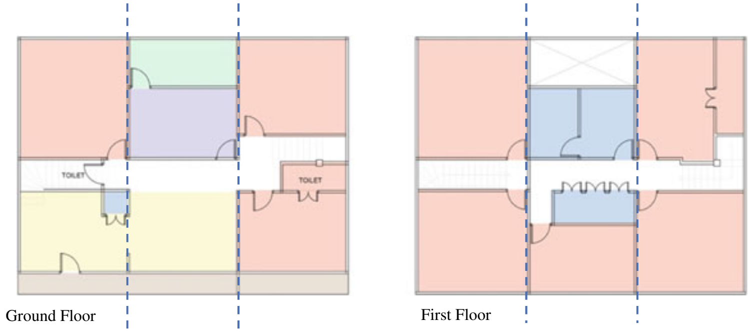


First Floor

Mclane Boutique Hotel



The Boutique Residence Hotel



Sweet Cili Boutique Hotel

Legend:

- Lobby/Reception/Lounge
- Guest room
- Dining area/Restaurant/Café/Bar/Kitchen
- Courtyard/Air well
- Border of the original shophouse
- Storage
- Office/Souvenir shop/Gallery/Workshop
- Five foot walkway
- Swimming pool

Appendix 2

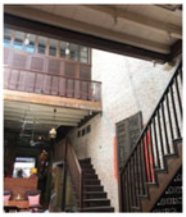
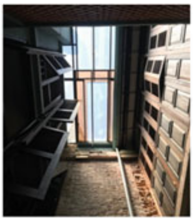
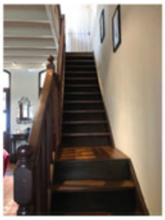
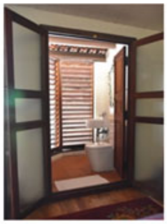
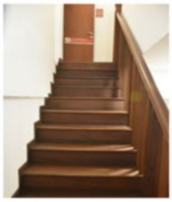
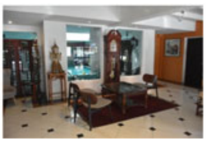
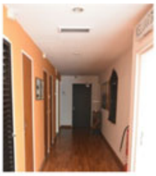
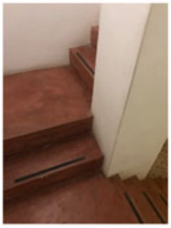
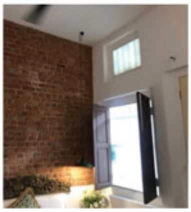
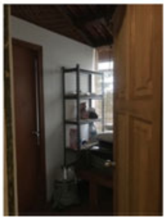
		

Figure 6	Figure 7	Figure 8	Figure 9
			
Figure 10	Figure 11	Figure 12	Figure 13
			
Figure 14	Figure 15	Figure 16	Figure 17
			
Figure 18	Figure 19	Figure 20	Figure 21
			
Figure 22	Figure 23	Figure 24	Figure 25

			
Figure 26	Figure 27	Figure 28	Figure 29
			
Figure 30	Figure 31	Figure 32	Figure 33
			
Figure 34	Figure 35	Figure 36	Figure 37

References

1. Wooi TY (2015) Penang shophouses: a handbook of features and materials, 1st edn. Tan Yeow Wooi Culture and Research Studio, George Town
2. Penang State Government (2016) Special area plan: George Town historic cities of the straits of Malacca. George Town, Penang
3. Elnokaly A, Jun Fui W (2014) Demystifying vernacular shop houses and contemporary shop houses in Malaysia: a green-shop framework. In: 30th Int PLEA Conf Sustain Habitat Dev Soc Choos W Forw Proc, vol 1, no December, pp 295–303
4. Zubir Z, Koh JH, Hussain NH, Isip PF (2017) Rejuvenating the shophouse: conservation of historical buildings in Penang's UNESCO World Heritage Site. Int J Herit Archit Stud Repairs Maintenance 2(2):335–346
5. GTWHI (2019) Shophouses [Online]. https://gtwhi.com.my/our-work/shophouses/
6. Rahman S, Maliki NZ, Ahmad AG (2017) Built heritage commodification of boutique hotels in George Town World Heritage Site, Penang, Malaysia. Proc Int Conf Hosp Tour Sport Manag 1(August):152–170
7. Rahman S (2018) Emerging built heritage commodification of boutique hotels in world heritage site: evidence from George Town, Penang, Malaysia. Plan Malaysia 16(4):104–116
8. Khosravi S, Malek A, Ekiz E (2014) Why tourists are attracted to boutique hotels: case of Penang Island, Malaysia Sharareh. J Hosp Tour 12(January):26–41
9. McIntosh A, Siggs A (2005) An exploration of the experiential nature of boutique accommodation. J Travel Res 74–81

10. Khoo SK, Lim YM (2019) Dissecting George Town's human capital challenges in built heritage: voices from the stakeholders. J Cult Herit Manag Sustain Dev 9(3)
11. Aggett M (2007) What has influenced growth in the UK's boutique hotel sector? Int J Contemp Hosp 19(2):169–177
12. Ministry of Tourism Arts and Culture Malaysia (2021) Guidelines on classification of tourist accommodation premises for category of City Hotel, Resort, Highland, Boutique and Innovative, Putrajaya
13. Penang Global Tourism (2019) Heritage zones. MyPenang [Online]. https://www.mypenang.gov.my/culture-heritage/heritage-zones/?lg=en

Reduction of Temperature in Hot, Humid Climatic Context of Dhaka Through Building Regulations of Bangladesh

Najiha Afnan

Abstract Dhaka has witnessed a significant rise in temperature over the past few decades. The reasons behind this remarkable temperature rise are increasing population, destruction of green spaces, high building density, lack of open spaces, filling up water bodies and so on. The increasing temperature has contributed to uncomfortable living conditions. To improve thermal comfort under the hot, humid climatic conditions of Dhaka, authorities have developed some building regulations and achieved a considerable reduction in temperature by implementing those regulations which leads to a sustainable environment. Nowadays, architects are interested in green buildings, landscaping, roof gardening and vertical gardening. They play an important role by ensuring future-proof design solutions to overcome climate challenges and creating a positive impact on the environment. This paper highlights the reduction of temperature in the hot, humid climatic context of Dhaka through building regulations of Bangladesh. The observations obtained from this study can be implemented in preparing building regulations for a densely populated, hot, humid climatic context like Dhaka city in order to reduce temperature.

Keywords Temperature rise · Open spaces · Climate challenges · Sustainable environment · Reduction in temperature

1 Introduction

Dhaka, the capital of Bangladesh, is characterized by excessive population density. Dhaka's current population is 21,741,090 that makes it one of the most heavily populated cities in the world. In this city, 23,234 people live per square kilometer [1]. There is an acute scarcity of land in Dhaka. To accommodate this huge population, green areas are constantly being replaced by unplanned and uncontrolled build areas. Therefore, Dhaka city is losing its green spaces day by day [2]. The shortage of land is so acute that the rivers around the city are being filled up to make space for new buildings [3]. Consequently, there is a lack of open spaces in this city. According

N. Afnan (✉)
Department of Architecture, Ministry of Housing and Public Works, Dhaka, Bangladesh

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_37

to a study, the average temperature of Dhaka is 2 °C higher than the rural areas [4]. Moreover, the temperature is rising at an alarming rate day by day. Considering these factors, the authorities of Bangladesh have developed some building regulations for Dhaka city to deal with the temperature rise issue. These regulations have improved comfort to some extent and ensured a sustainable environment.

2 Temperature of Dhaka

Dhaka has a tropical climate which is mostly hot and humid [5]. Being one of the hottest regions of the country, Dhaka experiences an annual average temperature of 25.3 °C (77.5 °F). During the summer months, the average temperature reaches up to 28.3 °C (82.9 °F), while during the winter months, the average temperature drops to 18.5 °C (65.4 °F) [6]. The highest temperature recorded in Dhaka is 42.2 °C (108.0 °F), while the lowest temperature recorded is 6.1 °C (43.0 °F). The average relative humidity is 75% [5].

3 Causes of Temperature Rise in Dhaka

The temperature of Dhaka city has increased by almost 3 °C over the past couple of decades [7]. Various reasons are responsible for this extreme temperature rise. The population of Dhaka has been increasing day by day. The annual population growth is about 4.2% [1]. Many people are migrating to Dhaka from the rural areas and other towns for better opportunities [3]. This excessive population density plays an important role in the rise of temperature. There should be a minimum of 25% forest area in a city for a healthier environment. But Dhaka has only around 5% which is not adequate [2]. Green spaces are being constantly destroyed for the sake of building construction to accommodate the fast-growing population. This is one of the major reasons for the increasing temperature in Dhaka. Moreover, ponds, canals and surrounding rivers are being filled up for the construction of multi-storied buildings [7]. Destruction of these water bodies and wetlands is also accountable for temperature rising. Besides, the rapid pace of urbanization has contributed to the rise of temperature. There has been an increase in the number of high-rise buildings in Dhaka in the last thirty years [4]. The density of buildings and uneven building heights are responsible for temperature rise in Dhaka city. Other reasons include waste heat from transports, excessive use of air conditioning, poor environmental governance, etc. [7].

4 Effects of Temperature Rise

The increasing temperature is affecting the environment as well as the people of Dhaka city in diverse ways. The living conditions of the people have been declining due to temperature rise. It creates an extremely uncomfortable warm outdoor environment which hampers the well-being of the people and outdoor activities as well. Public health is being affected by increasing temperature as it induces various diseases such as, physical distress, breathing problem, tiredness, etc. [8]. According to a study when the temperature is above 29 °C, there is an increase of diarrhea by 40.2% for each 1 °C rise in temperature [9]. Moreover, people may die from heatstroke [8]. The increasing temperature has decreased the seasonal rainfall and increased unpredictable, excessive rainfall that leads to waterlogging. Waterlogging hampers several utility services. For example, water and energy supply, sewerage system, etc. The temperature rise contributes to greater demand for air conditioning which leads to higher energy consumption. Agricultural productivity and other livelihoods are also being affected by the rising temperature of Dhaka city. It contributes to rising sea levels and flooding as well [9].

5 Methodology

The methodology of this study involves two steps. Extensive literature reviews have been done to analyze the impact of green areas in the reduction of temperature and identify design principles that can be implemented to reduce the increasing temperature of Dhaka city. Besides, "The Dhaka Metropolitan Building Construction Rules 2008" and "Bangladesh National Building Code 2020" have been analyzed to find out the building regulations that contribute to the reduction of temperature.

6 Building Regulations to Reduce Temperature

Dhaka is becoming very vulnerable day by day in terms of sustainability. The city has produced significant changes to the ambient climate due to the lack of open spaces. The unplanned swelling of Dhaka city is now a major problem that needs to be controlled in order to restore its favorable living condition. Considering these facts, the authorities felt the necessity of new building regulations solely for Dhaka city. Consequently, "The Dhaka Metropolitan Building Construction Rules 2008" was established. These new regulations replaced the previous "Building Construction Rules 1996." One of the most significant features of these new sets of rules is the introduction of Floor Area Ratio (FAR) [10].

$$\mathrm{FAR} = \frac{\text{Total build area}}{\text{Land area}}$$

Table 1 Mandatory open space for the plot of health care buildings [11]

Plot size x (m^2)	Mandatory open space (%)
$335 < x \leq 536$	40
$536 < x \leq 670$	42.5
$670 < x \leq 938$	45
$938 < x \leq 1072$	47.5
$1072 < x \leq 1340$	50
$x > 1340$	50

Table 2 Mandatory open space for the plot of different building types [11]

Building type	Mandatory open space (%)
Residential	32.5–50
Educational institution	40–50
Institutional	40–50
Community space	35–50
Commercial	32.5–50
Industrial, warehouse and others	35–40

The term “Mandatory Open Space” was also introduced. Guidelines regarding mandatory open space for all building types were provided according to the size of the plot. Mandatory open space for the plot of health care buildings is given below.

From Table 1, it is observed that the mandatory open space for the plot of health care buildings ranges from 40 to 50% according to various plot sizes. Mandatory open space for the plot of other building types is given below (Table 2).

Thus more open spaces have been achieved through the new building regulations. To analyze the increment of open space after the implementation of new building regulations for Dhaka city, an imaginary site in a residential area has been taken. The plot size is 2090 m^2 and there is a 12 m road at the front.

In scenario 01, after providing the regulations of “Building Construction Rules 1996” regarding setbacks, only 289 m^2 open space is left. According to “The Dhaka Metropolitan Building Construction Rules 2008” for residential buildings, if the plot size is more than 1340 m^2, the mandatory open space shall be 50% of the plot area. Therefore, In scenario 02, applying the regulations regarding mandatory open space and setbacks total of 1045 m^2 open space is achieved. In this case, the open space has increased 36.17% after the implementation of new regulations for Dhaka city (Fig. 1).

The provisions of open space within a site provide an opportunity to improve outdoor thermal comfort conditions. According to “The Dhaka Metropolitan Building Construction Rules 2008” a minimum of 50% of the mandatory open space must be unpaved with or without vegetation so that the water can enter the soil. These green spaces significantly influence the climate by reducing the temperature of the outdoor environment. Even a single tree can influence its microclimate. Trees and shrubs control noise and dust. Several environmental factors are influenced by the

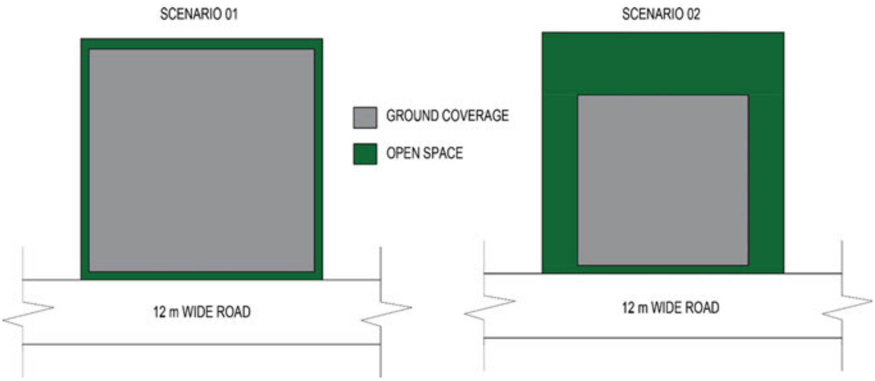


Fig. 1 Different site scenarios

city green such as air temperature, relative humidity, airflow, solar radiation, etc. all of which ultimately contribute to the reduction of temperature. Therefore, building regulations regarding mandatory open space have contributed to the reduction of temperature in Dhaka city.

Architect T Tariq conducted an experiment to analyze the impact of green space to reduce the temperature of Dhaka city [12]. ENVI-met software was used for analyzing the simulations of temperature and wind velocity at 6 am in April which is one of the warmest months of the year. An imaginary site in a residential area of Dhaka city was taken. There were three blocks—Block A, Block B and Block C. There were 30 m wide roads on east and west. On north and south, there were two 18 m wide roads (Fig. 2).

Both Block A and C had 10 plots (46 m × 20 m). For each Plot of Block B, the buildings were 12 storied with maximum ground coverage (50%) or 15 storied with minimum ground coverage (42%). Whereas for each Plot of block A and C, 6 storied buildings were considered. Two plots at the middle of Block B were filled up by a one storied building of 3 m in scenario 01, a brick pavement road in scenario 02 and a green area in scenario 03. Relative humidity was considered 73% and wind speed was 3.0 m/s for April. Building materials were constant in all three scenarios.

The highest temperature was 292.99 K or above which was found at the street level, while the lowest temperature was 292.91 K or below at the interior of the building. In Scenario 01 and 02, the temperature of the middle plots of block B was 292.99 K or above which was the highest temperature. But in Situation 03, the temperature was considerably cool which was around 292.98 K. Findings suggest that green areas are able to reduce the outdoor temperature.

The wind velocity was very low at the middle plots of block B which was under 0.35 m/s in scenario 01. But in scenario 02 and 03, a moderate wind speed was observed which was 1.18–1.46 m/s. Findings suggest that open spaces have a positive impact on the microclimate as airflow contributes to outdoor comfort [12].

Some new regulations have been incorporated in “Bangladesh National Building Code” which is applicable all over Bangladesh. According to these new set of rules

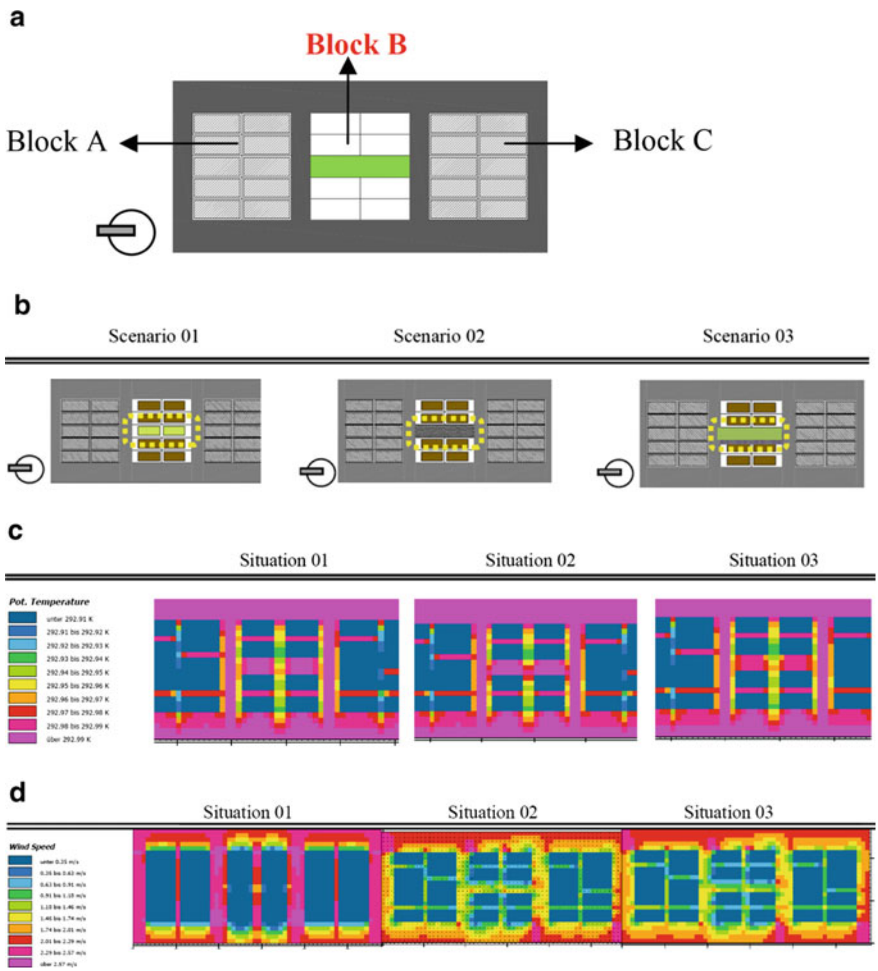


Fig. 2 **a** The conceptual site condition [12]. **b** Different scenarios of the site [12]. **c** Analysis of temperature simulation [12]. **d** Analysis of wind simulation [12]

50% of the roof slabs of educational, institutional and health care buildings shall have a green roofing system. Moreover, all types of buildings shall use solar or other renewable sources of energy [13]. Implementation of these regulations will surely contribute to the reduction of temperature.

7 Role of an Architect

Architects can play an important role in the reduction of temperature in Dhaka city in various ways. They should come up with innovative ideas to overcome climate challenges. A lot of considerations are required while designing. It is mandatory to have climate knowledge. They need to focus on every climatic factor. The physical and emotional needs of the people must be kept in mind too. Their design must create a positive impact on the environment. Planning in advance is necessary as well. Architects should follow the building regulations strictly. They should make the best use of the mandatory unpaved area by plantation of trees and shrubs. Participating in the policy making process is also important.

8 Recommendation

To reduce the increasing temperature of Dhaka, green roofing system should be mandatory for all the residential buildings. Vertical gardening should be encouraged as well. Regulations regarding building materials should be incorporated in the building regulations as materials also affect the environment. Besides, proper plantation must be provided in the mandatory open spaces.

9 Conclusion

Reduction of the increasing temperature is now one of the biggest challenges for survival in Dhaka city. Implementation of the new building regulations has contributed to temperature mitigation to some extent. The outdoor environment is more comfortable than before. More strategies should be developed to overcome the temperature rise issue. Architects, urban planners, environmentalists, policymakers all should work hand in hand to achieve a better habitat for the next generation. Proper implementation of building regulations must be ensured by law enforcement.

References

1. World Population Review publisher (2021) Dhaka population 2021 [Online]. Dhaka Population 2021 (Demographics, Maps, Graphs) (worldpopulationreview.com). Last accessed: July 2021
2. S Chowdhury (2016) Lack of green space in Dhaka city, [Online Newspaper]. The Financial Express, April 2016. https://thefinancialexpress.com.bd/views/lack-of-green-space-in-dhaka-city. Last accessed: July 2021
3. A Tasneem (2014) The concrete jungle. Dhaka Tribune, [Online New portal], June 2014. https://www.dhakatribune.com/uncategorized/2014/06/20/the-concrete-jungle. Last accessed: July 2021

4. FE Report (2020) "Dhaka's temp stays 2.0 degrees higher," [Online Newspaper]. The Financial Express, January 2020. https://thefinancialexpress.com.bd/national/dhakas-temp-stays-20-degrees-higher-1579496377. Last accessed: July 2021
5. Wikipedia contributors (2021) Climate of Dhaka Wikipedia, The Free Encyclopedia. April 2021. https://en.wikipedia.org/w/index.php?title=Climate_of_Dhaka&oldid=10168 65237. Last accessed: July 2021
6. Climate-Data.org publisher (2021) Climate Dhaka (Bangladesh). https://en.climate-data.org/asia/bangladesh/dhaka-division/dhaka-1062098/. Last accessed: July 2021
7. Molla MA (2021) Dhaka hotter in 20 years. The daily star, [Online New paper], April 2021. https://www.thedailystar.net/frontpage/news/dhaka-hotter-20-years-2079657. Last accessed: July 2021
8. Uddin ASMS, Khan N, Islam ARMT, Kamruzzaman M, Shahid S (2021) Changes in urbanization and urban heat island effect in Dhaka City. In: Under review at theoretical and applied climatology, research square. https://doi.org/10.21203/rs.3.rs-442136/v1. Last accessed: July 2021
9. Rabbani G, Rahman A, Islam N (2021) Climate change implications for Dhaka city: a need for immediate measures to reduce vulnerability. In: Resilient cities: cities and adaptation to climate change—proceedings of the global forum 2010. Local sustainability. https://doi.org/10.1007/978-94-007-0785-6_52, January 2011, Available on: (PDF) Climate change implications for Dhaka city: a need for immediate measures to reduce vulnerability (researchgate.net). Last accessed: July 2021
10. Shafi SA (2010) National building code and its implementation. Round table discussion on implementation of national building code, VIP Lounge, National Press Club, June 2010. https://www.blast.org.bd/content/key-note/national-building-code-29June.pdf. Last accessed: July 2021
11. Bangladesh Building Construction Regulatory Board (2008) The Dhaka metropolitan building construction rules 2008
12. Tariq T (2014) An ENVI-met simulation study on urban open spaces of Dhaka, Bangladesh. In: 30th international conference on passive and low energy architecture (PLEA 2014): sustainable habitat for developing societies: choosing the way forward. Available on: https://www.researchgate.net/publication/338197528_An_ENVImet_Simulation _Study_on_Urban_Open_Spaces_of_Dhaka_Bangladesh. Accessed: July 2021
13. Bangladesh National Building Code Council (2021) An addition to Bangladesh National Building Code (BNBC), 2006

Modeling Reinforced Concrete Beam with GFRP Bar and GFRP Sheet Using Finite Element Method

E. A. Z. Ikhsan, H. Parung, and R. Irmawaty

Abstract The use of FRP bar reinforcement as a rust-resistant material is one solution to increase the resilience of reinforced concrete structures in the marine environment. Innovations in the use of FRP reinforcement need to be developed to improve quality and reduce construction costs by eliminating concrete cover and shear reinforcement. Removing the concrete cover and shear reinforcement in the beam can minimize the cross-sectional height without reducing the effective height of the beam and simplify the placing of concrete. To replace the shear reinforcement, GFRP sheets are installed in the shear span. To validate the flexural behavior of reinforced concrete beams using FRP rods without concrete cover with GFRP sheet shear reinforcement in the experimental study, a numerical analysis was carried out using the finite element method using abaqus cae software. Modeling and treatment of test objects in numerical analysis is based on modeling and experimental treatment studies including material data used are the same as those in experimental research. The results obtained are that the flexural load capacity of the BFTS analyzed numerically is 12.45% greater than the experimental study. BFTS crack pattern in numerical analysis is wider than experimental study because the load resisted is numerically larger but basically the crack pattern experienced in the mid-span zone is similar.

Keywords Numerical analysis · Experimental study · GFRP sheet and GFRP bar

1 Introduction

The use of corrosion-resistant reinforcement on structural elements for very aggressive environmental conditions is more profitable than the use of steel reinforcement that is given rust protection by catodic protection, epoxy coating or galvanization methods [1]. In addition to being corrosion resistant, GFRP bars have high strength, are not affected by magnetism, have good fatigue resistance, are lightweight, have low thermal and electrical conductivity [2].

E. A. Z. Ikhsan (✉) · H. Parung · R. Irmawaty
Civil Engineering Department, Hasanuddin University, Makassar, Indonesia

M. Awang et al. (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 223, https://doi.org/10.1007/978-981-16-8667-2_38

Meanwhile, repairs due to shear reinforcement damage can be done by adding GFRP sheet as needed. Glass fiber materials have a more elastic strain energy capacity and a high strength to weight ratio compared to steel, as a result, the use of steel in concrete will be reduced. GFRP bars are more suitable for designing structural elements, demanding a high strength-to-weight ratio as well as high corrosion resistance.

The results of previous studies showed that beams with GFRP reinforcement were able to increase the flexural capacity of beams by 4.14% against normal beams [3]. Meanwhile, other experimental results show that the installation of GFRP sheet on the beam can increase the flexural capacity and ductility of the beam. They are 37.96% and 25%, respectively [4].

This paper aims to validate the experiment research with a finite element program. This paper is comperation and validation of experimental study of Kusnadi in 2020. Are the results of the numerical analysis in accordance with the results of the experimental study, it is necessary to conduct a study entitled "Modeling Reinforced Concrete Beams with Glass Fiber Reinforced Polymer (GFRP) Bars and Sheets Using Finite Element Method". Also, this analysis is expected as a reference material in the planning and repair of structures, especially in structures in the marine environment by considering the advantages and disadvantages of using GFRP bars and GFRP sheets.

2 Materials

2.1 Material Properties

The materials used in are concrete fc' 25 MPa, steel Ø8, steel D13, GFRP bar D13 and GFRP sheet 1.3 mm (Fig. 1).

(a) Concrete (b) Steel (c) GFRP bar (d) GFRP sheet

Fig. 1 The materials used

2.1.1 Concrete Damage Plasticity (CDP)

In this analytical study, CDP was chosen because compared to other models, CDP is able to simulate the elastic and plastic properties of concrete by considering the softening behavior in both compression and tension. CDP relies on two main failure patterns to control the behavior of concrete elements; compression crushing and tensile cracking. There are five standard parameters that Abaqus provides to solve functions (Tables 1 and 2).

The tensile damage parameter, dt is defined as the ratio of the cracking strain to the total strain. Similarly, the compressive damage parameter, dc is defined as the ratio between the inelastic strain and total strain. If damage parameters are not specified, the model behaves as a plasticity model (Fig. 2).

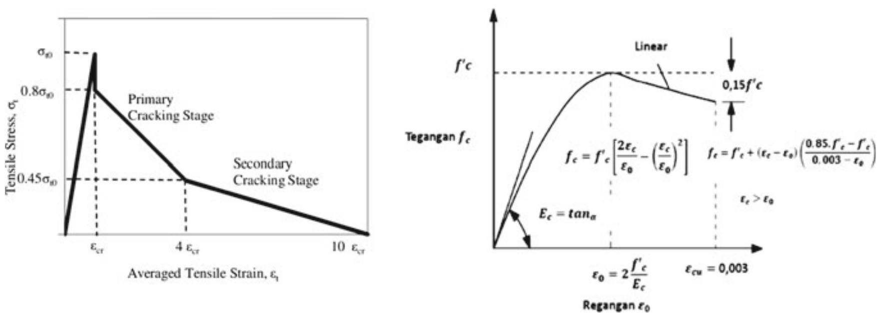
Table 1 Concrete behavior

Material	Compression strength fc' (MPa)	Tensile strength fct (MPa) Kusnadi 2021	Elastic modulus (MPa) Hamid Sinaei dkk. 2012	Poisson's ratio (MPa)	Density (tonne/mm^3)
Concrete	25	$0.50\sqrt{fc'} = 2.5$	$4700\sqrt{fc'} =$ 23,500	0.21	2.4×10^{-9}

Table 2 Parameter plasticity untuk concrete damage plasticity

Dilation angle	Eccentricity	$\frac{f_{b0}}{f_{c0}}$	K	Viscosity parameter
20	0.1	1.16	0.667	0

Source Walid Mansour, 2021



(a) in tension [5]

(b) in compression [6].

Fig. 2 Behavior of concrete

Table 3 Reinfrocements behavior

Material	Ultimate stress (MPa)	Elastic modulus (MPa)	Poisson's ratio (MPa)	Density (tonne/mm^3)
GFRP bar (D13 mm)	788	43,900	0.25	2.1×10^{-9}
GFRP sheet (1.3 mm)	575	26,100	0.33	2.6×10^{-9}
Steel (D13 mm)	370	200,000	0.3	7.85×10^{-9}
Steel (Ø8 mm)	240	200,000	0.3	7.85×10^{-9}

2.1.2 Steel

Steel is an isotropic material, the input data on abaqus uses density, plasticity and elastic data. Plastic behavior filled with yield stress and plastic stain values. Young's modulus value and poisson's ratio for the elastic and mass density for density.

2.1.3 GFRP (Glass Fiber Reinforced Polymer) Bar

Modulus of elasticity of GFRP bars (40–55 GPa) is lower than that of steel bars leading to larger deflections and wider cracks than steel-reinforced concrete, this is why GFRP bars are not usually used as compression reinforcement []. GFRP bar is an anisotropic material with a strong longitudinal axis governed by fibers and a weak or moderate transverse axis regulated by a fiber binding resin [5].

GFRP bar material is an isotropic material, the data input on abaqus uses density, plasticity and elastic data. Elastic behaviors are young's modulus and the position ratio, and mass density for density behaviour (Table 3).

2.1.4 Hashin Damage GFRP (Glass Fiber Reinforced Polymer) Sheet

GFRP Sheet is an orthotropic elastic material [6] and based on the (Abaqus Analysis User's Guide) the behavior of the glass fiber reinforced epoxy coating material is assumed to be orthotropic, with a stiffer response along the fiber direction and a more pronounced behavior soft in the matrix. Where the material data uses density, elastic type lamina and hashin damage.

Material behavior elastic for GFRP sheet using lamina type. Although based on abaqus manual version 6.14, GFRP sheet is assumed to be orthotropic, but the mechanical properties of advanced composite laminates are assumed for better mathematical modeling in structural analysis. Where the lamina itself in the big Indonesian dictionary means a thin sheet. Each lamina was treated as an orthotropic material under a field stress state and assumed to be transverse isotropic [7]. GFRP Sheet using

Table 4 Initial orthotropic damage properties of fiber-reinforced epoxy

Longitudinal failure stresses		Transverse failure stresses		Longitudinal and transversal
Tensile	Compression	Tensile	Compression	In-plane shear strength
(Mpa)	(Mpa)	(Mpa)	(Mpa)	(Mpa)
2500	2000	50	150	50

Source Abaqus user manual 6.14

Hashin damage, [8] proposed that the criteria for predicting the failure of composite materials should be based on the mechanism of material failure.

Hashin [8] proposed that the criteria for predicting the failure of composite materials should be based on the failure mechanism of the material, not simply extrapolating existing criteria to other materials as was the case in the Tsai-Hill and Tsai-Wu Criteria. These failure criteria are used to predict different failure modes such as fiber breakage in stress, fiber buckling in compression, matrix cracking, and debonding. The specimen uses the Hashin-Rotem criteria, 1973 because the material is in a state of biaxial stress, the alpha value in the material behavior is equal to 0 (Table 4).

2.2 Modeling Specimens

The specimen is BFTS, fiber beam without cover concrete. Where dimension of the beam 150 × 250 × 3300 mm. The specimen uses some materials. It uses concrete fc' 25 MPa, steel Ø8 as compressive reinforcement, GFRP bar D13 as tensile reinforcement, and GFRP sheet as shear reinforcement. Figure 3 shows the beam using GFRP bars as tensile reinforcement and GFRP sheets as shear reinforcement without covers (BFTS).

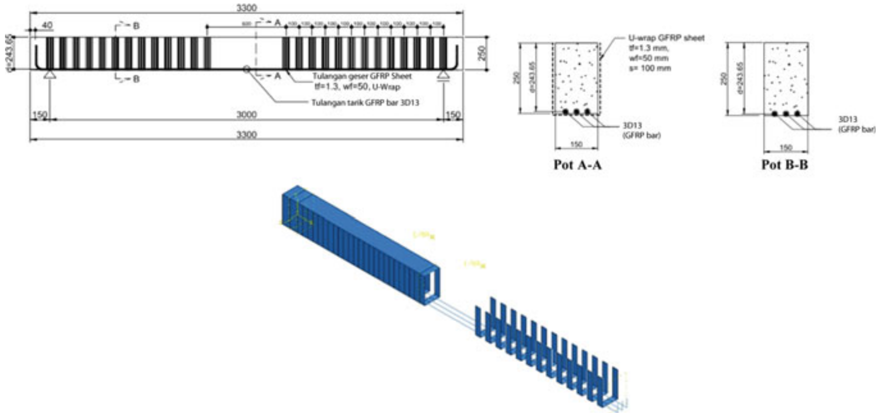


Fig. 3 Modeling scheme of fiber beam without cover concrete (BFTS)

2.3 Modelling of the Interface Surface Between Concrete and GFRP Sheet

The model is simulated using a perfect bond as a tie constraint where no separation between the two surfaces is allowed [9]. The value of friction is obtained from the product of the coefficient of friction and the nominal stress. Table 5 shows the coefficient of friction for the unsmoothed concrete surface is 0.60 while Eq. (1) shows that the nominal stress value reaches one [9]

$$\left\{\frac{\sigma_n}{\sigma_{n\,\max}}\right\}^2 + \left\{\frac{\tau_t}{\tau_{t\,\max}}\right\}^2 \left\{\frac{\tau_s}{\tau_{s\,\max}}\right\}^2 = 1.0 \tag{1}$$

where σ_n is the tensile stress of the interface in MPa units, τ_t and τ_s are the interfacial shear stress, n t and subscripts represent the direction of the adhesive thickness of the stress component in mm, $\sigma_{n\max}$ is the maximum tensile strength of the cohesive surface. While σ_{t0}, $\tau_{t\max}$ and $\tau_{s\max}$ are the maximum shear strength of the cohesive surface (Fig. 4).

$friction = \mu\ \sigma_n = 0.60 \times 1 = 0.60.$

Therefore for the coefficient of shear between the surfaces is 0.60.

Table 5 Cohesion and friction coefficient values

Surface characteristics of the interface	c	μ	Ra (mm)
Very smooth (steel, plastic, specially treated timber formwork)	0.025	0.50	Not measurable
Smooth (concrete surface without curing)	0.35	0.60	<1.5
Rough (strongly roughened surface)	0.45	0.70	>1.5
Very rough	0.50	0.90	>3.0

Source fib Model-Code (2010)

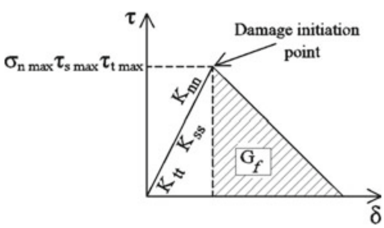


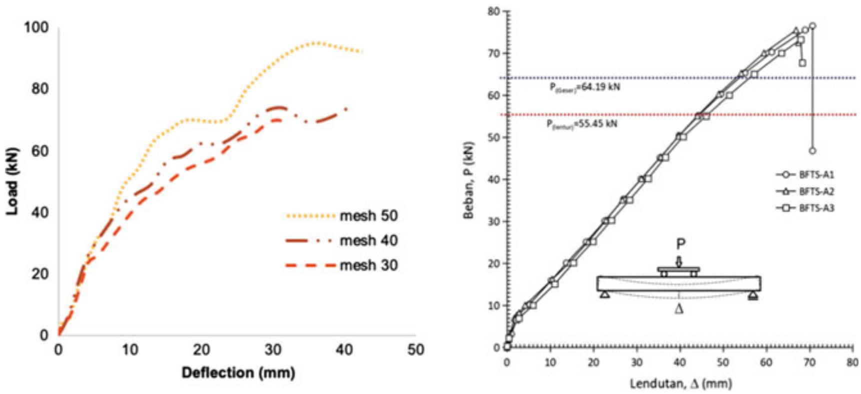
Fig. 4 Traction separation modeling (tensile) for a cohesive surface *Source* Walid Manosur, 2021

3 Result and Discussions

3.1 Load–Deflection Curve

Figure 5 shows the load and deflection responses of numerical analysis result and kusnadi's experimental study which are summarized in Table 5. The deflection reported here was the deflection at the mid-span of the beam. Generally, all the beams exhibited similar behavior until the first crack. After that, the slope of load–deflection curves reduced differently. The curve of mesh 50 is higher than mesh 40, then curve of mesh 40 is higher than mesh 30. Meanwhile, the stiffness of mesh 30 and mesh 40 is almost similar. This indicates that the use of mesh value at abaqus cae affected the stiffness of the beams. The shape of numerical analysis curve is different to kusnadi's experimental study curve in 2021.

As shown in Table 6, average maximum load value of numerical analysis is 78.83 kN which is higher than the experimental study 75.08 kN. This shows that there are factors in the experimental study that cause the results of the beam in the experimental study to be less able to resist 3.75 kN, with a higher accepted load, the beam analyzed numerically also only experienced 42% smaller deflection of the experimental study



(a) Numerical analysis (b) Kusnadi's Experimental study in 2020

Fig. 5 Load–deflection responses of BFTS

Table 6 Results of numerical and experiment analysis

Specimens	Load (Pu) (kN)	Deflection (Δu) (mm)
BFTS-mesh 30	69.076	32.564
BFTS-mesh 40	75.339	41.431
BFTS-mesh 50	92.07	42.423
Average numerical	**78.828**	**38.806**
Average experiment	**75.08**	**68.91**

deflection experienced. The load was constant, while the displacement still increased until the failure. This was a typical flexural failure mode.

3.2 Crack Pattern

Figures 6 and 7 showed the crack pattern of analysis numerical beams and experimental study at the ultimate load. The ultimate load of BFTS mesh 30, mesh 40, mesh 50 and BFTS experimental study were 69.08 kN, 75.34 kN, 92.07 kN, and 75.08 kN, respectively. Comparing to cracks pattern of the experimental study, the pattern of cracks on numerical analysis are wider but still similar. The long cracks were concentrated in the constant moment region at the span center. The mesh 50 pattern indicates that the GFRP sheet performs well to resist cracking under the beam however cracks still occur at the mid span. This was because the concrete of experimental study has not reach maximum load failure as numerical analysis beam can resists.

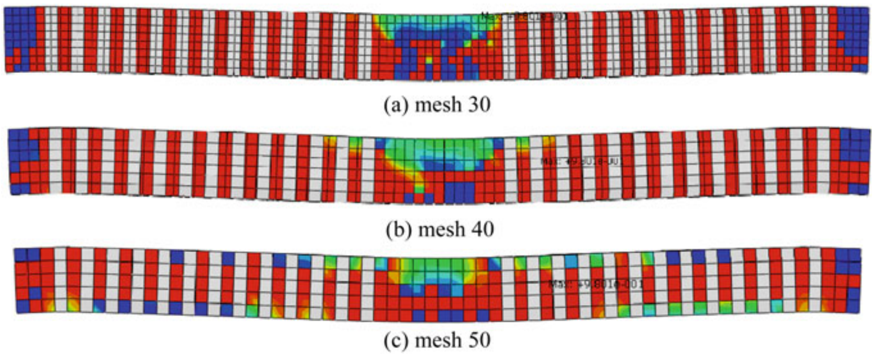


Fig. 6 Crack pattern BFTS at failure of numerical analysis

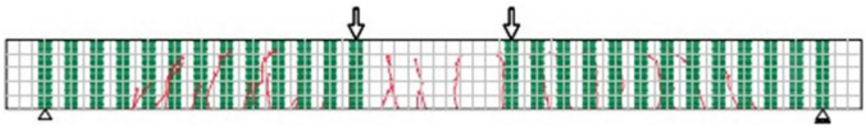


Fig. 7 Crack pattern BFTS at failure of kusnadi's experimental study in 2020

4 Conclusion

The comparation result of fiber beam without cover concrete between analysing with finite element method and experimental study show that:

1. The flexural load capacity of the BFTS analyzed numerically is 12.45% greater than the experimental study. Although the material data used are the same as those in the experimental study.
2. The BFTS crack pattern in the numerical analysis is wider than the experimental study because the numerically resisted load is greater but basically the crack pattern experienced in the midspan zone is the same.

References

1. Sultan M, Djamaluddin R (2020) Daktalitas dan Kapasitas Lentur Balok Beton Bertulang dengan Perkuatan GFRP-S. Konferensi Nasional Teknik Sipil 12. Batam, Indonesia
2. ACI. Committee 440.2R-08, 2008, Guide for the design and construction of externally bonded FRP systems for strengthening concrete structures. American Concrete Institute, USA
3. Hijriah, Parung H, Djamaluddin R, Irmawaty R (2020) Delaminasi Lembar GFRP pada Balok Beton Bertulang 18:1271–1276
4. Kusnadi (2020) Flexural behavior of GFRP bar reinforced concrete beam without concerete cover at the tension zone with GFRP sheet as shear reinforcement. Dissertation for Civil Engineering Department of Hasanuddin University
5. Ahmed E, El-Salakawy E, Benmokrane B (2010) Performance evaluation of glass fiber-reinforced polymer shear reinforcement for concrete beams. ACI Struct J 107:53–62
6. Alizadeh E, Dehestani M, Navayi Neya B, Nematzadeh M (2019) Efficient composite bridge deck consisting of GFRP, steel, and concrete. J Sandwich Struct Mater 21(1):154–174. https://doi.org/10.1177/1099636216688347
7. Naval Postgraduate School (2007) Identification of stiffness properties of orthotropic lamina using the experimental natural frequencies and mode shapes. California, p 5
8. Hashin Z (1980) Failure criteria for unidirectional fiber composites. J Appl Mech 47:329–334
9. Mansour W (2021) Numerical analysis of the shear behavior of FRP-strengthened continuous RC beams having web openings. Eng Struct 227