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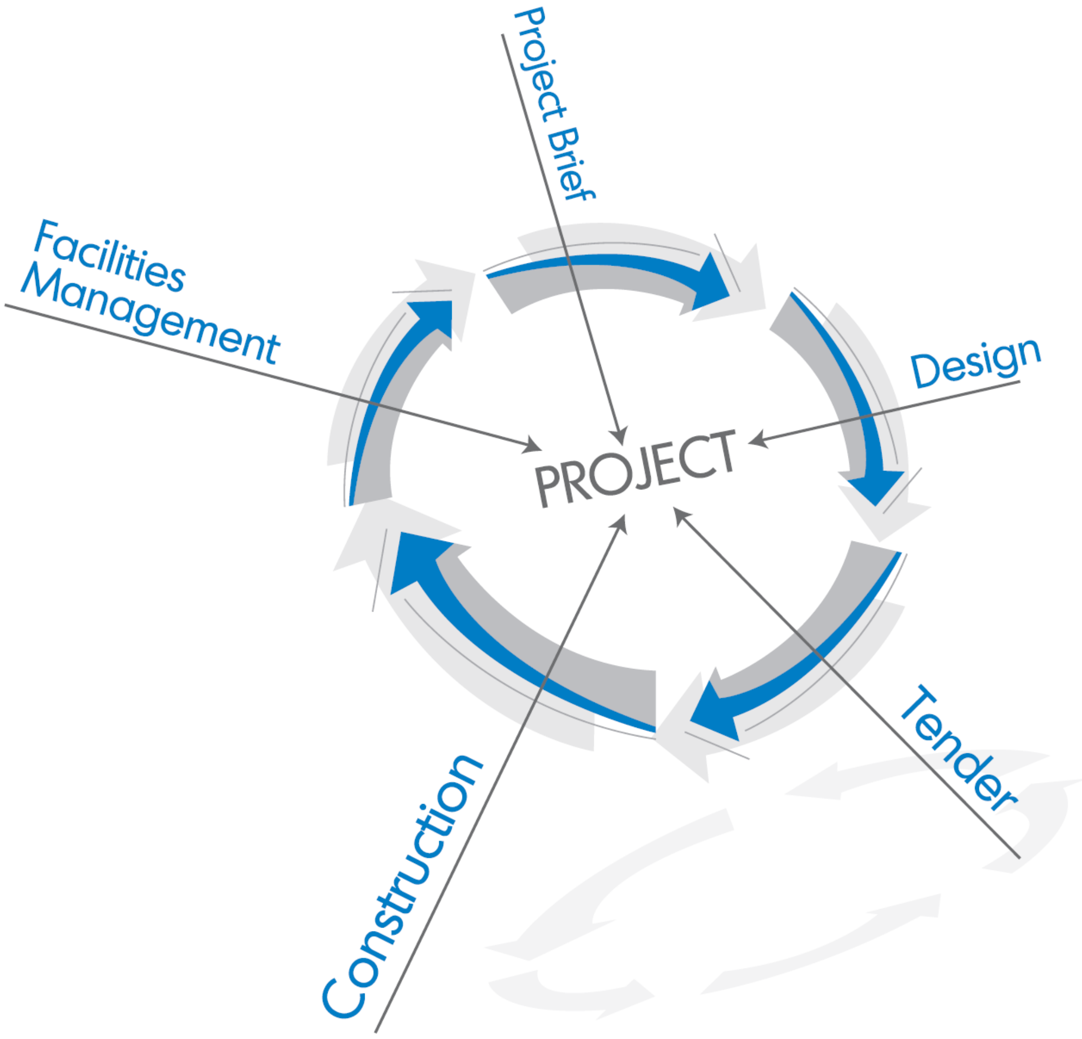

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Contents

Editorial Advisory Board

Editorial

Welcome from the Editors

Welcome to the twenty-seventh (27th) issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include eight papers that cover wide range of research area in construction industry. The editorial team would like to express our sincere gratitude to all contributing authors and reviewers for their contributions, continuous support and comments.

In this issue:

Mohamad Raduan Kabit et al., evaluated the impacts of signal metering strategy in improving the problematic roundabout's performance in Kuching, Sarawak due to unbalanced flow condition. The results showed that the use of signal metering improved the performance of the roundabout effectively provided that the traffic demands do not exceed the recommended range.

Fadzli Mohamed Nazri et al., evaluated drift performance of three-span reinforced concrete bridges during an earthquake using Nonlinear Time History Analysis (NTHA) method. Three types of concrete grades and two pier heights of a prototype bridge model was investigated. It was found that the selection of concrete grade for construction of the bridge structure is a vital aspect in determining the bridge structure while pier height significantly determines the stability of the bridge structure during earthquakes.

Dredged marine soils (DMS) are sediments that settle at the bottom of water body resulted from dredging activities. DMS can be reused as backfill materials in construction and **Siti Farhanah S.M. Johan and Chan Chee Ming** determined the physical properties of DMS to examine the consolidation behavior of DMS using different types of drainage – single and double drainage. The study showed that the double drainage gives better consolidation than the single drainage.

Jamil, M.N. et al., examined the reliability of rock probing in determining the precise micro pile setting depth on limestone karst bedrock. Three different sources of data from three different methods of ground investigation – rock probing, borehole and complete micro pile foundation - were evaluated with respect to the thickness of soil layer, bedrock and cavity in the limestone karst bedrock. The results showed in the paper reveals that the rock probing method of ground investigation is commendable for sustainability of vertical city in limestone with karst features formation.

Abd Nasir Matori and Amir Sharifuddin Ab Latip monitored the settlement of a Liquefied Natural Gas (LNG) terminal using Persistent Scatterer Interferometry (PSI) technique to detect any small movement or settlement. Continuous monitoring against such settlement is required to prevent any unwanted eventualities. The results of the study are elaborated in the paper.

Abdullah Basri and Zulhabri Ismail explored the challenges in implementing green buildings in Malaysia and assessed the effectiveness of the existing regulations in relation to green requirements through semi-structure interview analysis and doctrinal research. Based on the interview, twelve regulatory requirements for construction industry are also proposed by the respondents to formulate green regulations, policies and building codes in implementing green building projects in Malaysia which are explained in the paper.

Seng Hansen and Susy F. Rostiyanti done a literature review and a questionnaire survey to obtain views of practitioners in construction industry on problems in construction claim management encountered by Indonesia contractors. There are six stages in the construction claim management process and issues of each stage were outlined in the paper.

Construction industry is currently moving towards the fourth industrial revolution and Building Information Modelling (BIM) is one of the drivers for the industry to survive the revolution. **Afifuddin Husairi Hussain et al.,** conducted semi-structured interviews to organisations to investigate the attributes that encourage the organisations to institutionalise BIM in their business process. Eight attributes were identified and are elaborated further in the paper. The findings in this study also revealed that most of the Malaysia organisations have a positive propensity towards adopting BIM in their business process and are ready to venture into the fourth industrial revolution.

Editorial Committee

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AN EVALUATION OF SIGNAL METERING APPLICATION TO MITIGATE ROUNDABOUT'S UNBALANCED FLOW CONDITIONS: A CASE STUDY IN KUCHING

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Abstract
Signal metering is usually used to reduce the impacts of dominant flow at roundabouts. While some roundabouts in Kuching are experiencing this phenomenon, signal metering strategy has not been deployed to mitigate this problem. This study aims to evaluate the impacts of signal metering in improving the problematic roundabout's performance due to unbalanced flow condition. A case study was conducted at a selected roundabout in Kuching to examine the impacts of signal metering strategy on the roundabout capacity. The data was analysed by using SIDRA Intersection 4.0 by which the results before (base condition) and after the implementation of signal metering strategy were compared. The results indicated that use of signal metering has a significant impact in improving the capacities and the queue lengths of the controlling approach ($t(6) = 3.610$, $p = 0.011 < 0.05$). However, due to excessive traffic flow demands occurred at roundabout for the time intervals studied, the application of signal metering system yielded negative benefits for the metered approach and worsen the overall performance of the studied roundabout. The results provide good insights on the application of signal metering to improve roundabout performance due to unbalanced flow conditions provided that the traffic demands do not exceed the recommended range for an effective application.

Keywords: *Roundabout Capacity; Unbalanced Flow Pattern; Signal Metering; Queue Length; Average Delay*

INTRODUCTION

The concept of roundabout metering is an adaptation of motorway ramp metering where the changeable traffic signal is placed at the roundabout dominant approach (US Department of Transportation, 2000). Signal metering for roundabouts is designed to increase entry capacity at problematic approach due to dominant flow conditions which often used when certain conditions are met; i.e. very long queue has been detected, especially during peak hours where heavy traffic flows occur at roundabouts (Akcelik, 2008).

Under suitable flow conditions, installation of roundabout metering signals has been proven to be an effective strategy to alleviate the congestion level and hence reduce delays at roundabouts. While the use of metering signals has not been introduced in Malaysia, this study aims to evaluate the effectiveness of signal metering in increasing roundabout capacity under heavy traffic demands and the existence of unbalanced flow conditions. Subsequently, the results are used to determine traffic flow thresholds as to when signal metering application is no longer providing significant benefits in improving the roundabout performance.

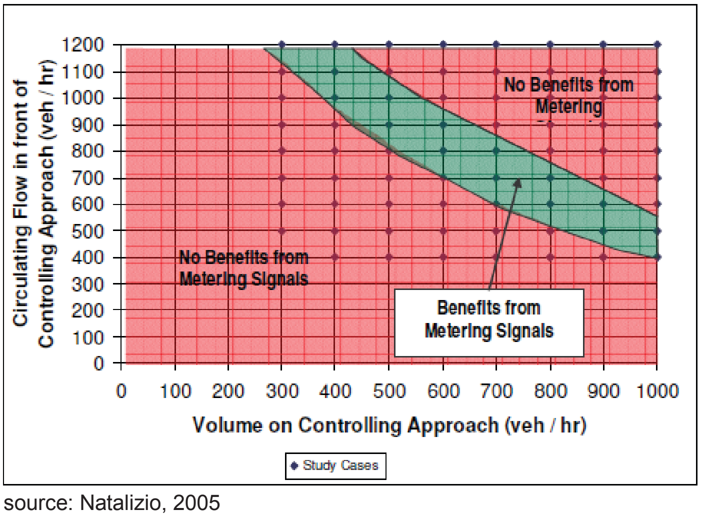
LITERATURE REVIEW

Roundabouts are better than signalised intersection in dealing with low to medium traffic demands with a considerable proportion of turning flows, which oftentimes are effective in minimising off-peak delays (Marjan, 2008). The US Department of Transportation (2000) concluded that a roundabout provides desirable capacities when there are sufficient longer and satisfactory gaps occur in the circulating flows. However, unbalanced flow conditions are often encountered during peak hours at roundabouts. In many circumstances, unbalanced flow patterns have led to roundabout inefficiency where insufficient gaps usually occur at the downstream legs.

Unbalanced flows at roundabouts occur when a traffic stream with heavy traffic demand dominate the roundabouts which then impede flows from the downstream legs to enter the roundabouts due to a very high circulating flow at entry approaches (Akcelik, 2004). As a result, substantial delays occur at the subsequent downstream approaches when dominant flows continuously entering the roundabout and hence provides very limited acceptable gaps for the traffic from the subsequent legs to enter the roundabout's circulating lanes.

In dealing with unbalanced flows at roundabouts, gap-acceptance method has been proven to produce a more reliable result a compared with empirical method (Akcelik, 2004). Akcelik (2006) deduced that many roundabouts in Australia with unbalanced flow issues were improved in capacity with the installation of signal metering system. The study discovered that with the installation of signal metering system, queue lengths and delays were decreased, which led to capacity improvement in all approaches of the roundabouts.

To appropriately use signal metering system at roundabouts, a set of guiding principles was developed by Natalizio (2005). In his report, Natalizio (2005) produced a figure (as shown in figure 1) which indicates the zone area which produce benefits under signal metering system with a consideration of the combined flow conditions of the controlling approach (X-axis) and its circulating flow at the entry approach (Y-axis).



source: Natalizio, 2005

Figure 1. Flow conditions that would benefit by installing signal metering

METHODOLOGY

Figure 2 shows the study flowchart. A problematic roundabout was chosen for this study. The roundabout connecting Kuching and Kota Samarahan district was chosen as shown in figure 3. Using video recording method, a two hour AM peak traffic flow data was collected at the selected study site. The data were then reduced and converted to passenger car equivalent unit (PCU) using conversation factor in table 1.

Table 1. PCE Factor (Arahan Teknik Jalan 8/86) (1986)

Type of Vehicle	Rural	Urban	Roundabout	Traffic Signal
Passenger car (PC)	1.00	1.00	**1.00**	1.00
Motorcycle (M)	1.00	0.75	**0.75**	0.33
Light Vans (LV)	2.00	2.00	**2.00**	2.00
Medium Lorries (ML)	2.50	2.50	**2.80**	1.75
Heavy Lorries / Buses (HL)	3.00	3.00	**2.80**	2.25

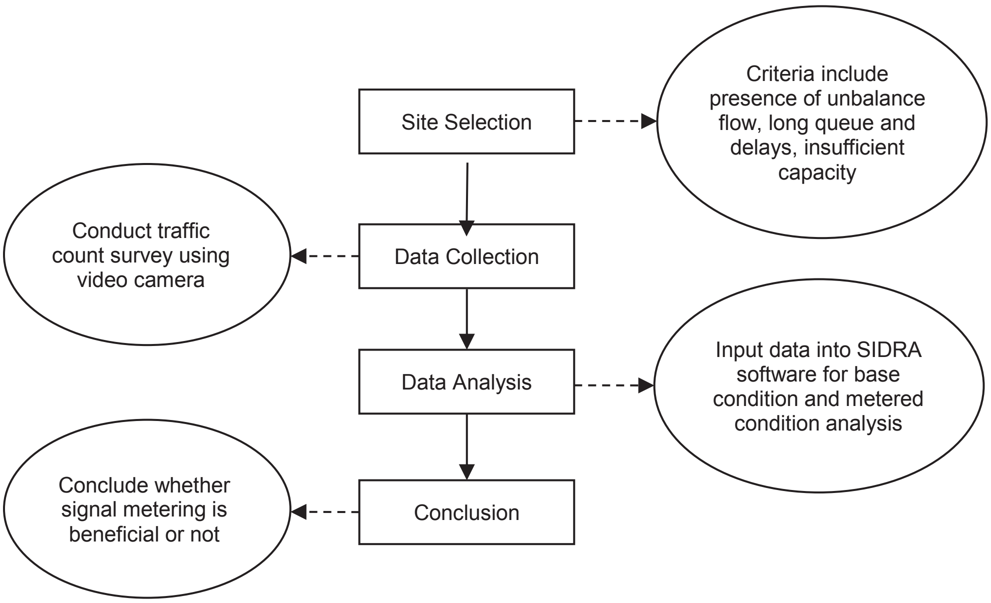


Figure 2. Research methodology flowchart

Source: Google Map

Figure 3. Case study roundabout (intersection between Jalan Canna and Kota Samarahan Expressway)

Before further analysis on roundabout performance under signal metering was undertaken, determination of unbalanced flow was carried out. Unbalanced flow condition was determined using the formula as follows (Krogscheepers & Roebuck, 2000):

$$\rho_w = \frac{Q_{sw}}{Q_{sw}+Q_{nw}+Q_{ew}} = \frac{Q_{sw}}{Q_{nc}} \quad (1)$$

Equation (1) shows the calculation for ratio-of-imbalance, ρ_w where Q_{sw} represents the traffic from south passing west, Q_{nw} represents the traffic from north passing west, and Q_{ew} represents the traffic from east passing west.

Upon determining unbalanced flow condition, SIDRA software was used to analyse a two-hour peak hour traffic flow data, by which analysis results under without and with signal metering conditions were compared. From the observation made, traffic entering the roundabout from BDC approach have suffered a considerable difficulty due to heavy circulating traffic flow from Kota Samarahan approach. Thus, to improve capacity on BDC approach, Kota Samarahan was chosen as the metered approach while BDC approach was the controlling approach.

RESULTS AND DISCUSSIONS

Analysis of Unbalanced Flow Condition

From the site observation made during traffic data collection, the roundabout connecting Kuching and Kota Samarahan showed an obvious sign of dominant flow conditions during the observed peak hour period. Due to the dominant flow effect of Kota Samarahan to Jalan Canna direction, traffic from Jalan Stutong experienced considerable difficulties in negotiating the roundabout circulating flow. Thus, a very long queue occurred as a result. By using traffic data as shown in figure 4, unbalanced flow analysis was undertaken.

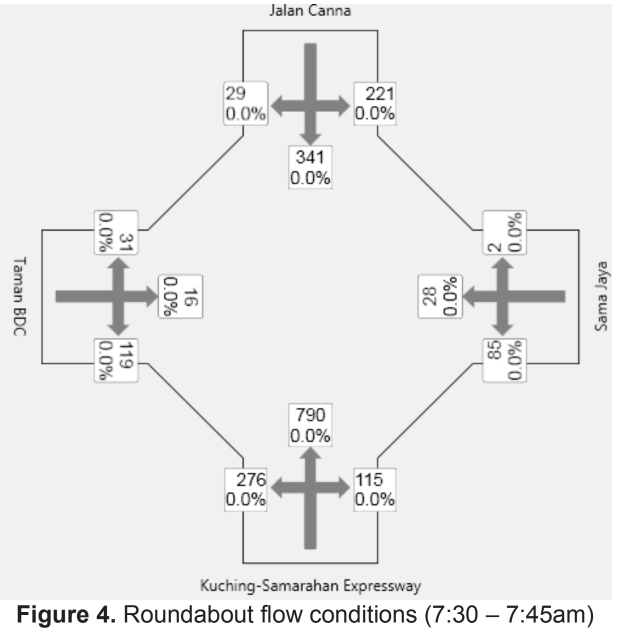


Figure 4. Roundabout flow conditions (7:30 – 7:45am)

Using equation 1, the ratio-of-imbalance flow obtained was 0.998. This implies 99.8% of circulating flow at Jalan Stutong entering approach was dominated by traffic flow from Kota Samarahan to Jln Canna direction.

The Controlling Approach Capacity Comparisons

Jalan Stutong approach was the most problematic approach due to highway circulating flow as a result of dominant flow from Kuching-Samarahan Expressway. The approach degree of saturation for the first three-time intervals (7:30 – 7:45am; 7:46– 8:00 am; 8:01 – 8:15am) were 1.587, 1.773 and 1.733 respectively. Overall, the approach entry emand exceeded the approach capacity by 58% up to 77% during these periods. For the time intervals between 8:15 – 9:15am, the degree of saturation for 15 minutes time intervals were 0.952, 0.980, 0.843 and 0.477 which indicated considerable demand occurred at the approach.

As far as the approach capacities are concerned, the results showed that signal metering system has significantly improved the controlling approach capacity. From Table 2, under signal metering condition, the controlling approach capacities were considerably improved. For example, from 7:30 am until 9:00 am the controlling approach capacities were improved by 89% up to 199%. However, the application of signal metering has negative impacts on the metered approach capacities. The metered approach capacities were reduced by -4% up to -18% as a result of signal metering system strategy.

In addition, when the demand to capacity ratio for the controlling approach occurred below 1.0, the results indicated that application of signal metering approach yielded negative benefits and resulted in a significant reduction in the capacity.

Table 2. Impacts of signal metering on the roundabout approaches

Time interval	Approach	Capacity (without signal metering)	Capacity (with signal metering	Improvements
7:30 – 7:45am	Metered	2251	2162	-4%
	Controlling	300	813	171%
7:45 – 8:00am	Metered	2099	2026	-3%
	Controlling	300	896	199%
8:00 – 8:15am	Metered	2052	1830	-11%
	Controlling	300	761	154%
8:15 – 8:30am	Metered	2333	2201	-6%
	Controlling	786	1583	101%
8:30 – 8:45am	Metered	2117	1743	-18%
	Controlling	759	1352	78%
8:45 – 9:00am	Metered	2214	1972	-11%
	Controlling	954	1773	86%
9:00 – 9:15am	Metered	2297	1659	-28%
	Controlling	1240	1212	-2%

Queue Length Comparisons

Figure 5 shows a comparison of 15-minute interval queue lengths for condition without signal metering system (base condition) with under signal metering system condition (with metering). As can be clearly seen from figure 5, the use of signal metering system has significantly reduced the queue length at the controlling approach. While signal metering system is operational, the system generates more gaps in the circulating flow at the controlling approach which enables more vehicles to enter the roundabout resulted in a significant reduction in the queue length. For example, the estimated queue length at the controlling approach for the time interval of 8:00 am – 8:15am was reduced by approximately 83% (LOS F to LOS B) under signal metering strategy. However, such benefit was not significant when the demand to capacity ratios fall below 0.85 (time interval from 9:00 am – 9:15 am).

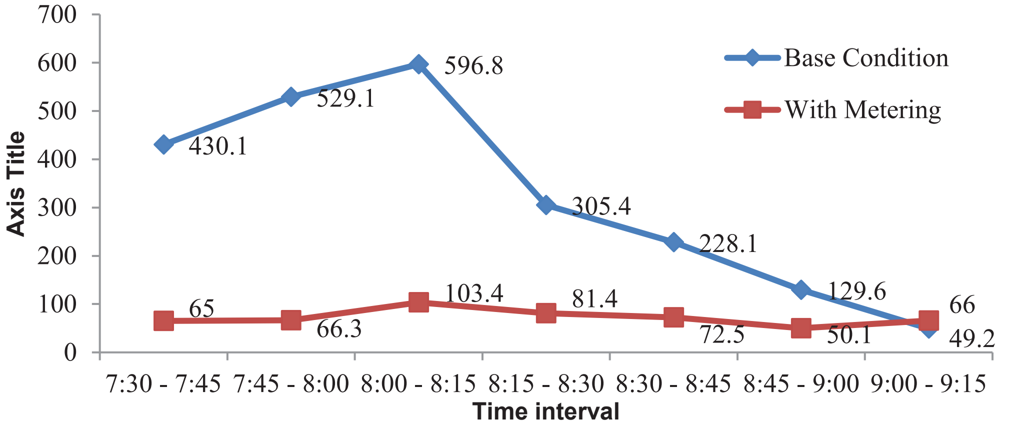


Figure 5. Queue length comparison at controlling approach (Jalan Stutong)

As for the metered approach, the use of signal metering system has resulted in a significant increment in the queue lengths as compared with the base condition as shown in figure 6. This is because signal metering prevents movement of vehicles into the roundabout when red light is shown at the approach. For example, the queue lengths were significantly increased up to 4953m for the time interval of 7:30 – 7:45 am.

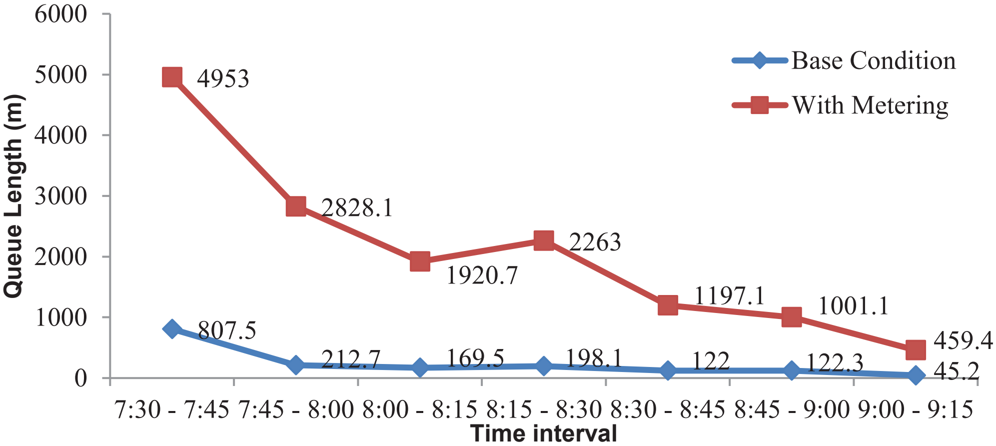


Figure 6. Queue length comparison at metered approach (Kota Samarahan approach)

While the aim of the use of signal metering system at the roundabout is to improve its capacity, obviously in the study context, it was not achieved for the studied roundabout as the queue length increased significantly up to 642% (time interval of 8:15 am – 8:30 am) for the metered approach. Although the controlling approach experienced significant benefits from the use of signal metering system, the metered approach on the other hand suffered severe delays as a result.

Evaluating the Impacts of Signal Metering on the Controlling Approach

An independent T-test was conducted to compare the queue lengths for base case condition (without signal metering) and with signal metering for the controllong approach. The results indicated that there was a significant difference in the scores (M=1711.0571, SD=1253.9275); t (6) = 3.610, p = 0.011 < 0.05. Therefore, reject H0 at α =5% and accept the alternative hypothesis, Ha = μd> 0. These results suggest that application of signal metering sytem have a significant effect at improving the controlling approach capacity.

The findings from this study is consistent with the findings of past studies by Rahmi (2008) and Natalazio (2005) which concluded that signal metering system is effective at improving the entry capacity of the controlling approach by reducing the dominant flow effect that occurs at the studied roundabouts.

Overall Impacts of Signal Metering System on the Roundabout

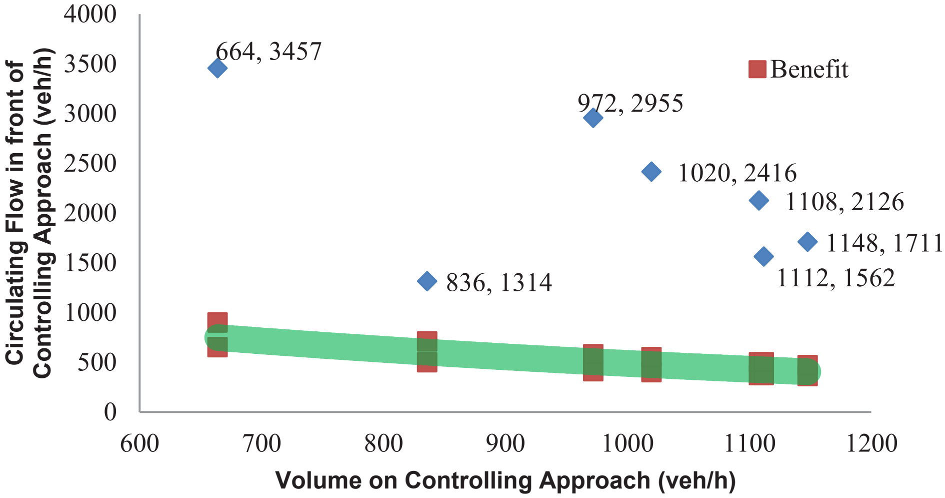
To examine the overall impacts of the use of signal metering system in improving the studied roundabout capacity, a further analysis was undertaken. Table 3 shows the overall roundabout performance estimated by SIDRA Intersection 5.1 software.

Table 3. Overall Roundabout Performance With and Without Metering Signals

Time interval	Scenario	Average Delay (s/veh)		Queue Length (m)	
7:30 – 7:45am	Without Metering	60		808	
	With Metering	722	(1103%)	4954	(513%)
7:45 – 8:00am	Without Metering	91		529	
	With Metering	412	(353%)	2828	(434%)
8:00 – 8:15am	Without Metering	68		597	
	With Metering	316	(365%)	1921	(222%)
8:15 – 8:30am	Without Metering	34		305	(642%)
	With Metering	167	(391%)	2263	
8:30 – 8:45am	Without Metering	26		228	
	With Metering	195	(650%)	1197	(425%)
8:45 – 9:00am	Without Metering	135		130	
	With Metering	74	(-45%)	1001	(670%)

For the time period from 7:45 am – 8:45 am, it is obvious that considerable increment in the roundabout average delays and queue lengths have occurred at the studied roundabout. Worst time interval was from 7:30 – 7:45 am, in which the estimated average delay increment under metering signal system at the roundabout was 1103%. However, the use of signal metering system in dealing with traffic flow demands only showed a significant benefit upon the reduction of the total traffic flows for the time interval of 8:45 – 9:00 am. For the concerned time interval, the average reduction of vehicle delays achieved was 45%.

Figure 7 shows a comparison of the analysed study data with Natalizio (2005) recommended benefits of signal metering application (green band indicates the sum of traffic flows on the controlling approach and the circulating flow in front of the controlling approach that would benefit from the operation of signal metering system).



(*Note: the data labels indicate both x and y values*)

Figure 7. Flow conditions on Taman BDC

It can be clearly seen that none of the analysed data for the studied roundabout were within the limit of the recommended range. In fact, all the data points for the 15 minutes time intervals were significantly higher than the recommended range. This clearly explains as to why the use of signal metering for the studied roundabout have failed to achieve its intended objective.

CONCLUSIONS AND RECOMMENDATION

Signal metering system is useful in improving roundabout performance in dealing with unbalanced traffic flow conditions. The main conclusions that can be drawn from the results are:

a) Signal metering system is a useful tool to mitigate delays at roundabout problematic approach due to unbalanced or dominant flow conditions. The results showed that the average queue lengths at the controlling approach was significantly reduced up to 83% under signal metering condition. This is further supported by a T- test results which indicated a significant difference between signal metering condition and non-metering condition ($t(6) = 3.610$, $p = 0.011 < 0.05$)

b) However, due to excessive traffic flow demands (demand to capacity ratio more than 1.0), signal metering system failed to improve the overall roundabout capacity albeit the capacity of the controlling approach was improved significantly.

c) In addition, the results confirmed the recommended range for the sum of traffic flows (approach entry demand and approach circulating flow) as suggested by Natalizio (2005), i.e. from 1300 – 1400 vehicles per hour for an effective operation of signal metering system in dealing with roundabout's unbalanced flow conditions. Thus, since the overall traffic flows (sum of traffic demand at the controlling approach and the circulating traffic flow at the entry approach) were significantly higher than the recommended values, obviously the results indicated that no overall benefits were achieved under signal metering condition.

To verify further the benefits of signal metering application in improving roundabouts performance due to unbalanced flow conditions, it is suggested that a further research should focus on roundabout that deals with lower traffic flow demand but inefficient in terms of capacity as a result of dominant flow patterns.

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EVALUATION OF THE SEISMIC FRAGILITY CURVES OF THREE-SPAN RC BRIDGES USING NONLINEAR TIME HISTORY METHOD

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Abstract
This study presented the development of fragility curves in three-span reinforced concrete bridges. A prototype model was designed based on British Standard (BS 5400) (Part 4). The model included three-span structures with different concrete grades and pier heights. Eurocode 8 (EC8) was used as reference for seismic consideration similar to BS 5400. Part 4 does not specify any seismic provision. SAP 2000 software was used as the main tool for nonlinear time history to facilitate incremental dynamic analysis (IDA). Ground motion from Ranau earthquake was used to examine IDA curves. The five performance levels stated in FEMA-273 were identified based on IDA curves. These performance levels include: (i) operational phase (OP); (ii) immediate occupancy (IO); (iii) damage control (DC); (iv) live safety (LS); and (v) collapse prevention (CP). These levels will be used as main guideline in observing the bridge structure's performance. The fragility curves discussed in this study developed as a result of different concrete grades and height of bridge piers. Concrete grades 50 and 55 have better drift performance than concrete grade 45. Piers with a height of 5 m have better drift performance rather than those with 8 m height.

INTRODUCTION

Malaysia is situated close to countries with high seismic activities. Bridges in areas with low and moderate seismicity such as Malaysia are at risk of collapse; this collapse may be caused by near-field earthquake (especially in Sabah) and far-field earthquake (especially in Sumatra and peninsular Malaysia) (Meldi, 2011). Most bridges in Malaysia, especially in Sabah and Sarawak with the exception of the first and second Penang bridges, do not consider earthquake loading when conceptualizing structural design. This deficiency suggests the importance of seismic vulnerability assessment when conducting pre-earthquake planning for future seismic events.

Given the catastrophic effects of earthquakes, assessment of the seismic vulnerability curves of bridges has become an important issue in recent years (Mohd Zamri and Adnan, 2016). This study provides engineers and practitioners in civil engineering insights on the fragility curves of bridges and useful tools for assessing damage that can be sustained by a certain level of earthquake. This study shows that the different concrete grades and pier heights of existing bridges design will determine the performance levels of bridge structures. The effects of concrete grade and pier height can be observed based on the drift limit and fragility curves of bridge structures. The engineering-friendly assessment proposed in this study will improve the performance level of bridges. The increasing frequency of disasters and their impacts on communities strengthened the need for efficient safety measures, disaster risk reduction, and adequate management plans (Anudai et al., 2016). Thus, the seismic vulnerability of bridges should be identified. Such vulnerabilities are associated with various states of damage that range from loss of serviceability to collapse.

The seismic vulnerability of bridge structures depends on several aspects of structural forms; examples of structural forms include single or multispan structures, continuous or internal support, simple support, single column or multicolumn bend, straight or skewed abutments (Pottatheere and Renault, 2008). Seismic vulnerability is demonstrated as fragility curves, which are determined by considering uncertainties in seismicity, structural characteristics, and soil–structure interaction. The fragility curves of bridges are useful tools in vulnerability assessment. These tools facilitate assessment of damage that may be sustained for a certain level of earthquake. Fragility curves combined with analysis of seismic hazard in bridge sites can facilitate reliable assessment of the seismic risk of highways and can even be used by authorities to prioritize in-situ investigation of the structural integrity of bridges in an area hit by a strong earthquake (Karakostas, 2006).

Vulnerability information in commonly developed from fragility curves. This approach is widely practiced when the information being developed involves uncertain sources, such as estimation of seismic hazard, structural characteristics, soil–structure interaction, and site conditions. The following four methods were classified for developing fragility curves: (1) professional judgment; (2) quasi static design code consistent with analysis; (3) utilization of damage data associated with past earthquakes, and (4) numerical simulation of the seismic response of structure based on dynamic analysis (Shinozuka, 2000). Fragility curves are emerging tools used in the evaluation and assessment of seismic risk. Fragility curves also can be used to optimize retrofit methods for bridges (Padgett, 2007). Fragility curves emerged as important tools for identifying potential seismic risk and consequences during and after earthquakes.

Fragility curves transitioned from empirical to analytical methods (M. Billah and Shahria Alam, 2014). Different methods and approaches were developed to examine fragility curves. These methods include field observations, advance analysis using analytical models, and hybrid methods. Fragility curves, which are effective tools in seismic risk analysis, are becoming increasingly popular. Fragility curves are not only useful in seismic risk assessment, but also in retrofit prioritization of bridges and post-earthquake response. Fragility curves can be used in updating a bridge network to highlight vulnerable bridges and maximize the functionality of an entire bridge network. In actual post-earthquake situations, fragility curves can assist decision makers in making rapid decisions on bridges closures.

The scope of this study is limited to the investigation of three types of concrete grades and two pier heights of a prototype bridge model. This study evaluates the drift performance of the three spans of Reinforced Concrete (RC) bridge based on Nonlinear Time History Analysis (NTHA). This study also develops the fragility curves of the three spans of RC bridge based on NTHA.

METHODOLOGY

NTHA was conducted to evaluate drift based on the performance of an existing bridge structural model during earthquake. The methodology is summarized as follows:

1. Data required for the proposed research project are collected.
2. The bridge model is designed based on the data collected by SAP 2000. Existing software such as SAP 2000 will be used as the main tool for this study.

3. The following analyses will be conducted to obtain a nonlinear analytical model of the representative bridge. NTHA will be used for dynamic analysis. Damage Measure (DM) and Intensity Measure (IM) will be used as main indicators. DM shows that the drift performance of the bridge is attributed to its performance level. IM will assess intensity measure based on peak ground acceleration subjected to bridge failure.
4. Fragility curves are developed based on the nonlinear analytical modelling of the representative bridge.

Structural Model

A set of bridge model with different pier heights and concrete grades was analysed. The models are designed based on BS 5400 Part 4 code. Figure 1 illustrates the bridge model. This model consists of three spans with the same length. Tables 1 and 2 respectively show the span length and concrete grades used for the bridge model. Pier height was set to 5 m and 8 m in accordance with the findings of NBI Database (NBI, 2011), which stated that the column height of bridges built after year 2000 should be between 4 m and 8 m.

Figure1. View of the bridge model

Table 1. Length of the span for the bridge model

No of span	Length (m)
1	40
2	40
3	40

Table 2. Concrete grade of the bridge model

Height of the piers (m)	Concrete Grade		
5	C45	C50	C55
8	C45	C50	C55

Ground Motion

Incremental Dynamic Analysis (IDA) analysis requires a suitable set of ground motion records. According to Nazri and Alexander (2015), several parameters should be considered when selecting ground motion; these parameters include event magnitude (6.1), peak ground acceleration (0.123 g), distance (60 km – 70 km), and soil type. The ground motion used for this analysis is was obtained from the database of the Ranau earthquake. The Ranau earthquake is considered moderate, but it was the strongest earthquake recorded in Malaysia.

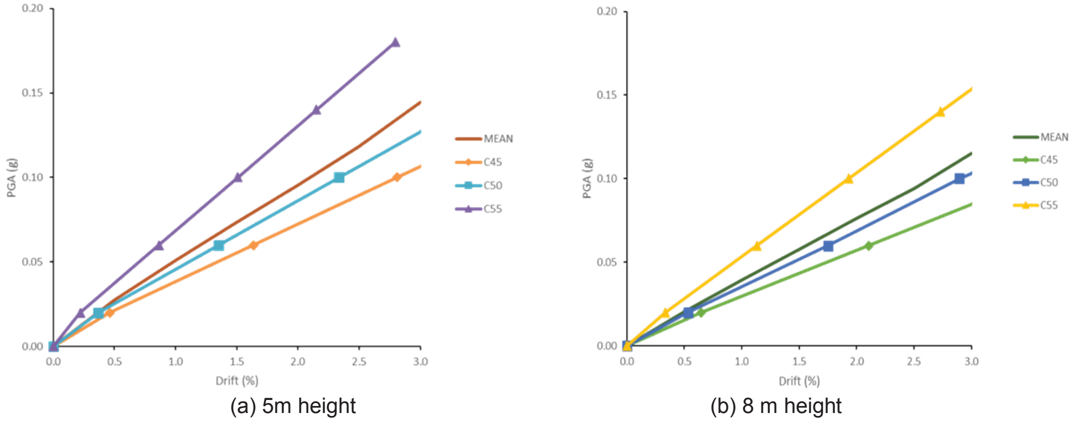
RESULT AND DISCUSSION

Incremental Dynamic Analysis (IDA)

Incremental Dynamic Analysis (IDA) is a useful method for evaluating the seismic performance of a structure until it collapses. NTHA was conducted for structures under monotonic scales, which are considered ground motions, to evaluate DM. The IM of the scaled ground motions and the IDA curve of DM were plotted to provide an overview of the seismic behavior of structures subjected to earthquakes until they collapse.

The analysis is performed using SAP 2000. NTHA was conducted on the ground motion of the Ranau earthquake. PGA scaling increased every 0.02 until 0.20 g was achieved. The analysis was stopped at PGA 0.20 g because most of the structures were unstable at PGA 0.12 g to 0.20 g. The maximum drift of the bridge is considered because it is a global deformation measure for structural and non-structural measurement. IDA curves were then generated. Each structure with unique characteristic and pier height will record a different pattern of IDA curve. These IDA curves indicate the relationship between drift and PGA. This analysis solely focused on drift until 3% drift is achieved. This process is based on (Xue et al., 2008) who suggested that the development of fragility curve limits maximum drift attributed to performance level.

Five performance levels were used referred to assess structural performance. The vertical gridlines at drifts of 0.5%, 1.0%, 1.5%, 2.0%, and 2.5% respectively represent OP, IO, DC, LS, and CP. Figures 3(a) and 3(b) show the IDA curve obtained from the analysis of Ranau earthquake; these IDA curves have different concrete grades and pier heights. IDA curve was developed using SAP 2000. PGA varies between 0.02 g and 0.20 g. Figures 2(a) and 2(b) show that concrete grades 50 and 55 demonstrated better drift performance than concrete grade 45 because concrete grades 50 and 55 have higher compressive strength than concrete grade 45. According to (Leroy 2012), concrete grades 30 to 45 are commonly used for build the arch of bridges. Concrete grade 45 is not suitable for constructing the structure of bridges, especially the piers of bridges.



(a) 5m height (b) 8 m height

Figure 2. IDA curve for (a) 5 m height of piers with three concrete grades based on Ranau records; (b) 8 m height of piers with three different concrete grades based on Ranau records

Mean drift was calculated for every PGA to show the average of IDA curve. Mean drift was then compared with limit state as shown in Figure 3. Figure 3 shows that pier height of 5 m demonstrated better drift performance than structures with a pier height of 8 m. This finding is attributed to the stronger stability of piers with 5 m height than those with 8 m height even for different concrete grades. For an example, to reach DC limit, 5-m pier height requires 0.072 g, whereas 8-m pier height requires 0.06 g. This finding suggests that 8-m pier height will collapse earlier than piers with 5 m height even with different types of concrete grade materials.

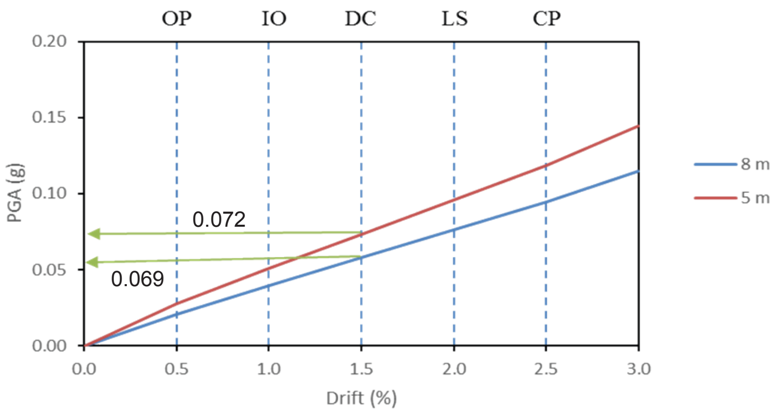


Figure 3. Mean IDA for 3 concrete grades with two different heights of the piers based on Ranau records

Fragility Curves

Fragility curve is the conditional probability that a structure will meet or exceed a specified damage level. A number of parameters can be used to develop fragility curve. These parameters include PGA, spectral acceleration, and peak ground velocity. PGA was selected because it was used to conduct NTHA. The equation below was used to develop fragility curves. This equation was simplified by (Ibrahim and El-Shami, 2011).

$$P[D/PGA] = \phi\ ((In(PGA)\text{-}\mu)/\sigma) \qquad (1)$$

Two parameters, namely, mean and standard deviation, we used to develop fragility curve. The mean and standard deviation of the PGA were calculated for every point across the limit of state vertical gridlines at drifts of 0.5%, 1.0%, 1.5%, 2.0%, and 2.5%. Table 3 shows the calculated parameters.

Table 3. Parameter of log-normal distribution for different pier heights with three concrete grades based on Ranau field record

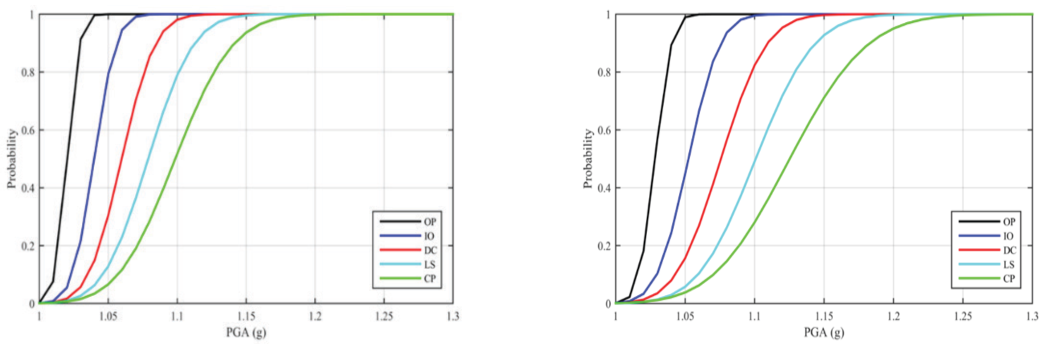
Height (m)	OP		IO		DC		LS		CP	
	μ	*σ*	*μ*	*σ*	*μ*	*σ*	*μ*	*σ*	*M*	*σ*
5	0.028	0.009	0.051	0.017	0.073	0.024	0.096	0.030	0.118	0.039
8	0.020	0.007	0.039	0.012	0.058	0.018	0.076	0.024	0.094	0.030

Seismic fragility curves can be presented in two ways, namely, damage probability matrix and damage probability curve. This study presented seismic fragility in damage probability curve (Fragility curve). Figures 4(a) and 4(b) show the sets of fragility curves.

When 1.05 g ground motion was exposed in the Ranau field, the probability of reaching or exceeding the OP level is approximately 100% for pier heights of 5 m and 8 m. The probability of reaching and exceeding the CP level is approximately 2% for pier height of 5 m and 4% for pier height of 8 m.

When the 1.2 g ground motion was exposed in the Ranau field, the probability of reaching and exceeding the OP level is approximately 100% for pier heights of 5 m and 8 m. The probability of reaching or exceeding the CP level based on Ranau field records is approximately 95% for pier height of 5 m and 100% for pier height of 8 m.

Figures 4(a) and 4(b) show that the probability of reaching or exceeding the OP level for two different pier heights is 100% when PGA is 1.05 g. At PGA of 1.2 g, probability of reaching or exceeding the CP level when pier height is 8 m is higher (100%) than that at pier height of 5 m (95%). Results showed that this particular bridge is most vulnerable at the highest level of pier height.



(a) 5 m height (b) 8 m height

Figure 4. Fragility curve for (a) 5 m height of piers with three different concrete grades based on Ranau records; (b) 8 m height of piers with three different concrete grades based on Ranau records

CONCLUSION

This paper conducted a general review of seismic fragility curves for three-span RC bridges using NTHA method. The following conclusions are drawn from this research: IDA curves based on Ranau field records show that concrete grades 50 and 55 have better drift performance than concrete grade 45. Pier height of 5 m has better drift performance than pier height of 8 m. Concrete grade 50 with 5 m pier height can sustain up to 0.12 g, whereas concrete grade 55 can sustain up to 0.16 g before bridge collapse. Concrete grade 45 can sustain up to 0.09 g. However, the results for 8 m pier height are different in terms of collapse state. Concrete grades 50 and 55 with 8 m pier height require 0.085 g (grade 50) and 0.14 g (grade 55) before bridge collapse. This phenomenon is attributed to the high compressive strength of concrete grade 55 at pier heights of 5 m and 8 m. Before a bridge collapses during an earthquake, this height can last longer and absorb more energy than those with lower concrete grades. Concrete grade 45 at 8 m pier height require 0.07 g before collapse. The results showed that the selection of concrete grade for construction of the bridge structure is an important aspect that determines bridge structure. Pier height significantly determined the stability of a bridge structure during an earthquake.

The ground motion in Ranau suggest that piers with 8 m height with different types of concretes have the highest probability of reaching and exceeding the OP and CP level when 1.2 g ground motion was exposed. Probability is approximately 100% for both OP and CP level. The probability of reaching and exceeding the OP and CP level when 1.2 g ground motion was exposed were approximately 100% for OP level and 95% for CP level when pier height was 5 m with different types of concrete strength.

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CONSOLIDATION OF DREDGED MARINE SOILS WITH SINGLE AND DOUBLED DRAINAGE

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Abstract
Large volume of dredged marine soils (DMS) were produced in Malaysian waters during construction or maintenance the port structures. DMS have poor engineering properties and consider as geo-waste materials. The samples were essentially high-water content, limited strength and excessive compressibility. The main purpose of this study was to examine the suitability and effectiveness of DMS compressibility characteristics of DMS with different type of drainage (singly and doubly). It shows that the doubly drained can hasten the consolidation than single drainage. Dredged marine soil was remoulded at high water content and allowed to settle. Thus, the settlement of soil particles along the column can be expected.

INTRODUCTION

Dredging activities are carried out in order to deeper the sea vessels for the harbour structure. It is necessary to keep the waterways unblocked and prevent the rivers from flooding as well as to restore the ecosystem in rivers (Winkels and Stein, 1997; Zhu et al., 2007; Kim et al., 2011; Ganesalingam et al., 2011). The volume of sediments in different countries are as follows, i.e. United States – 300 million m^3 (Wang et al., 2012), China - 100 million m^3 (Zhu et al., 2007), South Korea - 95.3 million m^3 (Ganesalingam et al., 2011), France – 50 million m^3 (Amiran et al., 1999), Japan with 10-15 million m^3 (Chan et al., 2013) and Malaysia - 3.5 million m^3 (Chan et al., 2011). The volume of sediment from dredging activities are continuously increase because the industrial development near the ports.

The sediments from dredging operation referred to Dredged Marine Soils (DMS) that settle at the bottom of water body. DMS consist of loose particles such as rock, gravel, sand, clay and silts (Bortone, 2007). This DMS is well-known as a geo-waste material with poor engineering properties (Goldbeck, 2008). It can be considered as very soft soil with high water content, limited strength and excessive compressibility. DMS just can hold the shear strength <50 kPa only (Chiu et al., 2008). Moreover, some additional water can be mix with soil during the dredging operation. Thus, an increasing of water content happens even further (Berilgen et al., 2015). Commonly, DMS are disposed back into designated open water, landfills or hydraulic onshore at certain longitude and latitude (Siaw and Chan, 2013). In Malaysia, the dumping sites for the DMS are 10 nautical miles (1.852 km) from the shoreline (Ganesalingam et al., 2011). However, there would be high possibility for the DMS to return to the river mouth because of the wave flow and rapid of sedimentation (Salim et al., 2012).

Dredged marine soils can be used for construction materials or wetland restoration because it is clean and usable product (Shahri and Chan, 2015). These types of sediments have a potential to be reuse again as a backfill materials instead dumped into the ocean (Azhar and Chan, 2015). As a consequence, reuse the DMS will give major contribution to the sustainable development and environmental impact (CEDA, 2010; Zentar et al., 2009). Therefore, the dredged soil needs to be improved its engineering properties in order to represent a form of sustainable development such as the land reclamation.

Thus, in this paper the physical properties of dredged marine soils such as Atterberg limit, particle size distribution etc. were determined in the laboratory. On the other hand, 1-D consolidation test was carried out by using the oedometer test. The main focus in this study was the acceleration of consolidation by different porous media i.e. single and double drainage.

MATERIALS AND METHODS

Materials

In collaboration with the Marine Department of Malaysia, the samples were retrieved from Kuala Perlis (Figure 1). The samples of DMS were dredged by backhoe dredger at depth of 4 – 6 m from sea level (Figure 2). Then the samples of DMS were taken manually into the covered containers with placing it by double layer of plastic sampling bags. The samples were finally stored indoors to avoid the direct sunlight and heat. The DMS was in a slurry form, dark grey in colour and with an unpleasant smell because of the microbiological activities as shown in Figure 3.

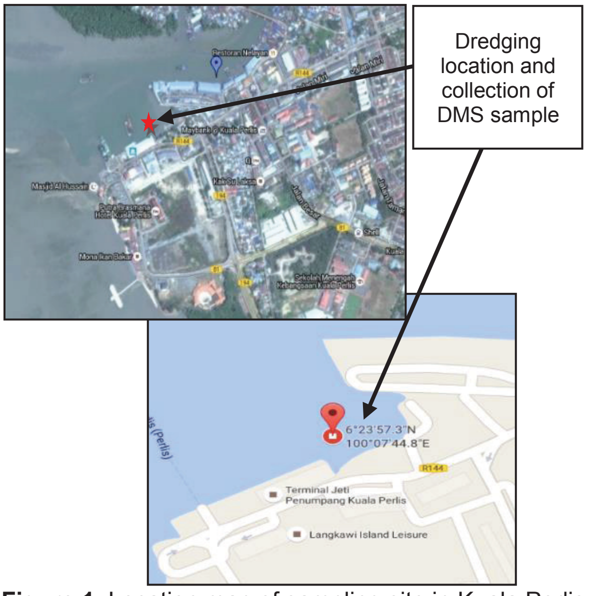

Figure 1. Location map of sampling site in Kuala Perlis

Figure 2. Backhoe dragger on the barge

Figure 3. Dredged marine soils from Kuala Perlis

Methods

Physical Characteristic Tests

To prepare the samples for the properties, at required quantity was scooped from the container, and then and stirred by using the mechanical mixer. The mixing required 10-20 minutes to form a uniform mixture. All the physical properties test was performed in accordance with BS1377:1990 (British Standard Institution). The test for water content is to determine the moisture content of samples as percentage of its dry mass. The oven-dried method of the samples at 105°C for 24 hours to remove the entrapped water.

Atterberg limits test is a basic measure for the fine-grained soil. The test consists of liquid limit and plastic limit. Liquid limit test is to determine the changes of soil from plastic to liquid state. In this study, the method of cone penetration been used to understand the behaviour of soil. From the test, it can be predicted that higher penetration will represent the lower stiffness of the sample and vice versa. The sample was penetrated by the cone for 5 seconds with three reading consecutive readings were taken. Meanwhile, plastic limit is to determine the changes from semi-solid to plastic state. The samples were rolled into thread at least 0.3 mm in diameter.

Particle size distribution of DMS was obtained by wet sieving and hydrometer analysis. The wet sieve test was conducted for soil which contains of silt, clay or both. The hydrometer analysis is a method used to the percentage of fine sand, silt, clay and inorganic fraction of soils passing sizes from No. 200 (63 μm) sieve. Both data of wet sieve and hydrometer were combined.

The pH value of the sample was determined by using a pH meter. Specific gravity (Gs) is defined as the ratio of the unit weight of a given material to the unit weight of water. Distilled water is normally used as the density bottle fluid, but an alternative liquid (i.e. kerosene and white spirit) should be used if the soil contains soluble salts. Considering that the sample was retrieved from the sea, kerosene was used in this study.

Oedometer Test

The oedometer test were carried out by following the procedure prescribed in BS1377: 1990 (British Standard Institution). In this test, fully automated oedometer was used to run the consolidation test for the dredged marine soils. The ring with 75 mm diameter and 20 mm height containing the cured specimen was placed between the two porous stones, one at the top of the specimen and another at the bottom for double drainage. Meanwhile, for single drainage, only one porous stone was placed on top and for the bottom used the smooth metal without any porous surface. The load on the specimen was applied and the compression was measured by imbedded control system. Incremental vertical stress was applied as 5, 12.5, 25, 50, 100, 200, 400 and 800 kPa, with each load being maintained for 24 hours. While unloading stress was taken as one quarter of the previous stress.

RESULTS AND DISCUSSION

Physical and Chemical Properties of DMS

Dredged marine soil from Kuala Perlis was a mixture of fine-grained silt and clay as shown in Figure 4. The specific gravity of DMS is determined to be 2.68. The natural water content of the DMS is 218.07 % with 3LL higher than the sample Kuala Perlis by Salim et al. (2013) with 66.13 %. Usually, it happens because of the sedimentary process on different environment, both physical and engineering properties of DMS. The pH is used to measure the acidity and alkalinity of the certain material. Hence, the pH value for DMS material from Kuala Perlis was 8 and classified as moderate alkaline.

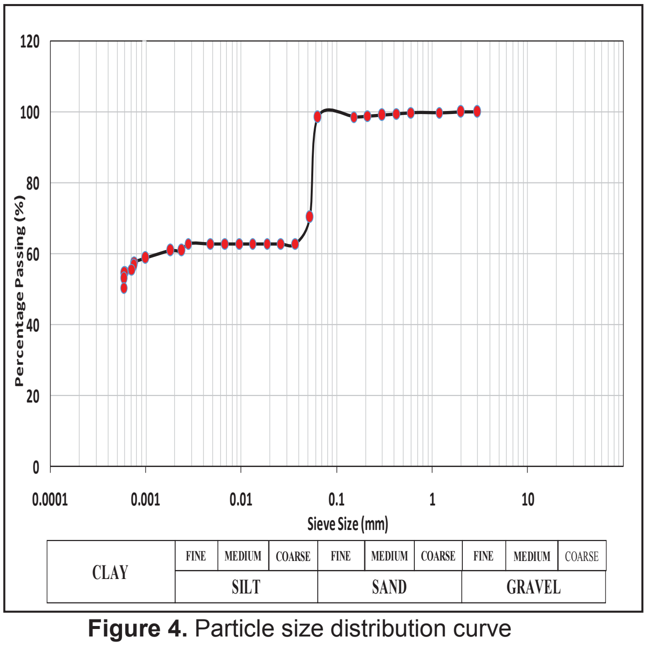

Figure 4. Particle size distribution curve

Based on the Unified soil Classification System (USCS), specimen of DMS is classified as high plasticity silt (MH) with LL > 50 % (Figure 5). Table 1 shows the summary of soil classification. Moreover, sand and silt can be found due to the location of dredging areas and the activities surrounding because it near to the shore.

Table 1. Summary of properties for dredged marine soils

Properties of Dredged Marine Soils	
Natural water content, w_{nat}	218.07 %
Specific gravity, G_s	2.68
Liquid limit, LL	66.5 %
Plastic limit, PL	55.8 %.
Plasticity index, PI	10.69
pH	8.0
Soil classification	MH (high plasticity silt)

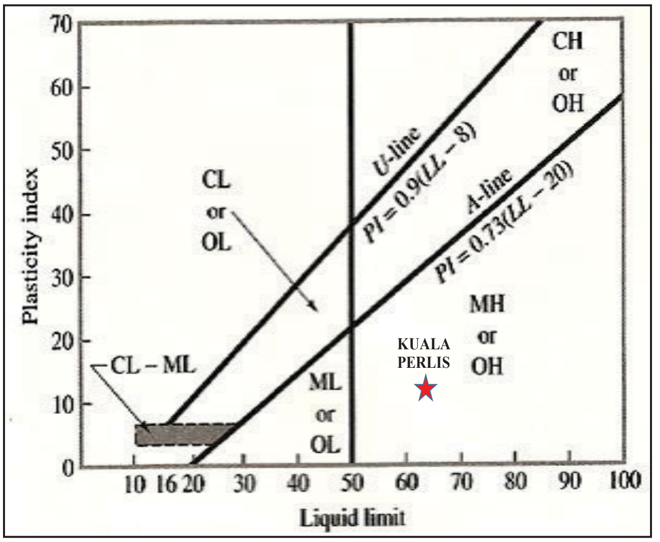

Figure 5. Plasticity chart for dredged marine soils of Kuala Perlis

Oedometer Test on DMS

The oedometer test was used to determine the compressibility and characteristics of consolidation for the soft soil. In this case the specimen was dredged marine soils. Analysis was carried out for both specimens by relating the drainage path either single or double drainage. As mentioned before, the incremental load for this test from 5 kPa until 800 kPa. But both specimens only can stand up until 200 kPa as a final loading. The arm lever of oedometer already reach the limit because the conditions of soil itself with high water content. Note that, the samples were natural DMS without any mixing or treatment of outer materials but used different types of porous media. Referring to Figure 6 and 7, it seems that the settlement for double drainage much faster than single drainage because it has top and bottom to dissipate the water from the soil than the single drainage.

The relation of void ratio at the end of primary consolidation with σ_v' was plotted during the loading as shown in Figure 7. As expected, the gradient lines were steeper at post-yield gradient for both samples. This shows that both specimens were in the same conditions even though in different type of drainage.

The behaviour of consolidation for DMS was expressed in terms of compression index, Cc and recompression index, Cr. The compression index, Cc and recompression index Cr were estimated over an approximate stress range of 50 – 100 kPa and 5 – 12.5 kPa respectively. The value of doubly drainage for Cc and Cr was 1.87 and 1.33 with respectively. Meanwhile, for single drainage was 1.80 and 1.27. On the other hand, the values of C_v for DMS are usually dependent on the pressure in the wider range of pressure as shown in Figure 8. The value of C_v for both conditions do not remain unchanged in the low-pressure range but increase with the increasing pressure. In addition, the consolidation in doubly drained can hasten the drainage path than under single drainage condition. When the specimens of double settle at one-point, single drainage specimens need to double the time. At the end of settlement, both of drainage will meet each other.

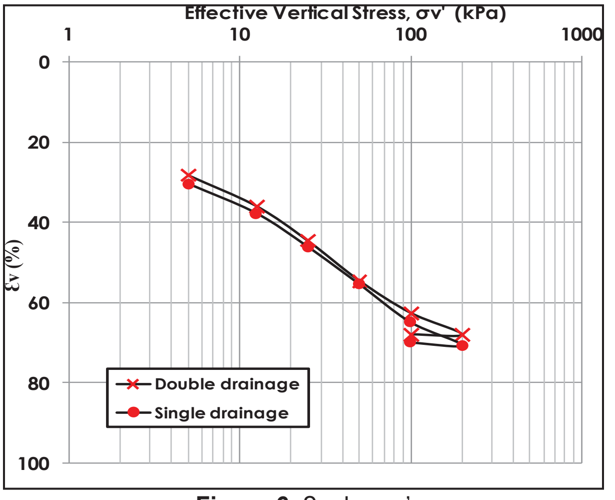

Figure 6. ε_v - log σ_v'

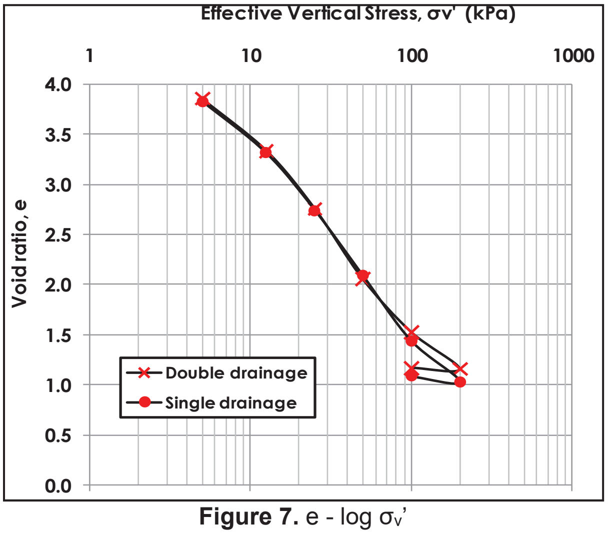

Figure 7. e - log σ_v'

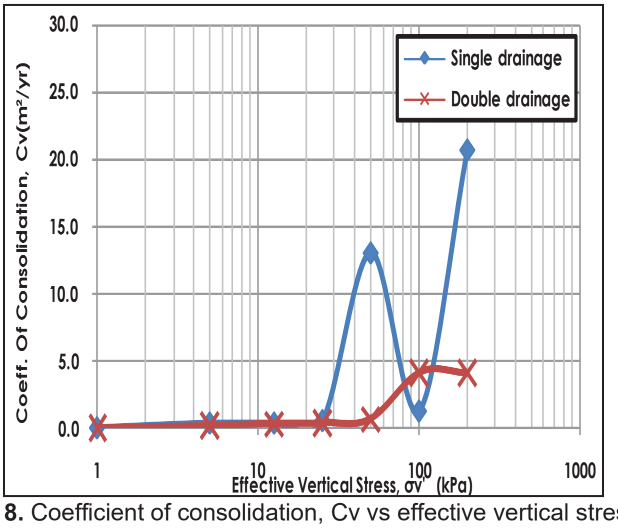

Figure 8. Coefficient of consolidation, Cv vs effective vertical stress, σ_v'

CONCLUSIONS

This paper examines the consolidation behaviour of dredged marine soils. Together with its basic properties from the laboratory test, it proven that the dredged soil has high water content and low compressibility with high plasticity of silt (MH). The oedometer was conducted to prove that the samples with different types of drainage can be a good guide in estimating the time of consolidation. It seems that double drainage gives a better or hasten the consolidation of DMS samples. In addition, the present study indicates a promising application of the drainage material such as recycled materials for the future work either in improving the DMS engineering properties.

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RELIABILITY OF ROCK PROBING FOR MICROPILE FOUNDATION IN LIMESTONE KARST BEDROCK

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Abstract
Pile foundation on limestone bedrock requires an extensive geotechnical investigation to determine and verify the soundness of bedrock. Karst features due to complex tropical weathering such as pinnacle, floater, overhang or cavity are the main challenges. This paper discusses how the evaluation of three sources of data from three methods of ground investigation concludes the reliability of rock probing in determining the precise micro pile setting depth. The case study area is located at the Daerah Dang Wangi, Kuala Lumpur construction site with an area about 1.4 ha. The data were evaluated and studied with respect to thickness of soil layer, bedrock and cavity in limestone karst bedrock. The reliability analysis of rock probing to the micro pile installation depth is classified. Result shows that comparatively the rock probing at the propose pile cap has higher reliability as to borehole alone in determining the soundness of the limestone bedrock. Therefore, the investment on rock probing is commendable for sustainability of vertical city in this formation.

Keywords: *Rock Probing; Micropile; Reliability; Limestone Karst.*

INTRODUCTION

One of the major rock formations encountered in Peninsula Malaysia is limestone with karst features. When designing foundation structure in this formation, the design and construction approach could vary significantly depending on the degree of anomaly and experiences. Geological area in Klang Valley region is known with abundance of limestone rock formation. Under tropical humid condition, the calcite and dolomite limestone or their metamorphosed equivalents develop tropical features which show spectacular tall steep-sided hills (Jennings, 1982) and solution features such as pinnacles, sinkholes and cavities. The underlain extensive limestone bedrock formation is also known as Kuala Lumpur Limestone. Tan (1981) has studied limestone boreholes and concluded that the depth from ground surface to limestone karst bedrock in Kuala Lumpur area can reach up to 50 m which is comparatively deeper than Ipoh area where the limestone karst bedrock can generally be found in less than 20 m deep. The treacherous and almost unpredictable karst bedrock associated with extremely variable overburden soil properties is a typical feature of limestone (Yeap, 1985), which leads to a variety of geotechnical challenges and hazards. The foundation engineering work of the area is well documented by Chan (1985) and Chow (1996) respectively. These heterogeneous profiles and anomalies are of major concern to the foundation engineers (Neoh,1998). Waltham and Fookes (2003) proposed a classification system for karst with respect to the degree of variability of the karst features. It was found that Malaysia climate give rise to karst type kIV (complex) or kV (extreme) with possible cave width of 10 m. Thus, the 10 m depth is used as a guideline for continuous solid rock coring in limestone bedrock. The geological hazards in limestone such as subsidence and sinkhole can induce the risk of sudden collapse of ground surface over time and loss of facilities.

The foundation engineering challenges commonly encountered in limestone bedrock are related to determination of precise pile length and pile setting depth for bored pile and micropile. If micropile which is relatively costly compared to others is adopted as foundation systems, proper ground logging must be carried out. The information especially on the cavity is needed for the design and modification to suit the soil and rock condition of the site (Tan and Chow, 2014). In addition, the mechanical probes are also representing the relatively accurate tool for detecting the depth of caves and sinkholes by critically observing the rate of drilling in relation to the depth (Abdeltawab,2013).

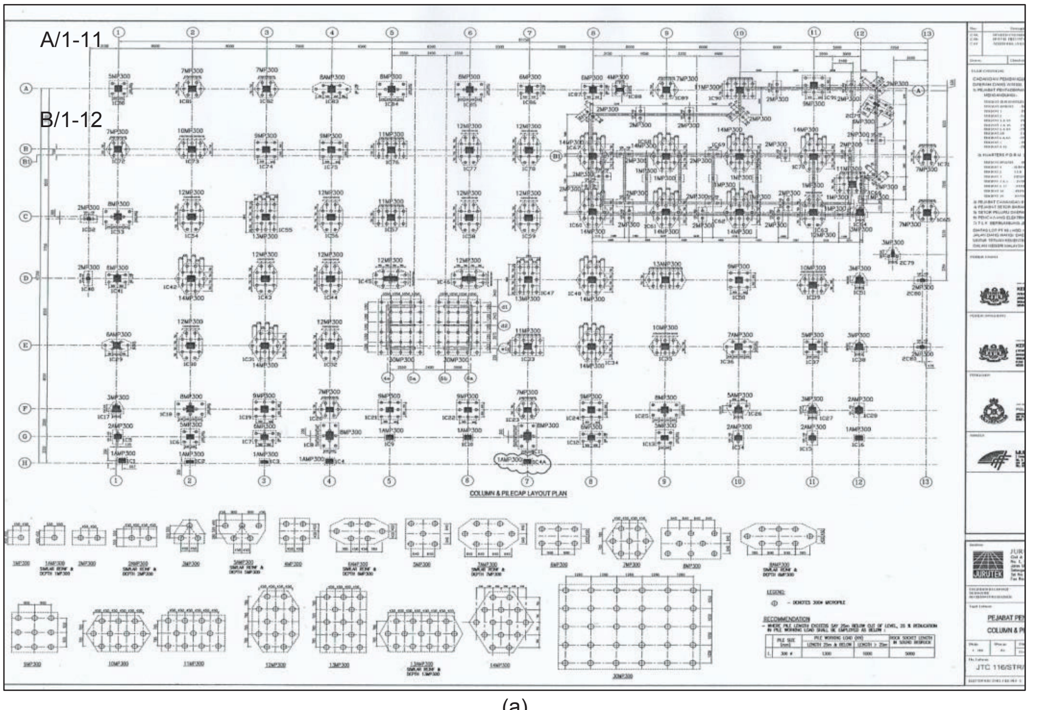
Recently, the rock probing drilling is recommended to be conducted as part of final subsoil exploration in limestone formation before proceeding to piling work. The purpose is to specifically identify the location of any anomalies below the proposed building platform. Hence any associated risk to the structure performance can still be reviewed and alleviated during foundation work. The most common pile design in limestone is by socketing the pile into limestone bedrock by ascertain design depth. Due to the karstic nature of limestone formation, the depth of limestone between pile points within the same pile cap can vary tremendously and the encountered limestone might actually be overhang, floaters or cavities could also be present below the socketed length. This paper presented a case study of rock probing ground exploration in limestone karst bedrock and evaluating the reliability of a single rock probing per pile cap in determining the limestone bedrock profile for micro pile foundation. A comprehensive analysis was based on three sources of data logs of subsoil investigation works carried out at the same site where one of it was rock probing and the other two were borehole and completed micro pile foundation. The thickness of soil, depth of bedrock and presence of cavity in limestone were evaluated critically, hence classified in term of reliability index. The reliability index will produce reading of 100% or equal to 1 when the analysis on the three sources of data conclude the same finding.

MATERIAL AND METHOD

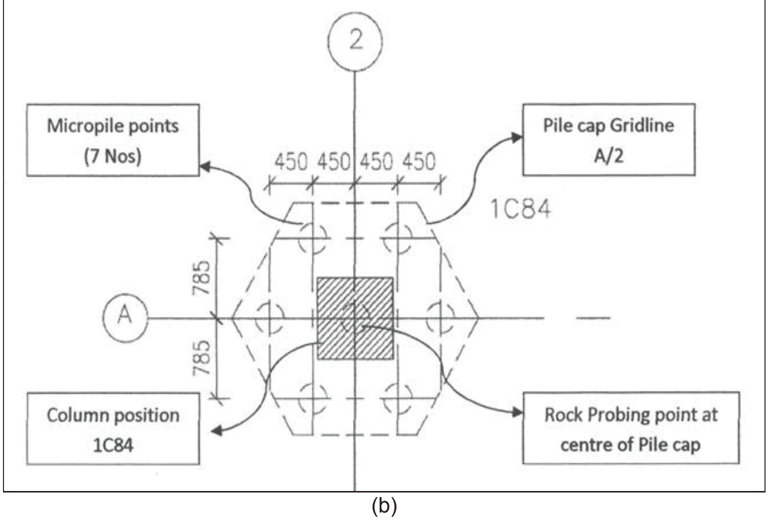
The site investigation works on the 1.4 ha development site is located at Daerah Dang Wangi, Seksyen 40 Jalan Dang Wangi, Kuala Lumpur, Malaysia. The subsurface investigation works carried out at the site were done in phases since year 2007, started by borehole drilling, rock probing and micro piling work which was completed in the year 2010. The site topography plan indicated that the site is generally flat with reduce ground level (RL) range from 31.20 m to 31.50 m. The sample area of study was the admin block specifically focus on each gridline A and gridline B with length of 80 m and 88 m respectively. A comprehensive data was extracted from the borehole log (BH), rock probing log (RP), micro pile log (MP) and foundation layout plans of the admin block. Figure 1a below shows the admin block layout plan indicating gridline A and gridline B both demarcated by broken lines. Whereas Figure 1b below shows the rock probing position with respect to micro pile points at the pile cap. The information extracted from each source are hereafter summarised and evaluated.

Site Investigation

The site investigation procedure and specification is as according Public Work Department, Malaysia, MS 2038:2006 - Code of Practice for Site Investigation, MS 1056: 2005 - Method of Test for Soils for Civil Engineering Purposes and BS 5930: 1999 - Code of Practice for Site Investigation (Mohd Naharudin,2018). The scope of work consists of sixteen (16) numbers of deep borehole (BH) at an interval of 60 meter. However, only 4 boreholes (BH1, BH2, BH3 and BH4) were found within the study area therefore only these data were assessed. The material extracted from the borehole was described as pale grey highly to moderately weathered, very poor Limestone. The rock probing drilling was conducted by drilling into the center point of each pile cap (PC). The total number of rock probing recorded were 24 where 12 points were conducted along gridline A and 12 points were conducted along gridline B. Micro pile drilling at the admin block was carried out by the same company conducting the rock probing drilling. There were 85 points of micro pile along gridline A and 202 points of micro pile along gridline B, both summing up to 287 points. The proposed micro piling foundation was designed with termination depth of 6 metres and the pile was socketed into limestone bedrock.



(a)



(b)

Figure 1. a) Admin block layout plan indicate gridline A/1-11 and gridline B/1-12, b) Rock probing point per pile cap

The reference construction drawings used were site investigation layout plan, site plan with survey topography, column and pile cap layout plan, earthworks layout plan and micro pile details. The drawings were superimposed on each other by using AutoCAD software in order to map detail information such as the position and distance of each BH to the other, the RP and MP locations. Subsequently, similar procedure of analysis was conducted for gridline B/1-12 as well. Table 1, is a summary of information compiled from A / 1-11 and B/1-12 representing the number of micro piles, number of rock probe and the nearest borehole reference for each pile cap.

Table 1. Summary of data extracted at A/1 -11 and B/1-12

Gridline A/1-11													Σ
Grid	1/A	2/A	3/A	4/A	5/A	6/A	7/A	8/A	8a/A	9/A	10/A	11/A	
PC	1C83	1C84	1C85	1C86	1C87	1C88	1C89	1C90	1C91	1C92	1C93	1C95	
RP	1	1	1	1	1	1	1	1	1	1	1	1	12
MP	5	7	7	6	6	6	6	6	5	6	3	8	71
BH	BH1	BH1	BH1	BH1	BH2	BH2	BH2	BH2	BH2	BH3	BH3	BH3	
Gridline B/1-13													
Grid	1/B	2/B	3/B	4/B	5/B	6/B	7/B	8/B	9/B	10/B	11/B	12/B	
PC	1C75	1C76	1C77	1C78	1C79	1C80	1C81	1C70	1C96	1C71	1C82	1C72	
RP	1	1	1	1	1	1	1	1	1	1	1	1	12
MP	7	10	9	9	11	12	12	14	15	14	14	14	141
BH	BH1	BH1	BH1	BH1	BH2	BH2	BH2	BH2	BH2	BH2	BH2	BH3	

Rock Probing

Rock probing drilling was carried out as a final ground investigation before proceeding to piling work. The rotary wash drilling was adopted with hole diameter at approximately 75 mm. When bed rock is encountered, the NLMC core barrel of 38 mm diameter was used to continue drilling into the limestone bedrock. The sign of cavity is detected by observing the rate of drill string penetration which should be faster than the rate of drilling in rock medium, or a sudden drop of drill string when the probe punch through a cavity. When a cavity is encountered, the drilling shall continue until the termination depth is determined by supervision engineer. The termination depth of rock probing was determined by continuous drilling up to 6 meters, without any anomaly.

RESULT AND DISCUSSION

From Table 1 above, the study area has 24 points of rock probing (RP) which represents 24 numbers of pile cap, 212 points of micro pile (MP) and 4 boreholes data. These data logs were tabulated into excel spread sheet format for further extraction of detail information of the ground and the example is shown in Table 2 below. Further illustration and interpretation of Table 2 is reflected in both Figure 3(a) and Figure 3(b). Figure 3(a) shows a typical plot of bar chart describing the profile of limestone in term of depth soil, rock and cavity from RP, MP and BH logs. While Figure 3(b) shows a typical line graphical plot by in percentage for Grid 1/A, setting RP data as a datum line with coordinate (0,0). Reliability analysis is carried out by taking the RP as datum against MP and BH. The difference in data recorded is calculated in percentage as shown. Similarly Figure 4(a) and Figure 4(b) show the analysis for grid 1/B.

The schematic diagram as in Figure 2, illustrate how the interpretation and comparative analysis were done. The reliability analysis and discussion is elaborated as below, taking grid 3/A as an example of how the analysis was done. A similar approach was applied to all grids as shown in Table 2 in order to derive to the classification of the reliability of rock probing for micropile foundation.

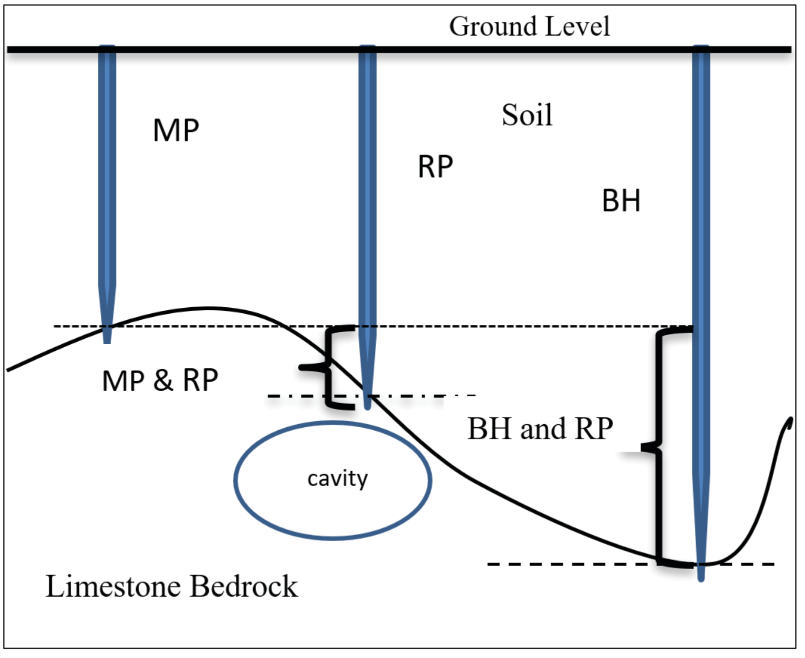


Figure 2. Schematic diagram for analysis purposes

Table 2. Example of Excel Spread sheet summarises the information at Grid 3/A

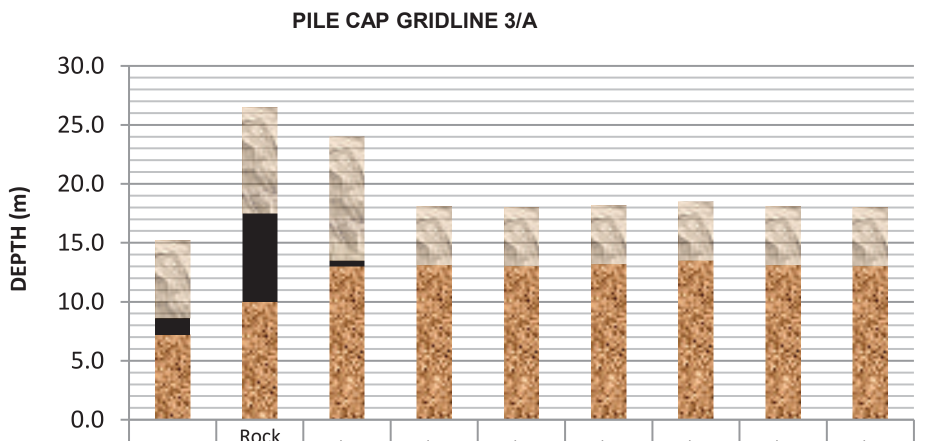
Grid Line	Column No.	Point Name	Depth In **Soil** from GL (m)	Different in depth of soil per point with RP	Percentage Difference BH / MP wth RP **(Soil)**	Thickness of **Rock** (m)	Different in thickness of rock per point with RP	Percentage Difference BH / MP wth RP **(Rock)**	Size of **Cavity** (m)	Different in size of cavity per poin with RP	Percentage Difference BH / MP wth RP **(Cavity)**	Termination Depth of hole(m)	Remark	
													Ground Level (m)	Date Bore
3/A	1C85	BH 1	7.2	-2.8	-28.0	6.6	-2.4	-26.7	1.4	-6.1	-81.3	15.2	31.19	8/10/2002
		Rock Probing	10.0	0.0	0.0	9.0	0.0	0.0	7.5	0.0	0.0	26.5	30.21	26/1/2007
		3/A-1	13.0	3.0	30.0	10.5	1.5	16.7	0.5	-7.0	-93.3	24.0	30.27	23/05/07
		3/A-2	13.1	3.1	31.0	5.0	-4.0	-44.4	0.0	-7.5	100.0	18.1	30.27	6/5/2007
		3/A-3	13.0	3.0	30.0	5.0	-4.0	-44.4	0.0	-7.5	100.0	18.0	30.27	23/05/07
		3/A-4	13.2	3.2	32.0	5.0	-4.0	-44.4	0.0	-7.5	100.0	18.2	30.27	6/1/2007
		3/A-5	13.5	3.5	35.0	5.0	-4.0	-44.4	0.0	-7.5	100.0	18.5	30.27	6/9/2007
		3/A-6	13.1	3.1	31.0	5.0	-4.0	-44.4	0.0	-7.5	100.0	18.1	30.27	30/05/07
		3/A-7	13.0	3.0	30.0	5.0	-4.0	-44.4	0.0	-7.5	100.0	18.0	30.27	6/6/2007

Reliability Analysis of Rock Probing at Gridline 3/A

The pile cap at grid 3/A has 7 points of micropile (3/A-1, 3/A-2, 3/A-3, 3/A-4,3/A-5, 3/A-6, 3/A-7). The nearest BH 1 was located at 10 metres from RP. A bar chart was plotted as in Figure 3(a) to summarise the data extracted from BH, RP and MP with respect to depth in bedrock, depth or size of cavity found and thickness of soil from ground level. The BH recorded a cavity of size 1.4 m, rock probing found a cavity of size 7.5 meter while micro pile 3/A-1 located cavity of size 0.5 m. The depth of bedrock from ground level which is represented by thickness of soil from BH and RP data log were 7.2 m, 10 m respectively while MP recorded a range of 13 m to 13.5 m.

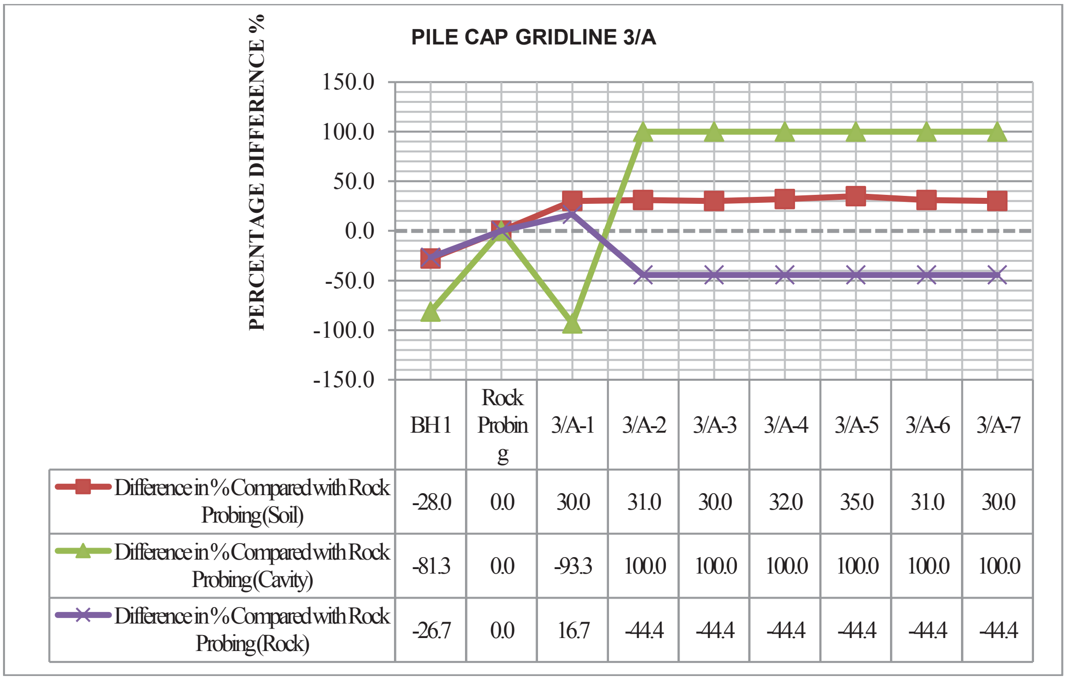
A line graph was plotted by setting RP as a reliable datum (0,0) and hence the percentage difference for each parameter was calculated. Figure 3(b) shows the percentage difference in soil thickness between RP and MP is between 30.0% to 35.0%. However, the percentage difference of RP to BH is 28.0%. The percentage difference in bedrock depth between the RP and MP is between 16.7% to 44.4% and the percentage difference of RP to BH is 26.7%. The reliability analysis is calculated in term probability of cavity found based on the data is between 93% to 100% and that indicated the reliability is below 10%. Therefore, it can be said that the seven points of micro pile installed at gridline 3/A only sit on a relatively small size cavity.

The above analysis showed that out of 7 micro piles installed at grid 3/A the lowest percentage difference of 16.7 % is at point 3/A-1. Hence the reliability of result is about 83.3%. Similarly, the micro piles number 3/A-2, 3/A-3, 3/A-4, 3/A-5, 3/A-6 and 3/A-7 has percentage of reliability equivalent to 55.6%.



	BH 1	Rock Probing	3/A-1	3/A-2	3/A-3	3/A-4	3/A-5	3/A-6	3/A-7
Depth In Rock (m)	6.6	9.0	10.5	5.0	5.0	5.0	5.0	5.0	5.0
Depth In Cavity (m)	1.4	7.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Depth In Soil (m)	7.2	10.0	13.0	13.1	13.0	13.2	13.5	13.1	13.0

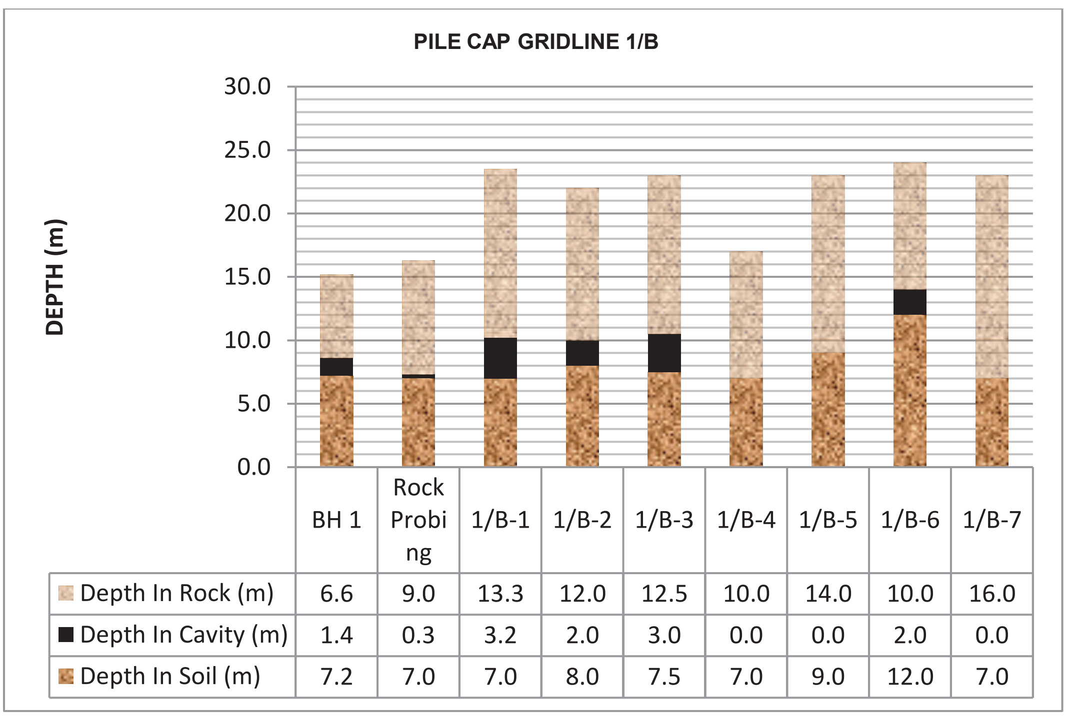
Figure 3. (a) Plot of Bar Chart of BH, MP and RP – 3/A



	BH1	Rock Probing	3/A-1	3/A-2	3/A-3	3/A-4	3/A-5	3/A-6	3/A-7
Difference in % Compared with Rock Probing (Soil)	-28.0	0.0	30.0	31.0	30.0	32.0	35.0	31.0	30.0
Difference in % Compared with Rock Probing (Cavity)	-81.3	0.0	-93.3	100.0	100.0	100.0	100.0	100.0	100.0
Difference in % Compared with Rock Probing (Rock)	-26.7	0.0	16.7	-44.4	-44.4	-44.4	-44.4	-44.4	-44.4

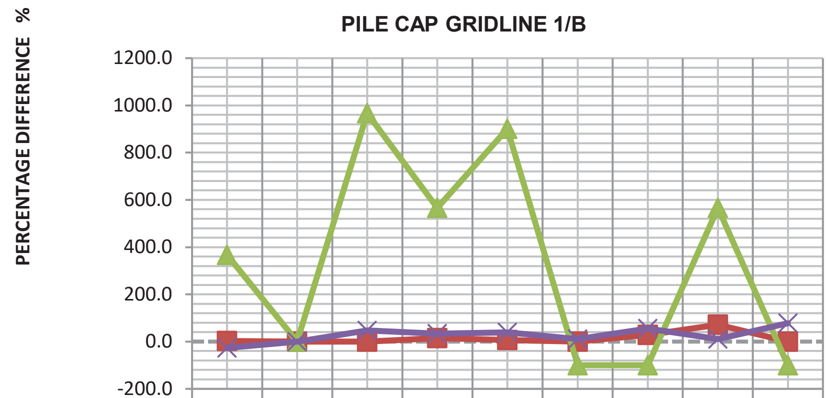
Figure 3. (b) Plot of Line Graph % depth (m) – BH, MP and RP – 3/A

Figure 3(a) and Figure 3(b) show a bar chart and a line graph 3/A respectively.



	BH 1	Rock Probing	1/B-1	1/B-2	1/B-3	1/B-4	1/B-5	1/B-6	1/B-7
Depth In Rock (m)	6.6	9.0	13.3	12.0	12.5	10.0	14.0	10.0	16.0
Depth In Cavity (m)	1.4	0.3	3.2	2.0	3.0	0.0	0.0	2.0	0.0
Depth In Soil (m)	7.2	7.0	7.0	8.0	7.5	7.0	9.0	12.0	7.0

Figure 4. (a) Plot of Bar Chart of BH, MP and RP – 1/B



	BH 1	Rock Probing	1/B-1	1/B-2	1/B-3	1/B-4	1/B-5	1/B-6	1/B-7
Difference in % Compared with Rock Probing (Soil)	2.9	0.0	0.0	14.3	7.1	0.0	28.6	71.4	0.0
Difference in % Compared with Rock Probing (Cavity)	366.7	0.0	966.7	566.7	900.0	-100.0	-100.0	566.7	-100.0
Difference in % Compared with Rock Probing (Rock)	-26.7	0.0	47.8	33.3	38.9	11.1	55.6	11.1	77.8

Figure 4. (b) Plot of Line Graph % depth (m) – BH, MP and RP – 1/B

Figure 4(a) and Figure 4(b) show a bar chart and a line graph 1/B respectively.

CLASSIFICATION ON RELIABILITY OF ROCK PROBING

A comprehensive analysis was carried out for all the grids within the area of study. The classification of reliability of rock probing was done by clustering the results of soil depth and bedrock depth at an interval of 10%, assuming that the reliability or percentage of accuracy of the rock probing with respect to micropile is at 90%. The total number of micropile that fall within the interval is calculated to the percentage of 287 micropiles. The classification of reliability for grid A and grid B are tabulated and as shown in each Table 3 to Table 5 below.

Table 3 shows that the classification of reliability for thickness or depth of soil. Seven number of MP or equivalent of 2.4% of the MP is in compliance with RP, thus read as 100% reliable or accurate. It can be seen that at less than 10% (< 10%) difference between MP to RP, the number of MP are 86 or equivalent to 30% of MP fall within 90% reliability score. Considering a reliability score of 50% and higher, the total number of MP is 268 out of 287 numbers which is about 93% of the MP installed has average different in soil thickness recorded less than 0.5. The balance of 9 MP differed by more than 50%.

Table 4 shows the classification of reliability for size of cavity. This analysis assumed the vertical size of cavity encounter per drill point as a single value. Result showed that 204 numbers of MP has the highest percentage difference with RP of more than 90% (> 90% - 100%), which is equivalent to 71% from total number of MP, thus the reliability is < 10%.

The result deduced that if RP does not encounter any cavity, so is the MP log. However, if both encountered cavity, the discrepancy may be only in term of the size of the cavity (vertical depth of probe) which is acceptable as cavity in limestone has irregular shape.

Table 5 shows the classification of reliability with respect to the thickness of sound limestone bedrock. The highest number of MP is 65 or equivalent to 22.6% of MP fall within the range of 40% to 50%, meaning the reliability score is 50%. More than 50% reliability is due to the distance factor between RP and MP. The analysis does not consider the distance factor between RP and MP as the analysis in made on vertical profile only. However, the distance between RP and MP were 0.45 m to 1.5 m from.

Table 3. Classification of Reliability by Thickness of Soil

No.	Cluster RP (%)	MP (Nos)	MP (%)	Classification of Reliability (%)
1	0	7	2.4	100%
2	< 10%	86	30	90%
3	> 10% - 20%	51	18	80%
4	> 20% - 30%	52	18	70%
5	> 30% - 40%	43	15	60%
6	> 40% - 50%	29	10	50%
7	> 50% - 60%	10	3	40%
8	> 60% - 70%	7	2	30%
9	> 70% - 80%	2	1	20%
10	> 80% - 90%	0	0	10%
11	> 90% - 100%	0	0	< 10%
12	> 100%	0	0	0

Table 4. Classification of Reliability for Size of Cavity

No.	Cluster RP (%)	MP (Nos)	MP (%)	Classification of Reliability (%)
1	0	24	8.4	100%
2	< 10%	4	1.4	90%
3	> 10% - 20%	0	0	80%
4	> 20% - 30%	5	1.7	70%
5	> 30% - 40%	8	2.8	60%
6	> 40% - 50%	9	3.1	50%
7	> 50% - 60%	0	0	40%
8	> 60% - 70%	3	1	30%
9	> 70% - 80%	8	2.8	20%
10	> 80% - 90%	2	0.7	10%
11	> 90% - 100%	204	71	< 10%
12	> 100%	20	7	0

Table 5. Classification of Reliability by Thickness of Sound Rock

No.	Cluster RP (%)	MP (Nos)	MP (%)	Classification of Reliability (%)
1	0	3	1	100%
2	< 10%	15	5.2	90%
3	> 10% - 20%	28	9.8	80%
4	> 20% - 30%	26	9.1	70%
5	> 30% - 40%	34	11.8	60%
6	> 40% - 50%	65	22.6	50%
7	> 50% - 60%	32	11.1	40%
8	> 60% - 70%	32	11	30%
9	> 70% - 80%	17	6	20%
10	> 80% - 90%	23	8	10%
11	> 90% - 100%	9	3.1	< 10%
12	> 100%	3	1.0	0

The overall analysis shows that the discrepancy reliability of rock probing to discover the size of cavity is low (< 0.1), that means the rock probing data log is dissimilar when compared to micro piles data log. The determination of the thickness of sound rock is more reliable (50%), where the discrepancies encountered can be considered relatively moderate. Whereas thickness of soil is good (90%) with discrepancy is less than 10%.

CONCLUSION

A reliable technique of subsurface geotechnical investigation in limestone karst bedrock is very crucial to mitigate the risk of sudden collapse due to presence of karst bedrock. The challenges of foundation problem encountered in the karst limestone may not be similar. This study has deliberately explained the reliability of a single rock probing per pile cap as an alternative, and a way forward for effective and cost saving geotechnical investigation in complex and extreme karst bedrock situation. The reliability of ground investigation data prior to design and construction of foundation in karstic bedrock shall promote safe, construction friendly and cost-effective foundation solutions. The rock probing has shown the benefits of the investment to ensure high safety to the stability of the future expanded vertical city build in this formation.

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SETTLEMENT MONITORING OF LIQUEFIED NATURAL GAS TERMINAL WITH PERSISTENT SCATTERER INTERFEROMETRY

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Abstract
Construction of engineering structures such as Liquified Natural Gas (LNG) terminal on reclaimed land may lead to ground settlement due to the weight of the structures or unconsolidated foundation where the structures were built. Excessive settlement could lead to serious safety issues and may lead to stop of production or even fatalities. Therefore, it is crucial for critical engineering structures such as LNG terminal built on reclaimed land to be monitored against any possible settlement to its foundation, which may weaken their structures. This study presents a settlement monitoring of an LNG terminal using Persistent Scatterer Interferometry (PSI) technique, where a stack of Synthetic Aperture Radar (SAR) images will undergo 'signal and image processing' process within PSI technique to detect small movement or settlement. The average settlement velocity observed, ranges from -19.1 to 22.8 mm/y along the sensor-target (line of sight (LOS)) direction.

Keywords: *InSAR; PSI; StaMPS; Settlement Monitoring; LNG Terminal*

INTRODUCTION

Due to limited availability of land space in coastal area, land reclamation becomes the option to accommodate the construction of engineering structures that should be located close to the coast such as Liquefied Natural Gas (LNG) terminal. Such terminal may require the existence of a port nearby for ease of loading their product to tankers for shipment purposes. Structures on reclaimed land however may undergo settlement process due to unconsolidated foundation, land subsidence, its own weight or construction of heavy structures nearby such as large diameter pipeline, storage tanks and ports that may affect the safety of the engineering structures which in turn may cause stop of production and even fatality. Therefore, it is prudent continuous monitoring against such settlement is practiced to prevent any unwanted eventualities. Ground-based techniques, such as leveling, total stations, Global Positioning System (GPS), accelerometers, tiltmeters, extensometers and fiber-optics are widely applied in geomatics and geotechnical fields for LNG terminal settlement monitoring. Although the ground-based techniques can provide settlement information with high accuracy and reliability, they only provide settlement information at specific observation points with a large investment in logistics cost, human resources, special equipment, and time consumption (Sousa et al., 2014). Satellite-based InSAR is an invaluable technique which can be used to remotely monitor structure settlement since it does not require direct contact with the monitored structures. Through the development of multi-temporal techniques, it has a high sensitivity to detect even a small settlement of structures over a long-time span with millimeter accuracy (Qin and Perissin, 2015). Furthermore, the relatively high spatial and temporal resolutions of current radar satellites, such as TerraSAR-X or COSMO-SkyMed (X-band satellites), allow the identification of a high density of measurement points and frequent surveillance of individual structures. The settlement results of the monitored structures can be further analyzed as a key data source for early warning systems for excessive movement indicating potential hazards that require a field inspection.

A wide range of techniques have been developed on the multi-temporal (time series) InSAR techniques. These techniques may utilize different algorithms for processing multiple acquisitions, simultaneously; each of them has its own strengths which can generate a high precision (millimetre range) of settlement estimation on the particular applications. The multi-temporal InSAR techniques (also called Persistent Scatterer Interferometry (PSI)) was pioneered by Ferretti et al. (2000, 2001), who patented the Permanent Scatterers InSAR (PSInSAR) technique. Since then, a significant amount research and development on multi-temporal InSAR techniques has been carried out within the InSAR community. Among those techniques, it is worth mentioning the Small Baseline Subset (SBAS) (Berardino et al., 2002; Lanari et al., 2007), the Stanford Method for Persistent Scatterers (StaMPS) (Hooper et al., 2004; Hooper, 2008) and the SqueeSAR (Ferretti et al., 2011) and Quasi Persistent Scatterers (QPS) (Perissin and Wang, 2012).

In this study, the InSAR (in the form of PSI/StaMPS) technique has been applied to monitor any settlement of the ground surface and/or movement of the structures at the LNG terminal, Bintulu as an academic research using high resolution TerraSAR-X datasets. The TerraSAR-X datasets were acquired from 21st April 2015 to 04th July 2016 over the above LNG terminal. At the end of this study, the PSI processing produced the average settlement velocity map and settlement time series to reflect the settlement of the LNG terminal. A validation process was also done by comparing the result with GPS observation at the nearby station.

MATERIAL AND METHOD

This section will explain the data and methodology used in order to estimate the settlement at the LNG terminal.

Study Area

A Petronas LNG terminal has been chosen as a test site to be monitored. It is located in Tanjung Kidurong, approximately 20km from Bintulu Town. The red rectangle in Figure 1(a) shows the illuminated area of the SAR data over the Tanjung Kindurong. The area of study is the green rectangle which approximately 27 km x 27 km while the LNG terminal area is enclosed in the yellow rectangle (see Figure 1(b)). There is a GPS station available within the InSAR image which located at Sekolah Menengah Teknik KM 12, Jalan Kidurong, Bintulu (called BIN1 MyRTKnet station) as marked with a red star in Figure 1(b). The GPS measurement can provide reliable results in terms of horizontal and vertical settlements, and hence the settlement rates derived at the BIN1 MyRTKnet station can be compared with the InSAR measurement.

Figure 2 shows the layout of the LNG terminal complex. It consists of storage tanks, large diameter pipelines, liquefaction plants and port infrastructures. The close proximity of the terminal to seaside and being built on reclaimed land warrants the terminal to be monitored against ground settlement which may be caused by unconsolidated foundation and underground water movement.

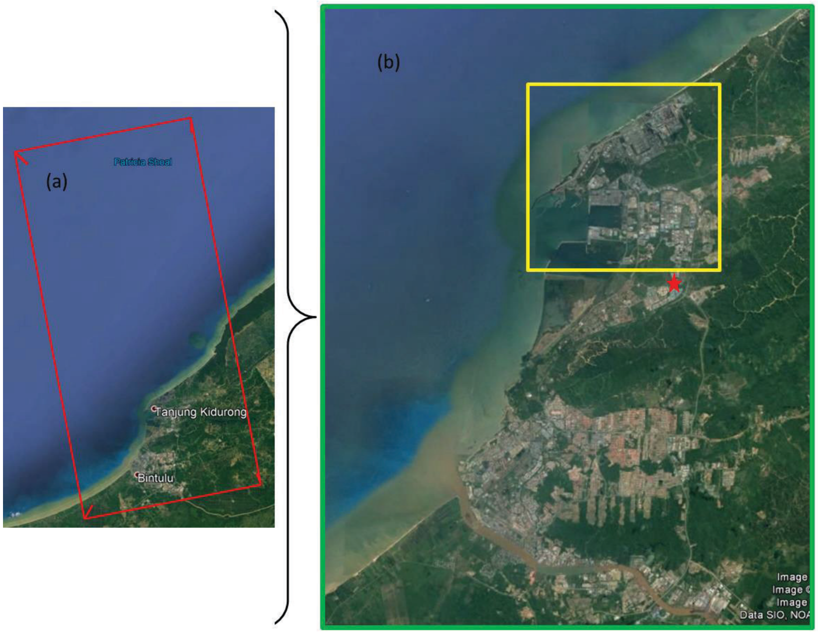

Figure 1. The location of the study area and GPS station

Figure 2. Bird-eye-view of LNG terminal

SAR Dataset Acquisition

10 TerraSAR-X images were acquired from 21st April 2015 to 04th July 2016 over the LNG terminal (see Table 1). The images were also acquired at around 6.46 pm each day along the ascending orbit (from South to North) with the incidence angles between 49.57 to 51.11 degrees. The acquisitions were in 3 m spatial resolution of StripMap imaging mode and the wavelength of the sensor was 3.1 cm. Each image scene has coverage of 30 km (width) x 50 km (length) enough to cover the whole area of the LNG terminal. Image acquired on the 14th October 2015, was selected as the master image, being almost in the middle of images acquisition which began in 21st April 2015 and end up on the 04th July 2016.

Table 1. Image number, date of the data acquisition, perpendicular and temporal baseline with respect to the master image

Image number	Date (dd/mm/yyyy)	Perpendicular baseline (Bperp) [meters]	Temporal baseline (Btemp) [days]
1	21.04.2015	4	176
2	04.06.2015	-42	132
3	18.07.2015	82	88
4	31.08.2015	19	44
5	14.10.2015	0	0
6	27.11.2015	125	44
7	10.01.2016	279	88
8	23.02.2016	-53	132
9	21.05.2016	-105	220
10	04.07.2016	-22	264

PSI Processing

The PSI/StaMPS process flow in order to detect the magnitude of settlement of the terminal is shown in Figure 3. It begins with images co-registration and interferograms generation, followed by Persistent Scatterer Candidates (PSCs) selection process and error removals in the interferometric phase to estimate the settlement magnitude of the terminal.

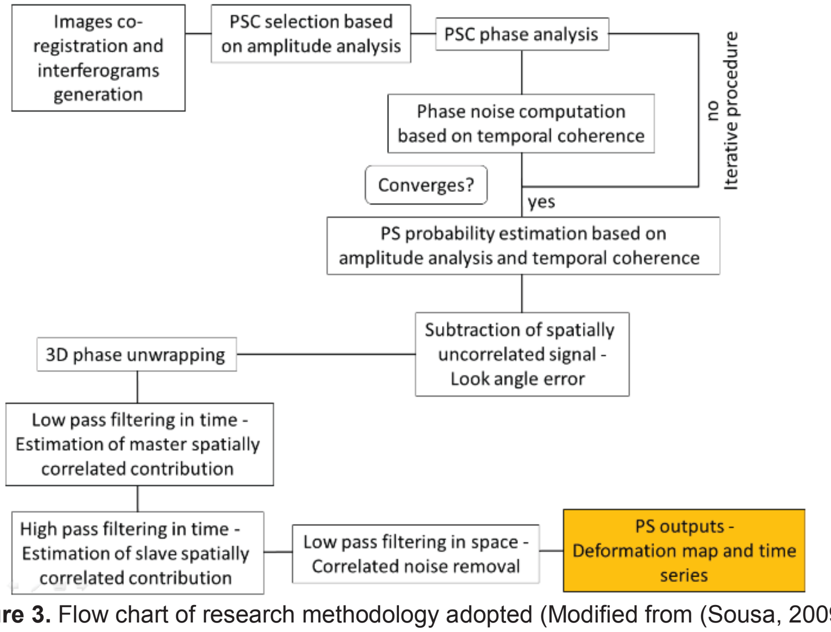

Figure 3. Flow chart of research methodology adopted (Modified from (Sousa, 2009)).

Reading, Cropping, Oversampling and Master Image Selection

The processing begins by reading SAR images (i.e., in the Single Look Complex format). Then, the SAR images were cropped to the LNG terminal area by sizing the window of the master image to the dimension of 9000 lines x 9000 pixels. After cropping the SAR images, they were oversampled by a factor of 2 in the azimuth (line) and range (pixel) directions. The oversampling was performed to obtain a high quality of generated interferograms and to increase the number of Persistent Scatterer (PS) points. The optimal master image was chosen based on perpendicular and temporal baselines as well as doppler shift in order to maximize the coherence in the series of interferograms.

Image Co-Registration

The oversampled images were the input for the co-registration of the master and the slave images. The co-registration procedure typically consists of two steps which are coarse co-registration and fine co-registration. These steps are important for ensuring each ground target contributes to the same pixel in both the master and the slave images. The coarse co-registration is a process to match the slave images to the master one with the accuracy of 1-2 pixels, while the fine co-registration is a process ensuring the slave-master match with the accuracy of approximately a 0.1 pixel.

Interferograms Generation

The co-registered images were processed to generate interferogram. The interferogram were formed by differencing the phase of all slave images to the phase of the master image. For N+1 SAR images, N inteferograms can be generated with respect to the same master image. The interferogram phase has generally appeared as a series of fringes. Each fringe in the interferogram represents one full colour cycle changing from red to green to blue. Each fringe on the other hand represents half of the wavelength $\lambda/2$ (e.g., 1.55 cm for TerraSAR-X) of surface movement.

StaMPS Technique

The interferogram of the large area LNG terminal has been divided into a number of patches that partly overlap in order to reduce the required processing memory. The initial selection of the PSCs was identified from the interferograms through the analysis of the amplitudes by setting the higher amplitude dispersion threshold value at 0.42. The phase noise level for each candidate was estimated after removing the spatially correlated errors (i.e., settlement, atmosphere, orbital and part of the digital elevation model (DEM) errors) and the spatially uncorrelated DEM error, and was then refined successively in a series of iterations. Temporal coherence was used as a measure of the phase noise/residual to reject any low-quality PSCs. Moreover, the number of acceptable candidates was further reduced by allowing a maximum of 20 random phase pixels per km2.

The PS pixels that appear to be dominated by the adjacent pixels and persist only in certain interferograms could be discarded. After that, the phase noise of the remaining candidates was compared with their neighbours (i.e., candidates who were connected by lines in the Delaunay network). Those pixels with a phase noise standard deviation smaller than the threshold were kept as the PS points; otherwise, they were considered as noisy pixels and were rejected. Also, the candidates with a noise level exceeding the weed maximum noise threshold were rejected. The spatially uncorrelated look angle error was estimated and subtracted from the wrapped phase before phase unwrapping. The spatially uncorrelated look angle error is caused by the difference between the assumed geometric center and the actual phase center for each pixel and can be estimated through its correlation with the perpendicular baseline.

The phase values can then be unwrapped in three dimensions (i.e., two spatial and one temporal). The temporal phase differences in each selected PS have to be estimated initially. The spatial unwrapping can then be performed for every step of a reference PS using an iterative approach. Next the unwrapped phase time series for each PS is then integrated in time. The unwrapped phase still contained the spatially correlated components of the look angle and atmospheric errors and hence the errors were estimated by spatial filtering of the unwrapped phase. However, the spatially correlated component of the orbital error was not estimated in the processing as the error was not expected to change within the small study area, and the error was mostly subtracted by referencing the results of the mean phase value of the reference area. Finally, removing the spatially correlated errors left the phase due to the settlement signal and residual of spatially uncorrelated component of the DEM error which could be considered as a noise. A detailed description of the StaMPS data processing can be referred to (Hooper, 2006; Sousa, 2009; Latip et al., 2015).

RESULTS AND DISCUSSIONS

The distribution of the PS points and their corresponding average settlement velocity are shown in Figure 4 which most of the PS points were predominantly found at the man-made structures. The average settlement velocity ranges from -19.1 to 22.8 mm/y along the sensor-target (line of sight (LOS)) direction. The settlement rates were estimated relative to an average phase value of all detected PS points on the chosen reference area, indicated by a red-dashed rectangle. The observed settlement was indicated by colour coded scale where stable areas were plotted in green colour, maximum subsidence areas in red (-19.1 mm/y) and maximum uplift areas in blue (22.8 mm/y). From Figure 4, a subsidence area can be clearly identified from the settlement map which is A (brake water), and two uplift areas which are B (LNG storage tanks) and C (LNG liquefaction plants).

The standard deviation was calculated to provide the precision of the estimated settlement rate. Figure 5 shows the standard deviation of the estimated settlement rate at the LNG terminal area was quite high ranges from 0.8 to 12.6 mm/y. Therefore, a significantly higher number of images would be required to improve such value by effectively modelling the DEM and atmospheric errors.

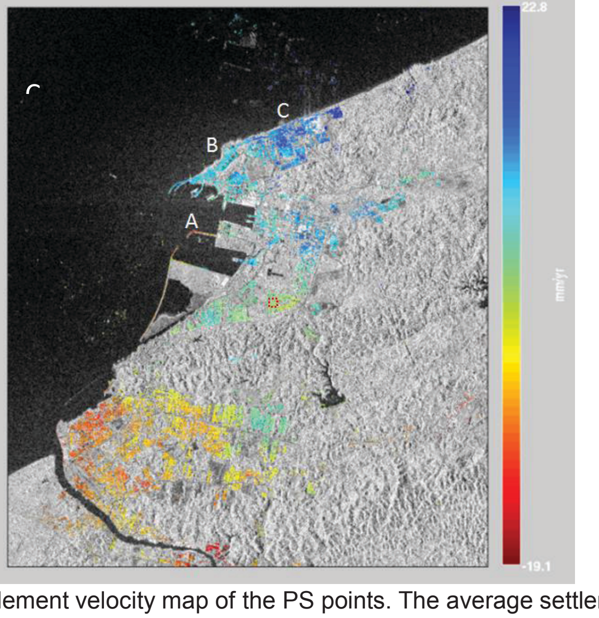

Figure 4. Average settlement velocity map of the PS points. The average settlement velocity ranges from -19.1 to 22.8 mm/y with respect to a reference area. The reference area is indicated by the red-dashed rectangle.

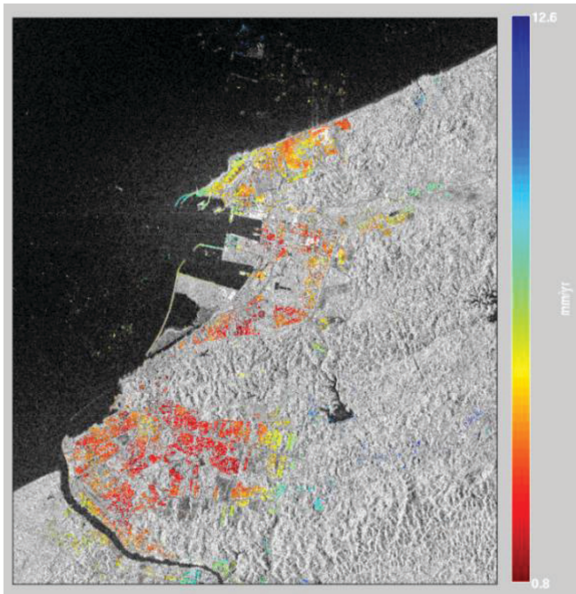

Figure 5. Standard deviation of the estimated settlement rate. The standard deviation ranges from 0.8 to 12.6 mm/y.

Figure 6, 7 and 8 show the settlement time series of the PS points located on the A, B, and C areas, respectively. Figure 6 shows obvious linear subsidence trend of the selected PS points observed at the A area from first to fourth data acquisition (movement up to 23 mm). Then, the points moved alternately up and down from fourth to tenth data acquisition. The causes of measured settlement in A are being investigated with assistance from personnel on site.

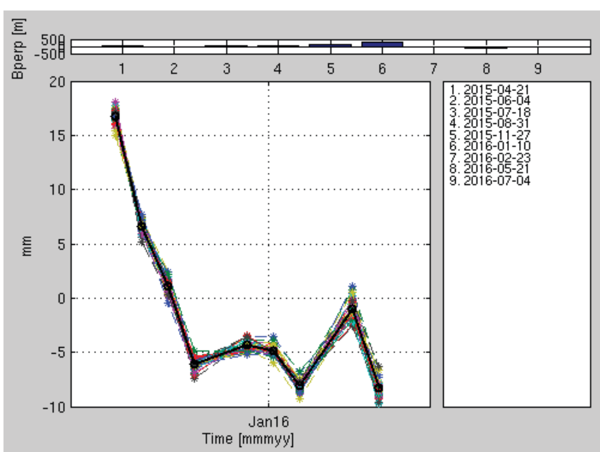

Figure 6. Settlement time series of A area (subsidence of brake water)

Figure 7 shows two periods of uplift visible which was from third to fifth and from seventh to ninth data acquisition. Moreover, two periods of uplift can also be noticed on the C area between third and fifth data acquisition and on the seventh to eighth (see Figure 8). However, the detected uplifts in B and C areas were totally unexpected in this case and some additional research on the methodology used and site investigations are being carried out to explain the results.

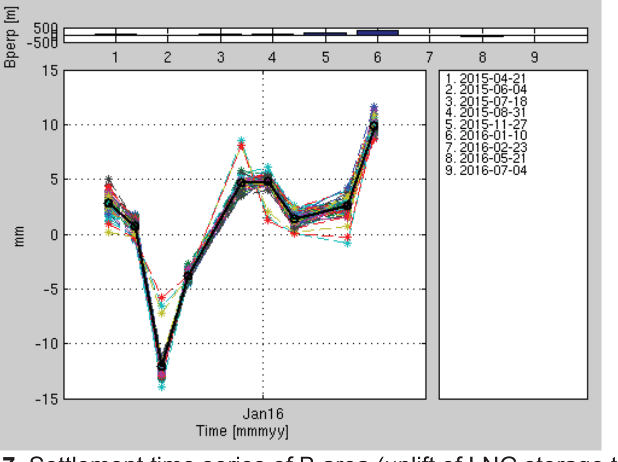

Figure 7. Settlement time series of B area (uplift of LNG storage tanks)

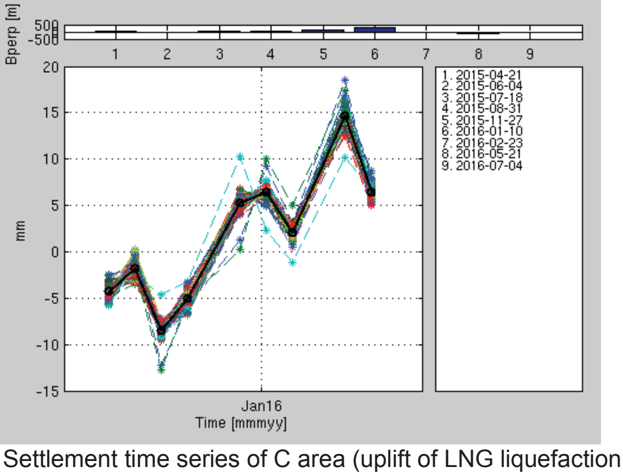

Figure 8. Settlement time series of C area (uplift of LNG liquefaction plants)

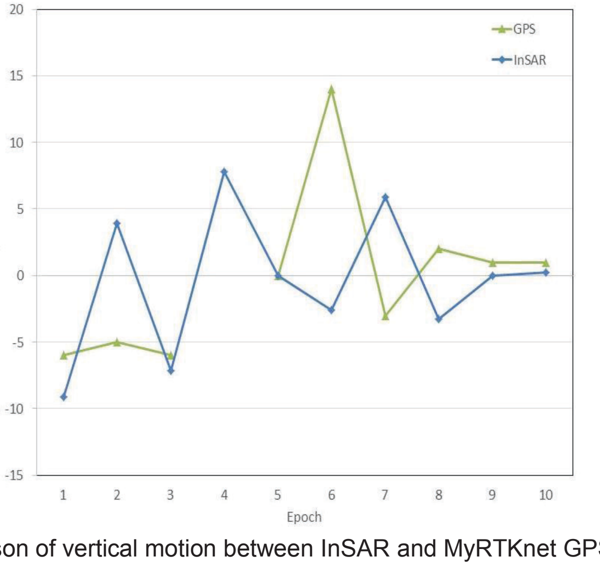

Figure 9. Comparison of vertical motion between InSAR and MyRTKnet GPS station (BIN1). Unfortunately, GPS data is not available for the fourth epoch of the InSAR data.

Figure 9 shows the comparison between the time series InSAR (blue) and GPS (green) derived surface settlement at the BIN1 MyRTKnet station. The time series of InSAR and GPS were relative to the selected master image time which was on October 14, 2015 (fifth measurement) as the temporal reference (settlement value was zero here). The InSAR derived settlement were close to the GPS on the first, third, eighth, ninth and tenth data acquisitions, which shows some degree of reliability of this settlement monitoring. The large difference between InSAR and GPS time series on the sixth measurement was due to the limitation of the InSAR to estimate the large settlement more than half cycle of movement (>15.5 mm) that occurred between the contiguous data acquisitions.

CONCLUSION

This study demonstrates an attempt to monitor settlement of LNG terminal using PSI/StaMPS technique. It detected maximum settlement in the form of subsidence and uplift rates of -19.1 to 22.8 mm/y respectively with standard deviation ranges from 0.8 to 12.6 mm/y, to some structures at the terminal. Assistance from the personnel on-site is needed in order to explain the subsidence and uplift observed at various points in this settlement monitoring. The potential of the PSI technique for settlement monitoring of the LNG terminal can be further enhanced by collecting ground-truth data on the LNG terminal area to improve the sensitivity and accuracy of the PSI technique.

ACKNOWLEDGMENT

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REGULATORY REQUIREMENTS IN THE IMPLEMENTATION OF GREEN BUILDING FOR PRIVATE HOUSING PROJECTS IN MALAYSIA

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Abstract
Sustainability is significant to the government policies. However, it has not been integrated into property development and investment practices in Malaysia. This is because the progress to develop the culture of sustainability among local building stakeholders is rather slow. One of the important challenges in adopting green building in Malaysia is lack of legislative framework for green technology. Thus, the aim of this research was to establish regulatory requirements in implementing green building for private housing projects through semi-structured interview analysis and doctrinal research. The qualitative research focused on three areas, namely: (a) exploring the barriers faced by the private housing developer, (b) assessing the existing policies and regulations related to sustainability, and (c) proposing the regulatory requirements in implementing green building projects in Malaysia. The content analysis, meta-analysis, and doctrinal research are important in this research to establish the regulatory requirements of green building implementation towards promoting sustainability in the built environment and raising environmental awareness. Eventually, this research established twelve regulatory requirements for the industry to formulate green regulations, policies, and building codes for its future implementation.

Keywords: *Green Building; Green Regulations; Sustainability.*

INTRODUCTION

The building sector has been the largest source of greenhouse gas (GHG) production (Jagarajan et al., 2015). Buildings use about 40% of global energy, 25% of global water, 40% of global resources, and a total of one-third GHG emission approximately (UNEP, 2016). According to Yusoff et al. (2015), construction, maintenance, and use of buildings impact substantially on our environment and are contributing significantly to irreversible changes in the world's climate, atmosphere, and ecosystem. Buildings are by far the greatest producers of harmful gases such as carbon dioxide. For instance, the green certifications have become popular in measuring building performance against the environment (Aliagha et al., 2013). However, Malaysia has a slow pace of green progress in the construction industry due to lack of guidelines, misconceptions over green or sustainability concepts, and high cost (Mohamad Bohari et al., 2015), resulting in less than two per cent of green building implementation (CITP, 2015). Thus, the Malaysian government has approached many policies and initiatives, hence leading the industry into becoming more sustainable in developing new projects (Mohamad Bohari et al., 2015).

According to Hashim et al. (2016), a green building incentive is an initiative by the government to encourage the construction firms in Malaysia to take part in green development. However, to date, the number of construction companies, developers, and other key players' involvement in green building are relatively low. Moreover, Zalina Shari and Soebarto (2014) mentioned that the progress in developing the culture of sustainability among local building stakeholders in Malaysia is rather slow. Although concerns for sustainability are now embedded in many government policies and initiatives, they are still not integrated into the Malaysian property development and investment practices. Similarly, Samari et al. (2013) highlighted that the level of developing the green building in Malaysia is not satisfying and the government has a key role in the development of green buildings.

Less than two per cent of the buildings and infrastructure in Malaysia are rated for environmental sustainability. This is driven partly by the lack of overarching policies and regulations that require these ratings or assessments and are exacerbated further by the perception that the application of the green concept is rather expensive. Wherever there are supporting green and sustainability-related policies, relatively limited enforcement contributes to a low take-up of sustainable practices (CIDB Malaysia, 2015). Malaysia's voluntarily commitment is expected to reduce to 40% of its greenhouse gas (GHG) emissions by the year 2020, which was announced at the 2009 United Nations Climate Change Conference in Copenhagen (COP-15). However, this commitment has not been greeted with much optimism; given limited support from existing legislation and restrained environmental awareness. Zaid et al. (2014) also mentioned that there is no mandatory energy efficiency legislation implemented in the building sector that causes an increase in carbon emissions and unsustainable path of the development in Malaysia.

Zalina Shari and Soebarto (2014) shared that most of the private housing developers are only concerned on achieving minimum mandatory standards and cost, resulting to the subsidy on electricity tariff not being fully utilised. In view of GBI adoption as a voluntary basis, it is recommended that some elements of mandatory clause or regulation should be introduced to make it mandatory (Aliagha et al., 2013). According to Abidin et al. (2012), some of the hindrances to a faster progress of Green Housing in Malaysia are lack of public interest and demand, the status quo in rules and regulation, disinterest organisation, project cost escalation, and local authority enforcement.

Thus, this research explored the barriers faced by the private housing developers in implementing green building projects, assessing the existing regulations in relation to green requirements, and eventually proposing regulatory requirements in implementing green building projects in Malaysia.

THEORETICAL FRAMEWORK

Malaysia as a developing country is adopting sustainable development and green building as part of its national agenda. The most important aspect that plays a crucial role in achieving sustainable development of the country is implementing sustainable construction and design practices into the construction industry. However, a number of studies have been carried out in the country to determine the barriers faced by the construction players (Zainordin et al., 2015). Zuhairi et al. (2012) mentioned that the barriers to the adoption of green projects are due to unclear policies, lack of skills among the industry players, lack of government awareness, as well as lack of study and research on the issues in relation to green requirements and products. Also, Shari and Soebarto (2012) highlighted a total of five primary barriers towards promoting sustainable building practices such as lack of interest in the clients' requirements, political will, legislation and enforcement, technical understanding among project team members, and consideration of sustainability measures by project team members, and real and perceived costs.

Moreover, Samari et al. (2013) outlined the main barriers to developing the green building in Malaysia including an increase of capital cost, the risk of investment, and less and higher final price. Other barriers highlighted in their research include lack of incentives, building codes and regulations, strategy to promote green building, public awareness, design and construction team, expertise, professional knowledge, database and information, government support, and technology and higher investment cost. Also, Abidin et al. (2013) discovered that the main obstacles of institutional enablers in relation to green requirements are due to lack of incentives and poor formulation of regulations, whereas in the technological aspects are due to lack of local green products.

According to Aliagha et al. (2013), private sector property developers and investors have not really made a bold and substantial commitment to green building probably not because of the benefits. This might be due to the Malaysia green tax incentives for obtaining GBI certification that is not robustly market driven and sufficiently attractive. To concur, Hashim et al. (2016) stated that the participation of key driver for developing green building shows less interest and un-readiness to participate in the green project. These proved that the existing incentives already in place and introduced by the government are not attractive to the construction key players in adopting green elements for their development project. However, some developers are aware of the type of incentives that could be benefited from the green initiative. Thus, serious attention and execution of sustainability concept is required to boost its adoption among private property developers (Razali & Mohd Adnan, 2015).

Malaysia is in need of changing the policy, economy, industries, and lifestyle in improving their contribution to the climate change. This is because the policy is vital to achieve target emission level as committed (Zaid et al., 2013). However, Yusoff and Kardooni (2012) pointed out four main barriers that prevent the development of renewable energy policy in Malaysia which are financial, market, administrative and political, and sociocultural. Although Malaysia has implemented some incentive policies and projects in terms of renewable energy, and some progresses on renewable energy have occurred, comparing target plan reveals a huge discrepancy. In view of promoting the environment, the policy framework requires support to enable the appropriate administrative for the organisations (Sim & Putuhena, 2015). Moreover, Algburi et al. (2016) concluded in their study that green building will be likely the most generally utilised construction of structural engineering. The construction of green building projects will be a vital centre of building holders and even governments around the world. In general, there are some issues and barriers that may delay the implementation of green building including unclear policy from the government and lack of programs to promote and implement.

RESEARCH METHODOLOGY

According to Creswell (2015), research is a process of steps used to collect and analyse information in order to increase knowledge about a topic or issue. A researcher must choose a methodological approach for finding a solution to the research questions or problems. Research is also a learning process that involves contextual factors that may influence the results by analysing the recorded data (Fellows & Liu, 2015). Generally, Clark and Creswell (2015) explained that the process of research consists of three steps; (a) posing a question, (b) collecting data about the question, and (c) analysing the data to answer the question. This research adopted the qualitative research through semi-structured interview and doctrinal research. The interviews were analysed using content analysis to uncover recurring points related to barrier and challenge for green development, and also to analyse comment on proposed regulatory requirements by the respondents.

Meta-analysis approach was adopted to review the literature results and correspond with the data collected from the research. Whereas, the doctrinal research through comparative analysis was used to establish the regulatory requirements desired for this research. The document review pertaining to green building regulations in Singapore and other selected countries were analysed to establish the basic requirements. Meta-analysis was intended to describe the extent to which variables are related as desired from previous research. The key procedures in this research were to gather and analyse the results from numerous completed research studies to determine the extent to which specific variables are related based on all of the completed studies (Creswell, 2015). Some of the aims of conducting meta-analysis include determining dependent variable, comparing the difference of economic value, and identifying the sample on the specific requirements of the research (Nelson & Kennedy, 2008). Thus, this research gathered as many as possible dependent variables and formed those in the meta-analysis presented in the subsequent section.

Doctrinal research provides a systematic description of the regulations enforced by the Government in the legal perspective, as it also analyses between the existing rules and highlights its limitation, even envisages the future (Hutchinson & Duncan, 2012). Doctrinal research is concerned with the formulation of legal doctrines through the analysis of legal rules. Within the common law jurisdictions, legal rules are to be found within statutes and cases, but it is vital to appreciate that they cannot provide a complete statement of the law in any given situation (Chynoweth, 2010). Doctrinal legal research, thus, involves; (i) systematic analysis of statutory provisions and of legal principles involved therein or derived therefrom and (ii) logical and rational ordering of the legal propositions and principles. The researcher gave an emphasis on substantive law rules, doctrines, concepts, and judicial pronouncements (Vibhute & Aynalem, 2009). Thus, this research adopted the doctrinal research to propose the regulatory requirements in green building. The legal document analysed included Building Control (Environmental Sustainability) Regulations 2008 from Singapore.

DATA ANALYSIS, RESULTS AND DISCUSSION

Semi-structured interviews were adopted in this research involving government agencies, GBI facilitator, local authorities, and property developer. The government agencies involved were Construction Industry Development Board (CIDB) and Malaysian Green Technology Corporation (GreenTech Malaysia). Both agencies have been contacted to arrange for the interview appointments; however, only CIDB was available for the interview session. CIDB Malaysia is a regulated body entrusted with the responsibility of making recommendations in the formulation of policies for the construction industry (CIDB, 2015).

Whereas, the local authorities involved in this study were the City Councils ("Dewan Majlis Bandaraya") and the Municipal Councils ("Majlis Perbandaran") from Wilayah Persekutuan Kuala Lumpur ("WPKL") and the Selangor state of Malaysia. Nine (9) local authorities from the Planning Department have been contacted to arrange for the interview appointments; however, only three (3) available for the interviews. The rationale of choosing Planning Department is that the Development Order (D.O) or Planning Permission

("Kebenaran Merancang") has been checked and approved by the department and various study highlighted that the green building requirements are stated in the D.O approval conditions. Whereas, another rationale of choosing the local authorities from WPKL and Selangor is because both WPKL and Selangor were amongst the highest GBI certified projects reported in 2016 (GBI, 2016) and value of construction project (CIDB, 2016).

The Property Developer involved in this study were from various states mainly based in Klang Valley area. Ten (10) property developers from Real Estate and Housing Developers' Association Malaysia (REHDA) members have been contacted; however, only six (6) were available for the interviews. The rationale in the selection of the participants is:

a) Top 10 Property Developers 2016 by The Edge Malaysia Property Excellence Awards 2016;
b) All selected Property Developers are REHDA Members; and
c) All selected Property Developers have current and past projects with Green Building certifications such as GBI, Green Mark, and LEEDS.

Thus, a total of eleven respondents in this research were gathered from various sectors. All eleven respondents from this research have extensive experience within the construction building sector and their job responsibilities indicate that they have the sufficient knowledge (Banawi & Bilec, 2014). The process involves selecting and interviewing eleven experienced professionals in the construction industry from the government agencies, local authorities, and top property developer that have knowledge in housing project related to the regulation of green building (Francis et al., 2010). Respondents meeting the criteria for involvement in this research study must have a minimum of five years of experience in building residential and demonstrated proficiency using sustainable designs as part of their business process for residential projects (Shofoluwe et al., 2012). The analysis of respondents' background and reference code is summarised as follows:

Table 1. Demographic background of respondents

Ref.	Organization	Designation	Experiences
GB01	Construction Industry Development Board (CIDB)	Manager, Sustainable Construction	8 years
GB02	Green Building Indec (GBI)	Director	15 years
GB03	Kuala Lumpur City Hall (DBKL)	Director, Planning Department	20 years
GB04	Shah Alam City Council (MBSA)	Deputy Director, Planning Department	20 years
GB05	Ampang Jaya Municipal Council (MPAJ)	Deputy Director, Planning Department	15 years
GB06	SP Setia	Manager, Development	16 years
GB07	IJM Land	Senior Manager, Development	20 years
GB08	Sime Darby Property	Manager, Development	20 years
GB09	UOA Development	Senior Manager, Development	15 years
GB10	IGB Corp	Manager, Development	8 years
GB11	UEM Sunrise	Senior Manager, Development	15 years

Rubin (2012) indicated that semi-structured interview includes a specific subject and some prepared questions with opportunities for follow-up questions; whereas the unstructured interview includes a general outline and the conversation flow generates subject specificity. Reviewing document from the local authority in relation to green requirements was carried out in this research while semi-structured interviews served as the primary data collection tool for this research. Thus, this research eventually discovered three salient points that are barriers in implementing green building, existing environmental law and policy, and proposed regulatory requirements in implementing green building which is discussed in the following section.

Barriers in Implementing Green Building Projects

Based on the interview, eight respondents highlighted that the main barrier to the green building implementation was lack of incentive. In line with this, Hashim et al. (2016) stated that the existing incentives introduced by the government were not sufficient for construction key players in adopting green elements for their building development project. In contrast, six respondents in this research stated that lack of or unclear law and policy are also the main concerns on the barriers to the implementation of the green project. To concur with this as discovered in the literature review, some of the primary barriers to promote sustainable building practices include lack of political will, legislation, and enforcement (Shari et al., 2012). Five respondents said that the implementation involves higher material and additional costs for them to implement it. Also, the low demand for housing projects was due to the incremental cost of 30% against the conventional method resulting in less interest among the buyers (Elias & Lin, 2015).

Other barriers and challenges highlighted during the interview are lack of awareness among players, inability to maintain green requirements, uncontrolled green labour and material, no urgency from the developers, too many certification standards, unclear authority requirements, and lack of professional experiences in the industry. On the same matter, from the study of literature from the previous topic that various studies mentioned on the main barriers in implementing green building projects are much similar. A qualitative analysis provides the best approach to discover information of residential project need regarding the cost benefits of the green building project (Starke, 2013). Hence, the comparative approach using meta-analysis was prepared in Table 2 to review the literature review discovered throughout the research against the outcomes from the research data collection.

Table 2. Meta-analysis of barriers in implementation of green building projects

Barriers in implementing GB	Literature (Author)	Respondents
Lack of policies and regulations	Kamar & Hamid, 2011; Saidur and Mekhilef, 2011; Saidur et al., 2011b; Adhikari et al., 2012; Shari et al., 2012; Yusoff & Kardooni, 2012; Muluken et al., 2012; Abidin et al., 2013; Samari et al., 2013; William et al., 2013; Zhang & Wang, 2013; Zaid et al., 2013; Mekhilef et al., 2014; Persson & Grönkvist, 2014; Powmya & Abidin, 2014; Sanchez et al., 2014; Heffernan et al., 2015; Sim & Putuhena, 2015; Algburi et al., 2016; Shen et al., 2016.	GB01, GB02, GB03, GB07, GB09, GB10
Lack of incentives	Abidin et al., 2013; Aliagha et al., 2013; Samari et al., 2013; Hashim et al., 2016; Shen et al., 2016.	GB01, GB02, GB04, GB05, GB07, GB08 GB09, GB10
Incremental cost	Kamar & Hamid, 2011; Robichand and Anantatmula, 2011; Hwang & Tan, 2012; Shari et al., 2012; Yusoff & Kardooni, 2012; Zuhairi et al., 2012; Samari et al., 2013; Yearwood Travezan et al., 2013; Chan et al., 2014; Kershaw & Simm, 2014; Wong & Abe, 2014; YiHsiu, 2014; Razali & Mohd Adnan, 2015; Vyas & Jha, 2016.	GB03, GB04, GB07, GB08, GB11
Lack of public awareness	Hurst, 2012; Hwang & Tan, 2012; Samari et al., 2013; Mekhilef et al., 2014; Powmya & Abidin, 2014.	GB07, GB9, GB10, GB11

From the table analysis above, the outcomes from the data collection are in line with the literature findings. Therefore, the results show that the lack of laws and policies, lack of incentives, and incremental cost have become three main concerns for the construction industry, especially in the implementation of green building projects in Malaysia.

Existing Environmental Law and Policy

In the interview session, all respondents were asked this question: "Do you know any environmental law or policy pertaining to building construction and green requirements?" Table 3 presents the content analysis transcribed from the interview.

Table 3. Content analysis of existing environmental law and policy pertaining to building construction and green requirements

Respondents	Quotations	Keywords
Government Agency & GBI Facilitator		
GB01	*"Department of Environment (DOE) is for construction but not specified for building construction. A policy such as Circular. Our rating tools are guidelines for certification that we considered environmental, but it is not considered as law or regulations, for instance, the tools required Environmental Impact Assessment (EIA) for certain projects..."* *"DBKL imposed condition in Development Order which center area to achieve certain higher level. For Penang and Johor, it implements Forest City, for Melaka it has Green Seal, whereas for Kelang, it implementing low carbon city. All these states have regulation pertaining to green requirements. For LCCF, it has been regulated under KeTTHA..."* *"Uniform Building By-Laws 1984 (UBBL) clause 39 has specified the requirement for energy efficiency, but to some extent, local authority unable to check due to lack of capabilities..."*	DOE, EIA, JKR Circular, Energy efficiency under UBBL, Development Order requirements.
GB02	*"Policy tied to land sales in different parts of the country. There are some building by-laws for energy efficiency, UBBL. But seems like enforcement is relaxed and checks are seldom done on site..."*	Energy efficiency under UBBL
Local Authorities		
GB03	*"We imposed the condition so that the development to achieve GB at Gold, but with this condition, they will do GB. If too loose, they not doing it, at least, it helps for implementation. They have no urgency to implement GB…"* *"Besides D.O, we also imposed to use glass that can reduce building heat, under the building plan requirements…"*	Development Order and Building Plan requirements
GB04	*"Policy exists but no enforcement. The details requirements for energy in the building plan department that you can check also..."* *"We take this requirement as priority in Planning Permission, like factory project, we also imposed condition like Rain Water Harvesting (SPAH), low carbon city…"*	Planning Permission and Building Plan
GB05	*"Perhaps such as DOE Malaysia consist of construction waste management, EIA, site air, water and noise pollution control..."* *"Yes, we also imposed in Development Order for well-being area in the City Centre..."*	DOE, EIA, Development Order
Property Developer		
GB06	*"Environmental Quality Act (EQA), Development Order by the local authority..."*	EQA, Development Order
GB07	*"...don't remember in law, open burning there is specific law, but a lack of enforcement of the green law in Malaysia in general..."*	-
GB08	*"DOE. From The Ministry of Energy, Green Technology and Water (KeTTHA) which impose GB requirements. Local authorities, there is guidelines provided but it is not compulsory. Maybe there is that I'm not aware of…"*	DOE, Under KeTTHA, Local Authority requirements
GB09	*"..there is, I'm not fully exposed"*	-
GB10	*"EQA and local authority requirements…"*	EQA and Local Authority requirements
GB11	*"Construction environmental control such as air pollution, noise and water..."*	EQA

Referring to the responses, all respondents were aware on the existence of the law and policy pertaining to environmental and green requirements. However, most of them could not recall properly, since the respondents are not keen in policy and regulation administration. Some of the law and policies that the respondents pointed out in common pertaining to the environmental and green requirements are analysed as follows:

Table 4. Analysis of environmental law and policy of environmental and green requirements

Law & Policy Requirements	Respondents
Local Authority requirements	GB01, GB03, GB04, GB05, GB06, GB08, GB10
Environment Quality Act (EQA)	GB01, GB06, GB10 and GB11
Department of Environment (DOE) requirements	GB01, GB05, GB08
Environmental Impact Assessment (EIA)	GB01, GB05
UBBL 1984	GB01, GB02
JKR Circular	GB01

From the analysis, most of the respondents highlighted that the local authority requirements become part of the policy when the condition imposed becomes compulsory. The local authority requirements include adhering to the environmental law and policy, and green requirements. In addition, four respondents said that the EQA Act becomes more common and applicable in their working exposures, followed by the DOE and EIA requirements. Two (2) responded to the UBBL requirements and one from JKR circulation. Thus, all the regulations and conditions mentioned are directly and indirectly related to the environment and green requirements. According to Moh and Latifah (2016), the Act also forms the basic instrument for achieving environmental policy objectives. The provision in the act is merely to prevent and control the environmental pollution such as Local Government Act 1976, Street, Drainage and Building Act 1974, and Environmental Quality Act 1974 (Mustafa, 2011).

Further to the discussion, the interview question was extended to determine the authorities' requirements in the green building implementation. Based on the finding result, eight respondents highlighted that the local authority has imposed the condition in implementing green building concept directly and any relevant condition related to green building such as energy and water efficiency through Development Order (D.O) or Building Plan approvals. Some of the responses highlighted that currently the green building requirements are applied for the gold level for an office building in the city centre of Federal Territory of Kuala Lumpur (WPKL). It is viewed that the green building office can attract multi-national companies to invest in WPKL by providing green space, which has the same level and standard with other countries. Additionally, one respondent mentioned that a requirement is essential to achieve GBI equivalent rating for certain land sales in WPKL. Thus, it is viewed that majority of the green requirements exist mainly in the Developer Order approval condition or requirements and also in land sales requirements.

Further to the discussion, the document review through content analysis from the available Development Order approval was analysed and tabulated as follows:

Table 5. Content Analysis of Development Order Approval (Residential Projects)

Local Authority	Year of approval	Development Order/ Planning Permission	Analysis
Dewan Bandaraya Kuala Lumpur ("DBKL")	2013	No green requirements imposed for residential development. Green required only for commercial building.	No green requirements.
Majlis Bandaraya Shah Alam ("MBSA")	2013	To adopt Green Building Index concept for the proposed design development.	To provide GBI certification or any other relevant certification at minimum certified level.
Majlis Perbandaran Ampang Jaya ("MPAJ")	2014	To provide rainwater harvesting (RWH) as stipulated in the amended UUK 10 and UBBL 1984.	To provide rain water harvesting system which this condition considered as part of GB requirement i.e. water efficiency.
Majlis Bandaraya Pulau Pinang ("MBPP")	2013	This project shall preserve the environment quality so that the sustainable development can be achieved.	To submit environment report as part of the requirement.

From the findings and discussion, it was discovered that only Shah Alam City Council (MBSA) clearly mentions the requirement, whereas Ampang Jaya Municipal Council (MPAJ), and City Council of Penang Island (MBPP) only impose the part of green building conditions. For Kuala Lumpur City Hall (DBKL), the council does not impose any requirements for related green implementation for residential projects as per the three D.O approval assessments made. However, DBKL strictly imposes green building implementation for a commercial building such as office building with gold certification level. In view of this finding, most of the local councils are uncertain on imposing green requirements for residential projects. It is highly important for this research to recommend green requirements to improve the number of green building adoption in Malaysia.

Regulatory Requirements in Implementing Green Building

In Malaysia, regulations enacted by several ministries including the Ministry of Natural Resources and Environment (RE) and Ministry of Housing and Local Government ("KPKT") are among efforts initiated by the government to standardise, preserve, and control all aspects of technology and environment. This way, regulations can be seen as the implementation standards for policy statements (MGTC, 2016). In view of GBI adoption as a voluntary basis Aliagha et al. (2013) recommended that some elements of mandatory clause or regulation should be introduced to make it mandatory for some classes of new building. Hence, this research adopted doctrinal research through evaluating the Building Control (Environmental Sustainability) Regulations 2008 and The Code for Environmental Sustainability of Buildings, 3rd Edition, 2012 from Singapore, subsequently, which proposes the regulatory requirements for Malaysia. The analysis is as follows:

Table 6. Proposed regulatory green requirements for housing projects in Malaysia

Regulatory Requirements	Description
(1) Implementation	Mandatory
(2) Sustainability rating system	Green Building Index (GBI)
(3) Statutory requirements	Street, Drainage and Building Act 1974 (Act 133) Uniform Building By-Laws 1984
(4) Scope provision	To set out the minimum environmental sustainability standard for residential buildings and the administrative requirements.

Regulatory Requirements	Description
(5) Applicability	Shall apply only to any of the following building works in which the application for planning permission is submitted to the local authority under Planning Act: Building works which involve a gross floor area of 2,000 square metres or more; Building works which involve increasing the gross floor area of an existing building by 2,000 square metres or more; and Building works relating to an existing building which involves a gross floor area of 2,000 square metres or more.
(6) Referenced code and standards	Part of Malaysian Standards (MS) but excluded from ISC/D, the Ministry of Works, CIDB Green Technology Initiatives.
(7) Responsibility	The qualified person appointed must ensure that the building works are still designed with physical features or amenities, and may be carried out using methods and materials, so that the total of all numerical scores assigned by every appropriate practitioner who assesses the building works or part thereof is not less than the minimum Green Building Index score applicable to those building works; but The developer need not submit to the Local Authority the total of all numerical scores assigned by the appropriate practitioners who assessed the building works or part thereof.
(8) Minimum Environmental Sustainability Standard	Meets the minimum Green Building Index score and the stipulated pre-requisite requirements. The minimum Green Building Index score for building works related to a residential. Applicable Criteria for Mixed-Use Building with GFA ≥ 2000 m2.
(9) Compliance Method	The environmental sustainability standard of building development shall be determined by the level of environmental performance and the numerical scores. The criteria consist of minimum six environmental impact categories based on GBI or equivalent namely: *Part 1* – Energy Efficiency (EE) *Part 2* – Indoor Environment Quality (IEQ) *Part 3* – Sustainability Site Planning and Management (SM) *Part 4* – Materials and Resources (MR) *Part 5* – Water Efficiency (WE) *Part 6* – Innovation (IN)
(10) Submission procedures	A declaration from each appropriate practitioner who assessed the building works stating the numerical score is correct; A statement from the qualified person appointed on the total of all numeric scores; and The total of all numerical scores assigned must not be less than minimum approved sustainability rating scores.
(11) Penalty	Any person who contravenes regulation (6) or (8) shall be liable on conviction to a fine. The amount to shall be determined by the local authority.

In the interview session, all respondents were asked this question: The green building implementation has become mandatory in Singapore. The proposed regulatory requirements for the housing building project are developed based on Singaporean regulatory requirements which is applied in Malaysia context (Table 6). What is your comment on the proposed regulatory requirements? Table 7 presents the content analysis transcribed from the interview.

Table 7. Regulatory requirements for implementation of green building

Respondents	Quotations	Requirements & Key points
Government Agency & GBI Facilitator		
GB01	*"To me, when we develop regulation and intend to make it mandatory, it's better to adopt Government rating tools instead, because Government not making profits. For instance, Green Mark is by BCA which is a Government body and also LEEDS and BREEAM from Government. If Government controls this, it tends to be unbiased. But for some area need to improve in MyCREST. Although GBI seems clearer and more experience. GBI can become an alternative. We have small contractor and developer in the industry…"*	Requirements (2), (5), (8), (9) and (10). Key points MyCREST, GBI become alternative and GFA.

Respondents	Quotations	Requirements & Key points
	"For applicability, I will suggest not start 2,000 m2 of gross floor area, we scared a lot of building in Malaysia will affect. We can do regulation with facilities and staggered inputs. Yes, without regulation, they not execute. Impose regulation and providing incentives…"	
GB02	*"Minimal certificate can be set and easily achieved with a minimum cost increase. Can be any rating tools as long as efforts are taken to ensure proper enforcement and administration. Yes, water efficiency should be easiest to score…"* *"Person who is empowered to submit needs to be clear. In Singapore, QP is architect submits and is responsible. Who checks the compliance BP stage and completion stage? Which agency develop the criteria?"*	Requirements (2), (7), (8), (9) and (10). Key points Any other rating tools with certified level and Architect as submitting person
Local Authorities		
GB03	*"You have to look into the benefit to general Public, if the research proposal to burden the people/citizen, that is not good, but with implementing GB would provide incentives then it is good. To see the additional cost and whether its burden to the end user, it is not suitable. Should look into incentives instead…"* *"For First/A Class office building, yes, it is good to attract the multi-national company to come to KL. To provide office space that the same level with other countries. Metropolitans area will attract investors to open branch office, and it will spin economy factor to other…"* *"We impose development more than 200 units, to provide affordable housing, it is good, and this is good condition for example…"* *"In a certain area and certain building to implement GB. We impose a condition to implementing GB for commercial building not residential and it is not necessarily limited to GBI. Follow up for residents, difficult for them to maintain and sustain and to get accredited every year. For office building, gold certified from any accreditation that they can choose…"*	Requirements (2), (4), (8), (9), (10) and (11). Key points Incentives, no penalties, include office building instead, not limited to GBI.
GB04	*"If mandatory, we worried the developer not able to execute or they not interested in developing it in future and they may not continue with the development. Should looks at incentives…"* *"Even with small area required for GB, the cost of a building also will increase, the design also has many type and kind. To see market whether any demand for it if the requirements at 2,000 m2 GFA, maybe it small...?"* *"Singapore they can do, they are small city and control a lot of thing unlike Malaysia, and we have many states and difference local authorities which governed by the state…"* *"For me, the housing is more important as the building used longer compared with commercial building…"*	Requirements (1), (2), (5), (8), (9), (10) and (11). Key points Voluntary, include incentives, bigger GFA, flexible to other rating tools.
GB05	*"GB is not new. Suggested that for urban area, the building development shall opt for higher certification area..."*	Requirement (4), (8) and (9). Key points Higher certificate for an urban area.
Property Developer		
GB06	*"Should not limit to GBI only because not all development is suitable to apply GBI. Should be mentioned the rating example Gold rating. For other requirements, I have no comment, its looks ok…"*	Requirements (2), (8), (9) and (10). Key points Not limited to GBI only.
GB07	*"…the question is how are we going to implement and enforce it, currently very lacking, the awareness is main issue and very lacking, the awareness is main issue, initially pain because it involves cost, because Malaysia is developing country. For the past 10 years nothing much happening, local authority needs to*	Requirements (3) Key points Enforcement promotes awareness.

Respondents	Quotations	Requirements & Key points
	promote it, not much awareness, you must constantly promote it, such as plastic, now cannot get plastic in shopping mall, cannot do one off event, Must have constantly awareness program…"	
GB08	*"I agreed, but it depends, if a low-cost project may not suitable if project says more than RM500k is possible but with minimum criteria/category. Currently, on commercial and residential, also involve culture and mindset, they always conflict with the current housing with the design that compact. The reality is there that the challenges in design which it also has limitation, now a lot of vertical development GB challenges and design. Eventually, back to dollar and cent, unless Government to provide incentive. To start with small, I agree to start with minimum and rating tools too…"* *"Singapore can do for all their projects but Malaysia have many types of building, commercial, mainly active design, the impact is greater for commercial..."* *"Start with commercial building and start with Government building as a role, most of it at Putrajaya, they had setting air conditioning at 22 degrees etc., many types of GB.…"*	Requirements (1), (2), (4), (5), (8), (9) and (10). Key points Exclude low-cost housing, include incentives, type of building and required gross floor area, other rating tools and start with a commercial building.
GB09	*"...assist in advantage to authority, again, we need support, through funding, incentives, etc. 3 countries already develop, we are talking about sustainable, help it maintain in the long run…"*	Requirements - Key points Maintain GB requirement and include incentives.
GB10	*"Yes, overall ok, indoor environmental quality to generally improve wellbeing. Adopt other GB cert. too…"*	Requirements (2), (8), (9) and (10). Key points Adopt other GB certification.
GB11	*"BCA made compulsory to all project, but they provide substantial incentives to the industry and the incentive quite good. To this, the proposed requirement to include this too. In Malaysia many types GB rating provided, the user can choose on their preferences..."*	Requirement (2), (8), (9), (10) and (11). Key points To consider incentives and other rating tools.

According to the responses and comments from all respondents on the proposed regulatory requirements presented in Table 7, the outcomes are analysed and discussed as follows:

Requirement 1: Implementation

Two (2) respondents commented that the mandatory requirements shall be re-visited. It might affect the industry decision to develop a new project and subsequently affect the industry and economy. Others commented that the mandatory shall not be imposed to the low-cost housing project. The regulation may apply to housing exceeding RM500,000.00 only. In view of these findings, the qualitative doctrinal analysis of green regulation is applicable to other countries in Dubai and California which have imposed mandatory requirements in the green implementation.

According to the comparative analysis, it was discovered that all selected countries have imposed these implementation requirements as mandatory except for California. In California, the code contains both mandatory and voluntary green building measures. The mandatory and voluntary measures are identified in the appropriate application checklist contained in the code, for instance, site selection which complies with at least one of the selected characteristics; i.e., infill and greenfield sites. Whereas, in Singapore, the implementation of green building is compulsory for all new construction projects based on applicability requirement described in subsequent “Requirement 5”. In view of the findings and considering on the discussion from qualitative analysis, it concludes that the implementation shall be mandatory for all new construction projects.

Requirement 2: Sustainability Rating System

The majority of the respondents (8 respondents) commented that the rating system requirements shall not be limited to GBI only. Perhaps, the industry can opt for any other available GB rating tools with minimum scoring at ‘certified level'. For instance, in WPKL, the office building can cater for the international market looking for green space for their office operation. On CIDB perspective, the green tools shall use government rating system as a priority since the rating under government control, similar to other established rating tools in the worldwide.

In the doctrinal analysis, the Singaporean regulation containing Green Mark is a preferred green rating system, in which the project may also use any other relevant Green Mark Certification. Also, for California, CALGreen is the benchmarking green rating tool but the project can opt for any available green rating tools accepted by the authority of the city. Whereas, Dubai has not imposed any specified green rating tools but set minimum criteria. Hence, it concludes that the requirement shall not adopt only GBI requirement but also to allow a relevant green building.

Requirement 3: Statutory Requirements

Only one respondent is concerned with this requirement of existing act and building code to be enforced. To address this, the statutory requirement has been presented to the respondents in the form of "Regulatory Framework Requirements" and the comment was recorded and analysed. Hence, it is proposed that the requirement is enforced by the local authorities, similarly with the Singaporean regulation.

Based on the doctrinal analysis results, the Singaporean regulation citations refer to The Building Control Act, The Building Control Regulations, and The Building Control (Environmental Sustainability) Regulations. For California, it was discovered that the statutory requirements refer to the Green Building Standard Code, California Code of Regulations, and Building Standards Code. On the other hand, Dubai has Green Building Regulations and Specification, Dubai Municipal Regulations, and The Administrative Resolution. In view of this, the regulations and standards codes referred in all selected countries are authorised and mandated the local authority to execute the approval of the new developments and set minimum green compliance. Malaysian building regulations are based on the Street, Drainage, and Building Act (1974) and the Uniform Building By-Laws (1984). These legal instruments stipulate guidelines for the approval of building plans and prescribe the control of construction. Hence, it concludes that this requirement would remain as proposed.

Requirement 4: Scope provision

Three (3) respondents commented that the scope provision shall be revisited. Some of the comments were that the requirement shall look into the users' and public's benefit and not increase the burden to the public to pay an extra cost. The respondents proposed replacing the home building with the commercial building to reduce the burden on the house building owner. The office buildings, especially in the city had high demands in terms of green space building which is catered for the international market. The other comment is that the regulation requirement may start with a commercial building first and the government building shall start as a role to the public. It is also commented that the high level of certification shall be imposed in the urban area.

As discovered in a doctrinal research, Singapore had set out the minimum environmental sustainability standard for buildings and the administrative requirements for all types of buildings. Whereas for California, the code provision had also been set to all categories of buildings with mandatory and voluntary measures but focused on planning, design, construction, and using occupancy for new construction. Also, Dubai imposes innovation on all regulated green buildings to all types of buildings and main provision on innovation. Hence, it concludes that the proposed minimum environmental sustainability standards for the residential building shall remain.

Requirement 5: Applicability

Three (3) respondents commented that the applicability shall be revisited. They were concerned with the gross floor area of 2,000 m2 that seems quite small which will affect many buildings and become uneconomic. The proposed requirements also shall look into market demand. Some responses commented that requirements must be contradicting with providing incentives to the users. The qualitative doctrinal research discovered that the Environmental Quality Act, 1974 (EQA) stipulated that "Housing development covering an area of 50 hectares or more" should be prepared for prescribed activities in preparing Environmental Impact Assessment Report. However, this justification is not sufficient to establish the requirements.

In the doctrinal analysis, Singapore had imposed gross floor area of 2,000 metres square and more would require adopting the Green Mark certification. For California, it required all residential buildings throughout California required the same certification regardless the size, but the authority of city determines requirements for submission. Whereas Dubai also imposes all new buildings to adopt green certification regardless the size of the building, which lies under the jurisdiction of Dubai Municipality to impose such conditions whether to set the minimum size. Thus, the requirements shall be maintained following the Singaporean regulations.

Requirement 6: Referenced Codes & Standards

There was no comment from any respondent for this requirement. However, the doctrinal research discovered that the reference codes and standards are part of the requirements. In Singapore, it has codes on envelope thermal performance for buildings such as SS 530, SS 531, SS 553, SS 554, SS CP 38, AHRI Standard, ANSI/ASHRAE/IESNA, and ASHRAE

Guideline 22. In California, it consists of California Building Code and California Residential Code, California Electrical Code, California Mechanical Code, and California Plumbing Code. Whereas, in Dubai, the codes and standards referenced in these regulations shall be considered as part of the requirements of these regulations that shall be the prescribed extent of each reference. Hence, the proposed requirement to include reference codes and standards as part of it shall be maintained.

Requirement 7: Responsibility

For this requirement, only one respondent commented that the person to submit empowerment needs to be clear. The respondent suggested that Architect is the person responsible for the submission. In the doctrinal research, Singapore imposes the developer or building owner to engage a qualified person and other appropriate practitioners who shall submit the building plan and be responsible for ensuring the minimum environmental standards is met. A qualified person is appointed under the Act in respect of those building works. For California, the responsibility and preparation documents are described as licensed professional design responsibility. Whereas, for Dubai, the building owner is responsible for ensuring the submission complies with the requirements. Hence, it concludes that the qualified person must ensure the building works are designed with physical features, which may be carried out using methods and materials so that the total of all numeric scores is not less than the minimum Green Building Index (GBI) score.

Requirement 8: Minimum Environmental Sustainability Standard

This requirement is reflected from the comment in Requirement 2. Most of the respondents (9 respondents) commented that the requirements shall not be limited to GBI only. Perhaps, the industry can opt for any other available GB rating tools with minimum scoring. A further qualitative document analysis is conducted to establish the criteria and minimum scoring for this requirement. The six established Green tools in the worldwide include Green Building Index (GBI), Green Mark (GM), Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), Green Star, Comprehensive Assessment System for Built Environment Efficiency (CASBEE) were analysed, and discovered based on their similarity.

In the doctrinal research, the Singaporean regulation containing Green Mark is a preferred green rating system and the project may also use other relevant Green Mark Certifications. Moreover, the benchmarking green rating tool for California is CALGreen. However, the project can opt for any available green rating tools accepted by the authority of the city. Whereas, Dubai has not imposed any specified green rating tools but is to set minimum criteria in the green assessment. Thus, it concludes that the requirement of "Green Building Index and relevant Green Mark Certification" as specified in Requirement 2 is added.

Requirement 9: Technical Requirements

This requirement is reflected from the comments in Requirements 2 and 8. Most of the respondents (9 respondents) agreed that the requirements shall not be limited to GBI only. In Singapore, the five (5) environmental impact categories include energy efficiency, water efficiency, environmental protection, indoor environmental quality, and other green features.

In California, its environmental impact categories are planning and design, energy efficiency, water efficiency and conservation, material conservation and resource efficiency, and environmental quality. Whereas, Dubai has ecology and planning, building vitality, and effective resources for energy, water, and materials and waste. Thus, it concludes that the requirement shall remain as GBI and relevant Green Mark Certification approved by the local authority.

Requirement 10: Submission Procedures

This requirement is reflected from the comments in Requirements 2, 8, and 10. Most of the respondents commented that the requirement shall not be limited to GBI only. In the doctrinal analysis, Green Mark score will be one of the Building Plan requirements in Singapore. The documentation required includes tender specification, relevant plan layouts, summary sheets, and details of the documented evidence. For California, the application for a building permit shall be based on the plans and specifications. The document required includes environmental and sustainability goals, energy efficiency goals, IEQ requirements, project program, equipment and system expectation, and O&M personnel expectations. Whereas the application must have a completed green building declaration appended to submission in Dubai. The documentations required includes construction drawing, signed and stamped green building declaration. Hence, it concludes that the requirement shall remain following Singapore.

Requirement 11: Penalty

Three (3) respondents commented that the requirement may be revisited so that it would not burden the end users. Hence, this research aimed to re-look on the specific penalty amount to be imposed on the industry. In the qualitative doctrinal analysis, it was discovered that only Singapore has included a penalty clause in their regulation. Singapore imposes any person who contravenes regulation 6 or 8 as guilty of an offense and shall be liable on conviction to a fine not exceeding $10,000. Hence, it concludes that the requirement shall include the specific amount and would be varied depending on the value of the projects.

Requirement 12: Incentives (Additional Requirement)

Five (5) respondents strongly recommended incentives in this regulation. The implementation of green requirements with incentive is good and motivates the users as the industry always needs the support, and Singapore is a good example where the government provides substantial incentives to the industry. Similarly, some of the instruments that the government may consider is to provide incentive and rebates to increase the interest of the industry player (Abidin et al., 2013).

In doctrinal research, although Singapore does not stipulate incentives in their regulations, the government still provides the substantial incentives to the industry. The requirement is also not stated in the California and Dubai regulations. However, the incentives requirement is considered as part of the proposed regulatory requirement in green implementation resulting from the analysis. One of the recommendations from interviews contradicted the development charge and increasing plot ratio as incentives would be good enough to encourage the industry.

Regulatory Framework Requirements

Resulting from responses in the semi-structured interview, the majority of respondents had no further comments on the proposed regulatory framework requirements. All their comments were already reflected in the previous analysis and discussion. Again, CIDB rainwater this framework shall replace GBI with the MyCREST instead since the rating tools belong to the government. Also, the framework shall include 'incentives' as a 'gift for a change' to the industry. Another comment was that the clearer picture on the enforcement shall be illustrated in order to make this regulation mandatory. To address those comments, a further qualitative document analysis was conducted, and the results of regulatory frameworks are presented in Figure 1 below.

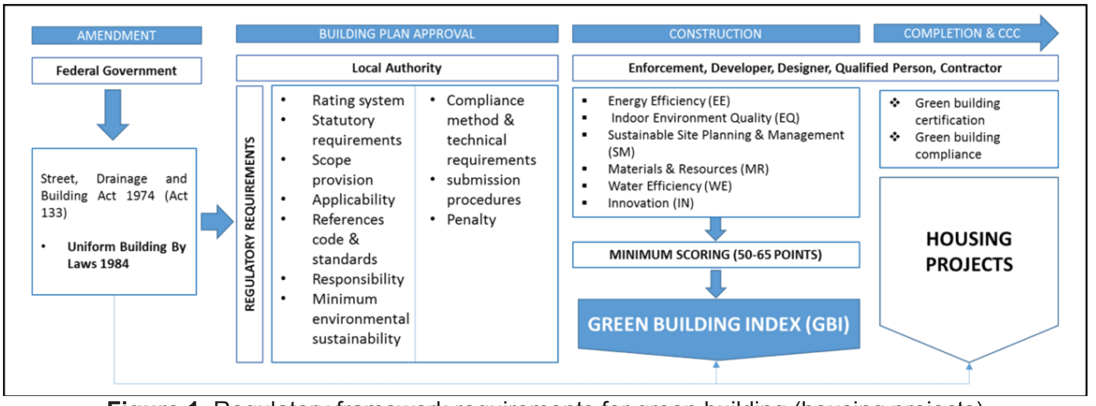

Figure 1. Regulatory framework requirements for green building (housing projects)

CONCLUSION

The research discovered the existence of the law and policy pertaining to environmental and green requirements. From the analyses, it was found that the Environmental Quality Act 1974 (EQA) is among the most relevant acts in the industry. For green requirements, the local authority has imposed the condition in implementing green building concept in the Development Order, and some other local authorities imposed the green requirements partly such as energy and water efficiency. UBBL has incorporated energy efficiency requirements in the building design; however, it has not been practicing by all local authorities. In addition, the current existing environmental law and policy in relation to a green building is not certainly effective due to lack of enforcement and awareness amongst the construction players. The salient points in this research present the regulatory requirements related to green building implementation. The doctrinal research through comparative analysis has been made to the three sets of regulations pertaining to green building requirements derived from Singapore, the U.S., and Dubai. Those countries have imposed the mandatory green requirements for the new construction projects desired from this research. Thus, from the analysis, twelve (12) proposed regulatory requirements have been established for the construction practices in Malaysia in view of green building implementation focusing on housing projects.

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INDONESIAN CONTRACTOR PROFESSIONALS' PERCEPTION ON PROBLEMS IN CONSTRUCTION CLAIM MANAGEMENT

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Abstract
Construction claim is one of many factors which influence the execution of construction projects. It is unavoidable especially in large scale projects where many parties are involved and work under pressure in regards to time and money constraints. Construction claims arise because of several causes including but not limited to change order instructions, delays, disruptions, and defective works. If not manage properly, these claims will eventually become disputes which may affect the construction project goals. Furthermore, construction claim management research has not been done extensively in Indonesian context. Therefore, this research will look into problems in construction claim management encountered by Indonesian contractors. The research method approach was a mixed method combining a comprehensive literature review and questionnaire survey to obtain the views of practitioners in this industry. Data from questionnaires distribution were then analyzed using Significance Index. This research shows that the significant problem of six construction claim management phases are related to lack of skilled and competent staffs on site, the unavailability of standard form, communication problems, and lack of documentation skill.

Keywords: *Project; Contractor; Claim Management; Problems; Indonesia.*

INTRODUCTION

Construction industry is one of the most vital industrial sectors in Indonesia which contributes significantly to Indonesia's GDP. This industry is regarded as one of the most important industry which plays a significant role in the achievement of Indonesia's infrastructure development. Nevertheless, this industry is always overshadowed with risks making it a risky business. It is also one of the most fragmented industries (Zaneldin, 2005). In regards to its complexity as well as the number of parties involved, many potential conflicts and events will be expected to arise and eventually become construction claims. With more new projects launched by the Indonesian government in recent years, construction claims can be predicted to occur even more. If these claims are not managed properly, they will eventually become construction disputes.

Research and literature related to construction claim management in Indonesia have been insufficient. This research aims to identify the problems encountered in construction claim management in Indonesian context from contractors' perspective. The approach taken is to conduct an analysis of the problems which exist in each claim management process. Previous study has been conducted on problems associated with claim management from employer's perspective. Since construction claims usually come from contractor to employer, this research will be very useful for contractors to find out the problems that exist in each stage of construction claim management. By understanding these problems, contractors will be able to make anticipatory efforts and increase the success rate of their claim submissions.

CLAIM AND ITS MANAGEMENT

Infrastructure projects and other large-scale construction projects typically face complex problems. The problems often trigger uncertainties during the execution of construction project (Lu et al., 2016). On the other hand, projects are unique and dynamic. These characteristics are unavoidable in most construction projects which may cause to a potential situation where conflicts and construction claims are taken place consecutively (Ren et al., 2001). Conflicts are often started when claims are submitted. These situations arise when the employer receives a claim proposed by contractors for additional payment or time extensions (Sears et al., 2015). The contractors propose their claims when the additional works beyond general terms and contract conditions occur in the project (Rostiyanti and Hansen, 2017). According to Puil and Weele (2014), almost no construction project that does not have any dispute or conflict between the parties involved.

Construction claim can be simply defined as a demand from one party to another. It is a request for additional compensation on account of any change to the original agreement (Khekale and Futane, 2015). In other words, claims will often arise from incomplete and bias contract documents. While contract essentially is a guidance for all parties involved in a project (Klee, 2015), lawsuits and other dispute resolution mechanisms have played a bigger role in settling construction disputes which will eventually cause additional costs (Clough et al., 2015). In their conclusion, Khekale and Futane (2015) pointed out that an effective claim management process is essential to ensure that any contractual claims are solved in a fairly manner.

In order to minimize or avoid construction claims, understanding on types and causes of these claims becomes an important task. This idea has also been delivered by Zaneldin (2005) that underlined the needs to determine construction claims main causes. In addition, Hadikusumo and Tobgay (2015) also stated that identifying claim types and their causes is essential in devising techniques to minimize and avoid them in the future.

Extensive studies related to this topic have already been done. In UAE, Zaneldin (2005) discovered that change order is the most frequent type of claim while contract ambiguity claim is the least one. From the same research, Zaneldin also found that the main cause of claims is change order instructions while planning error is the least frequent cause of claim. Hansen (2016) learnt that among 36 identified causes of construction claims in Indonesia, event of changes becomes the most significant cause and therefore variation order is the most frequent construction claim types in Indonesia. These findings are similar with Moura and Teixeira research in 2007.

Construction claim management can be described as "the processes required to eliminate or prevent construction claims from arising and for the expeditious handling of claims when they do occur" (PMI, 2003). It can be viewed from two perspectives, i.e. the claimant and the defendant. Enshassi et al. (2009) emphasized that the main purpose of construction claim management is to solve problems arise between two parties in an effective and efficient manner. Generally, there are 6 (six) phases of construction claim management process, i.e. claim identification, claim notification, claim examination, claim documentation, claim presentation, and claim negotiation (Kartam, 1999; Kululanga et al., 2001; Zaneldin, 2005; Enshassi et al., 2015).

According to Rostiyanti and Hansen (2017), claim identification is the first and the most important phase in construction claim management. It starts with the understanding on project scope and contract conditions. When a change related to project scope and contract conditions occurs, it can be anticipated by submitting a claim notification to the employer. This phase will give an opportunity for both parties to become aware of the potential problems.

The next phase is claim examination. At this phase, data need to be collected and examined in order to understand whether the occurrence of changes give entitlement for contractor to submit a claim or not. Claim documentation is the process to gather all facts and evidence from which a claim can be assessed and justified. When all documents and estimation have been made, contractor has to present his claim in a clear and concise report. The last phase is claim negotiation where both parties try to settle their differences and make an agreement.

A study of construction claim management problems in Malaysian construction industry has been conducted by Bakhary et al. (2015). Here, the Malaysian contractors and consultants were surveyed. Their findings showed that the lack of site staff awareness, inaccessibility or unavailability of relevant documents, and conflicts which arises during negotiation are all critical problems in construction claim management. They also highlighted the need for a good documentation and record keeping system in construction projects. Meanwhile in Indonesia, a pilot study on problems associated with claim management from employer's perspective had been conducted and the result showed that the most critical problems are the unavailability of standard guideline in claim management, the lack of competent human resources in dealing with construction claims, the lack of communication skills, and the lack of project documentation skills (Rostiyanti and Hansen, 2017).

METHODOLOGY

Design of Questionnaire

To ensure that the above objective is achieved, questionnaire survey technique was used to gather the data. The questionnaire survey was developed with input from some construction professionals' opinions and coupled with the result of comprehensive literature study. There are 2 (two) main sections in this questionnaire, i.e. (1) about the respondent's profile, and (2) about the problems encountered in construction claim management. The latter section was then developed into 6 (six) sub-sections, i.e. problems encountered during: (1) identification process, (2) notification process, (3) examination process, (4) documentation process, (5) presentation process, and (6) negotiation process. There were 49 questions which need to be answered in Section 2. Targeted respondents came from various construction companies in Indonesia, mainly State-Owned Contractors (SOC). Respondents were asked to rank their opinions on related issues. The rank was divided into four-point scale (starting from 1 to 4) based on Likert scale. There were 47 responses.

Figure 1 shows the respondents' profile. This profile describes the respondents' educational level and work experience in construction industry. Figure 1a shows that most of the respondents have educational level of undergraduate/diploma and post-graduate level, while Figure 1b shows that majority of the respondents have more than five years work experience in the industry.

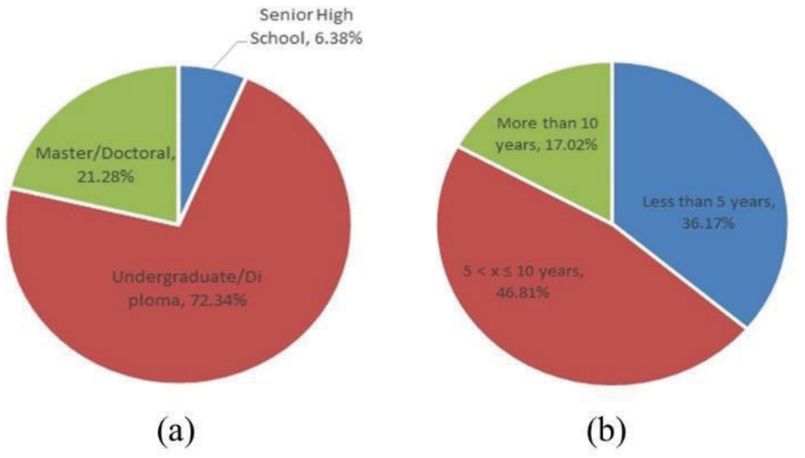

Figure 1. Respondents' Profile

Data Analysis

The Cronbach alpha reliability test was then carried out to determine the reliability of the responses obtained. According to Nunnally and Bernstein (1994), the minimum value of Cronbach alpha test is 0.700. The result shows that in this study, the Cronbach alpha value is 0.964. With Cronbach alpha value closes to 1, the data obtained from this questionnaire is reliable (Pallant, 2005; Cronk, 2008).

Data analysis was done using Significance Index (SI) method. This method has been adopted in previous research to describe risk significant (Ke et al., 2011) and to rank factors (Zhang, 2005; Zhang, 2006). The SI calculation uses a formula to simplify data calculation in Likert scale by giving the score of 1 to 100.

In this study, a scale from 1 to 4 was given for each option to express respondents' statement with a weight of 1 for 'disagree', 2 for 'quite disagree', 3 for 'agree', and 4 for 'very agree'. In SI method, each scale was given index value of 25, 50, 75, and 100; so that the formula is:

$$S_i = \frac{R_{i1} \times 25 + R_{i2} \times 50 + R_{i3} \times 75 + R_{i4} \times 100}{R_{i1} + R_{i2} + R_{i3} + R_{i4}}$$

S_i is significance index for factor-i; R_{i1}, R_{i2}, R_{i3}, and R_{i4} are numbers of respondent who gave responses to each scale (1 to 4) for factor-i respectively.

RESULT AND DISCUSSION

Based on the above data analysis, this study obtained SI value between 59.57 up to 82.98 for all 49 questions distributed in six construction claim management phases. Some attributes (problems) have the same SI value so that to rank the significance, standard deviation value was used. In this case, attribute with smaller standard deviation value is more significant or critical than other attributes.

Problems in Construction Claim Identification Process

This sub-section focused on the problems encountered in construction claim identification process in Indonesia. A list of 8 (eight) possible problems encountered during identification process was provided and respondents were asked to choose one of possible options. The result can be seen in Table 1.

From Table 1, it appears that three main problems during claim identification process according to contractors are "insufficient construction contract knowledge by project site staff" with SI value of 78.72; "difficulties in detecting any problems on site" with SI value of 74.47; and "ambiguous procedures related to claim identification" with SI value of 73.40. This provides the similar results from a study on claim management problems from employers' perspective conducted by Rostiyanti and Hansen (2017).

Claim identification is the first stage and starts with sufficient contract knowledge by site staffs. This involves the knowledge of contract scope and terms so that when there is any change in regards with contract scope or terms, adjustment can be done. Therefore, it is important that all site staffs understand contract provisions which has already been signed by both contracting parties. Whenever problems occur, they can refer to relevant clauses in the contract. Procedure in claim identification also needs to be stipulated in the contract to avoid ambiguity in claim identification process.

Interestingly, in this phase, the study shows that among the three main problems in claim identification, the roots of the problem can be divided into two sources, i.e. the availability of standard in claim management and the availability of competent human resources. The result shows a different outcome from the previous study. According to the employer's perspective, limitation of communication skills is also causing some problems in claim identification (Rostiyanti and Hansen, 2017).

Table 1. Problems in Claim Identification

	Problems	Average	Std Dev	SI	Rank
1	Insufficient construction contract knowledge by site staff	3.15	0.62	78.72	1
2	Difficulties in detecting any problem on site which potentially becomes a claim	2.98	0.57	74.47	2
3	Ambiguous procedures in claim identification	2.94	0.67	73.40	3
4	Poor communication between site staff and office staff	2.91	0.75	72.87	4
5	Site staff's lack of awareness to notice a construction claim	2.89	0.70	72.34	5
6	No skilled staff for detecting construction claim	2.87	0.71	71.81	6
7	Inaccessibility of documents used in identification of claim	2.79	0.75	69.68	7
8	Insufficient time due to high workload	2.74	0.74	68.62	8

Source: Calculation

Problems in Construction Claim Notification Process

In this sub-section, another list of 8 (eight) possible problems encountered during notification process was provided and the result is shown in Table 2. According to the contractors, the main problems in claim notification are "the short time of notification period as stipulated in the contract" with SI value of 72.87; followed by "poor communication and instruction to proceed" with SI value of 72.34; and "ambiguous procedures in claim notification" with SI value of 72.22.

The claim notification process provides the notified party with the opportunity to review the condition and take action to mitigate or resolve its impact (Bakhary et al., 2015). In a claim event, the contractor is required to notify the other party immediately. Notice needs to be done in written form and as detail as possible. However, from this study it is shown that many contractors in Indonesia face problem due to the short time of notification period. Therefore, it is suggested that both parties in the contract have to provide a more reasonable time period for claim notification. Communication problems related to claim notification mainly arise due to lack of coordination between parties involved. In addition, notification procedure needs to be explained in detail. By doing so, contractors can prepare and submit their claim notification in a well manner.

Previous study showed that there are two root problems in claim notification; the top three problems are related to the availability of standard in claim management and limitation of communication skills. On the other hand, this study presents another root problem which is insufficient of time management. This root problem is not occurred in any phase of claim management according to employer's perspective. The contractor perceives that time management is essential to ensure the success of claim management. The lack of time consideration may cause problems in managing claim.

Table 2. Problems in Claim Notification

	Problems	Average	Std Dev	SI	Rank
1	Notification period in the contract is too short	2.91	0.72	72.87	1
2	Poor communication and instruction to proceed with submitting the notice	2.89	0.63	72.34	2
3	Ambiguous procedures in claim notification	2.89	0.65	72.22	3
4	No clear contractual base in submitting claim/notification	2.79	0.72	69.68	4
5	No standard form used for preparing the notice	2.79	0.78	69.68	5
6	Ambiguous responsibility as to who should prepare the notice	2.77	0.76	69.15	6
7	Inaccessibility of supporting documents needed for notice	2.72	0.65	68.09	7
8	Insufficient time to thoroughly prepare the notice	2.60	0.68	64.89	8

Source: Calculation

Problems in Construction Claim Examination Process

In claim examination, the main problem encountered is "unavailability of records and documents used to analyze and estimate the claim amount" with SI value of 72.87. This finding is similar with the previous study on employers' perspective. However, the second and third most critical problems from contractors' perspective are different from employers' perspective.

From the results, it is indicated that records and documents are very important in claim quantification process. The availability of such records and documents is not only important in analyzing and estimating the claim amount, but also determines the success of a claim submission. The unavailability of records and documents is mainly due to poor project documentation skills (Rostiyanti and Hansen, 2017). In addition to lack of data, contractors may find difficulties in analysing and calculating the claim amount because of no standard formula established in Indonesia. Another root problem in claim examination comes from lack of communication skill among staff in the project.

Table 3. Problems in Claim Examination

	Problems	Average	Std Dev	SI	Rank
1	Unavailability of records and documents used to analyze and estimate the claim amount	2.91	0.62	72.87	1
2	No standard formula used to evaluate and calculate the claim amount	2.91	0.72	72.87	2
3	Poor communication to gather the required data/information to analyze the claim	2.89	0.67	72.34	3
4	No skilled staff who able to analyze and calculate the claim amount	2.85	0.78	71.28	4
5	Lack of contractual basis in examining and establishing the claim	2.83	0.70	70.74	5
6	Ambiguous procedures in claim examination	2.77	0.63	69.15	6
7	Insufficient time to thoroughly analyze and examine claim	2.77	0.63	69.15	6
8	Unclear responsibility on who should examine the claim amount	2.64	0.76	65.96	7
9	Unrealistic formula used to calculate the claim	2.55	0.75	63.83	8

Source: Calculation

Problems in Construction Claim Documentation Process

The next step is claim documentation. As can be seen in Table 4 below, there are 11 (eleven) possible problems during claim documentation process. "Some information and instruction is not made in written form" and "ineffective record keeping system" are top two problems encountered by both contractors and employers. While the main problem in claim documentation according to contractor is "employer and consultant often give verbal instructions" with SI value of 80.85.

Documentation always plays an important role when a claim event occurs. However, it often becomes negligible in practice, especially in Indonesia. Good documentation system consists of record obtaining system and record keeping system. In practice, contractors quite often received verbal instruction from the employers or consultants. If this happened, the contractors should ask for written confirmation from the instructors before carrying out those instructions. Record keeping also contributes to the effectiveness of claim documentation process. Documents that have been obtained must be kept in a neat, chronological, and safe place until the project is complete and there is no more possibility of a claim submission.

Table 4. Problems in Claim Documentation

	Problems	Average	Std Dev	SI	Rank
1	Employer and consultant often give verbal instructions	3.23	0.70	80.85	1
2	Some information and instruction is not made in written form	3.19	0.65	79.79	2
3	Ineffective record keeping system	2.94	0.73	73.40	3
4	Lack of staff's awareness to do documentation	2.91	0.75	72.87	4
5	Inaccurate recorded information	2.85	0.72	71.28	5
6	Poor communication in doing documentation	2.81	0.74	70.21	6
7	No standard form used to record project activities	2.77	0.81	69.15	7
8	Inaccessibility of documents when needed	2.74	0.71	68.62	8
9	No computerized documentation system	2.71	0.79	67.78	9
10	Insufficient time to routinely do documentation	2.49	0.75	62.23	10
11	High cost associated with retrieving required information/ document	2.38	0.77	59.57	11

Source: Calculation

Problems in Construction Claim Presentation Process

After documentation, the next stage is the claim presentation. As inferred in Table 5, the top three problems in claim presentation according to the contractors are "there is a tendency to delay the approval of claim presentation/report" with SI value of 80.32; "ambiguous procedures related to claim presentation" with SI value of 73.40; and "the unavailability of standard form of claim presentation" with SI value of 69.15.

The result shows two root problems in claim presentation: the lack time management aspect and the availability of procedures or standard employed by both parties in claim management. Delay in approval of claim report happens when there is no understanding the consequence of the delay to the other party. Delay can be triggered by negligence or by the unavailability procedure or standard in claim process. Claim presentation is an important process because at this stage the claimant will try to convince the other party to approve his claim submission. Therefore, claim presentation should be made properly and in details which clearly states the fact of the incident, the contractual bases, the claim amount, and submitted along with supporting documents. As there is no standard form in claim presentation, contractor tries to submit his claims in many different formats. When employer and consultant received his claims, they may find difficulties to understand the claim's background, evidence and calculation. This may fail contractor's claim submission. Hewitt (2016) describes two parts of a good claim presentation, i.e. claim narration and claim attachments. In addition, presenting a construction claim require a skilled and experienced person.

Table 5. Problems in Claim Presentation

	Problems	Average	Std Dev	SI	Rank
1	There is a tendency of one party to delay the approval of claim presentation/report	3.21	0.69	80.32	1
2	Ambiguous procedures in claim presentation	2.94	0.57	73.40	2
3	No standard form of claim presentation	2.77	0.79	69.15	3
4	Poor communication in presenting the claim	2.74	0.64	68.62	4
5	Inaccessibility of supporting/relevant documents to submit along with the claim as attachment	2.62	0.74	65.43	5
6	No skilled staff who able in preparing good claim report and presenting the claim	2.60	0.74	64.89	6
7	Insufficient time to thoroughly prepare claim presentation	2.57	0.65	64.36	7
8	Presentation/report made is difficult to understand	2.53	0.72	63.30	8

Source: Calculation

Problems in Construction Claim Negotiation Process

As inferred in Table 6, the respondents agree that "a tendency to protect own interest", "difficulties in settling claim" and "poor negotiation skill" are the main problems in claim negotiation process. Rostiyanti and Hansen (2017) state that claim negotiation is not a technical process but tends to be behavioural process since it focuses on human aspect and behaviour skill. Negotiation is always the first and best resolution method in settling any claim or dispute in this industry. In practice, negotiation between contracting parties should be done by those who have the authority to negotiate and make decisions. Strong evidence is needed so that defendant will understand and eventually approve the claim submission. Finally, a good negotiation skill is a must since this process could damage the relationship between contracting parties and the claim may develop into a construction dispute. Thus, according to contractor's perspective, claim negotiation is entirely influences by availability of competence human resources.

Table 6. Problems in Claim Negotiation

	Problems	Average	Std Dev	SI	Rank
1	There is a tendency to protect own interest	3.32	0.66	82.98	1
2	Difficult to settle claim without arbitration or litigation	3.13	0.65	78.19	2
3	Poor negotiation skill	3.11	0.67	77.66	3
4	Unsatisfactory evidence to convince other parties	3.06	0.76	76.60	4
5	Inadequate time to do a good negotiation	2.77	0.70	69.15	5

Source: Calculation

CONCLUSION

This study aims to identify the problems encountered in construction claim management in Indonesia from the perspectives of contractors. This study describes the six stages in the construction claim management process and outlines some issues for each stage. The findings emphasize the importance of contract knowledge by project staffs, particularly in terms of identifying a claim event. While contracts have usually provided a clause on claim notification period, contractors still find difficulties in giving a notice due to short time period. Therefore, it will be beneficial for both parties to agree a more reasonable time duration.

In addition, this study also indicates the importance of the documents and records as evidence in construction claim management. The availability of such records and documents is essential to claim success. Thus, it needs a good documentation system which includes the record obtaining and record keeping system. It also appears that in presenting his claim, contractor needs to present it in a detail and chronological way so that the other party will easily understand the reasons behind claim submission.

Finally, the root problems face by the Indonesian contractors in construction claim management are related to:

1. The availability of standard in claim management
2. The availability of competent human resources
3. The lack of communication skill
4. The lack of documentation skill
5. The lack of time management skill

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THE FOURTH INDUSTRIAL REVOLUTION AND ORGANISATIONS' PROPENSITY TOWARDS BUILDING INFORMATION MODELLING (BIM) ADOPTION

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Abstract

Ranging from the construction techniques to the project management solutions, BIM brings significant opportunities for organisations to increase productivity and efficiency. With these wide-ranging benefits, organisations must realise that BIM is no longer merely a choice, but it is a must in order to survive in the fourth industrial revolution. As the industry moves towards the fourth industrial revolution, the aim of this study is to investigate the attributes that encourage the organisations to institutionalise BIM in their business process. Qualitative research approach via semi-structured interviews was employed in this study. The target respondents of this study were 975 housings and property developers that are registered with REDHA, Malaysia. The total response rate was 17 percent. The findings revealed that 'to increase the transparency of the construction process' has become a deciding factor for BIM adoption for the client's organisations in Malaysia. Furthermore, the organisations can be categorised into 4 groups, namely, Exemplar, Competence, Mediocre, and Survivor. The obtained results indicate that 52 percent of organisations in Malaysia have a positive propensity towards BIM adoption and are ready to embark into the fourth industrial revolution. It is expected that the findings from this study will assist policy makers and stakeholders to design effective policies and strategies in line with the direction to increase the likelihood of the diffusion of BIM in Malaysia.

Keywords: *Building Information Modelling; Industrial Revolution 4.0; Rasch Measurement Model; Malaysian Construction Industry.*

INTRODUCTION

The proliferation of the fourth industrial revolution (or known as the digital revolution) is evolving at an exponential pace, which shapes the future of organisations across the globe. In this revolution, the survivor of the organisations is dependent on the ability to transform their business process into competitive digital ecosystems. The organisations' business process is impacted by emerging technology breakthroughs of artificial intelligence, robotics, big data, Internet of Things (IoTs), and the cloud system. The revolution introduces new intelligence in business paradigms and at the same time, it has the capacity to disrupt the existing business models. In all likelihood, the organisations must embrace the revolution process or lose business competitiveness. Thus, to embark into the fourth industrial revolution is inevitable rather than being an option.

The digital technology plays a monumental role to the fourth industrial revolution. Adopting and mainstreaming digital technologies bring significant opportunities to transform the landscape of the construction industry. Building Information Modelling (BIM) is a digital model-based process that provides reliable information to support the stakeholder's decisions throughout the construction lifecycle (Succar, 2009; Volk et al., 2014). BIM is a methodology of practice that assists the organisations to make smarter business decisions and predictions on the project by utilising reliable information. As the industry makes the monumental shift from having a paper-based to a digital-based process, BIM provides leading-edge methodology of practice to enhance productivity and efficiency through a seamless collaborative environment (Succar and Kassem, 2015; Azhar et al., 2015). BIM provides reliable analytic data through advanced modelling, cloud-based process and real time information (RTI). This enables relevant stakeholders to acquire accurate and up-to-date information (Reinhart and Davila, 2016; Wang et al., 2015; Johansson et al., 2015). This will further facilitate the process to collaborate information and ultimately, drive effective business decisions. With the greatest potential to enhance business survival, BIM holds a massive potential for organisations to build a competitive advantage and acts as a driver for organisations' growth.

Given the increasing global adoption, BIM has begun to garner considerable attention from the Government and industry stakeholders in Malaysia (Zainon et al., 2016; Enegbuma, 2016; Rogers et al., 2015). The Government of Malaysia has embarked on a major push to convince the industry stakeholders to adopt BIM as an innovation to increase industry productivity and efficiency. The development of BIM was aligned with the vision of the 11th Malaysia Plan and Construction Industry Master Plan (CITP) 2016-2020 which stated that the Malaysian construction industry shall be a world class, innovative and knowledgeable global solution provider (CIDB, 2015). Despite the significant efforts that have been made by the Government, overall, the uptake of BIM by the organisations remained slow, as they hesitate to adopt, causing ineffective diffusion rate (Hussain, 2015; CREAM 2014; Enegbuma, 2014; Zakaria et al., 2013). The organisation's attitudes towards BIM adoption remained unclear and there is no clear understanding of which factors affect intentions for adoption. The literature is also inconclusive about which factors are most influential for organisation to adopt BIM. Given this setback, BIM adoption in Malaysia is still perceived to be at an infancy stage (Mohd-Nor and Grant, 2014; Latiffi, 2013; Takim et al., 2013) and benefits of BIM have still not captured the attention of most of the organisations. Until this happens, the impact of BIM use on organisations in Malaysia is therefore quite unpredictable.

Although many factors influencing BIM adoption have been identified in the previous study (refer Latiffi et al., 2013; Zakaria et al., 2013; Harris et al., 2013; Rogers, 2015), the key to explaining the need for BIM adoption by organisations in the first place has been neglected, thus remain the gaps that are to be addressed. Towards that, this study will focus on the driving force at the organisational level. To enrich our understanding on the organisations' attributes towards BIM adoption, it is imperative to investigate the determinants that encourage organisations to institutionalise BIM in their business process. Through the use of a comprehensive set of variables, this study embarked on a systematic examination on the factors to increase the likelihood of diffusion of BIM in Malaysia. From that, this study will justify the organisations' propensity as they are predecessors to paving the direction of BIM in Malaysia. This study believes that understanding these factors could provide the essential mechanism to encourage more organisations to embark with BIM adoption.

To achieve this aim, this paper is structured into three parts. In the first part, a literature review that begins with a discussion on the BIM adoption in Malaysia is presented. The subsequent part describes research methodology, data analysis and discussion. The final part encompasses a conclusion by summarising some key findings and presents the implications for future research.

ORGANISATIONAL FACTORS FOR BIM ADOPTION: A REVIEW

When it comes to major decisions and large monetary commitments for a project, most organisations seek a methodology of practice to evaluate the feasibility of the project at an early stage. BIM stimulates the Business Intelligence (BI) solutions by engaging analytical data to support the decision-making process throughout the project life cycle. Stanford University's Centre for Integrated Facilities Engineering has discovered that by adopting BIM, they have managed to reduce unbudgeted changes up to 40 percent, increase the estimation accuracy up to 3 percent, reduce time taken to generate a cost estimate up to 80 percent, increase the contract's value up to 10 percent and reduce the total construction period by 7 percent (CIFE, 2007). This shows that BIM has the ability to automate and augment the complex construction activity into analytic data to facilitate the decision-making process. By leveraging analytic data, the organisations have the opportunity to virtually access real-time data to perform analysis, modelling, simulation, prediction, and optimisation prior to the execution of construction (Peng, 2016; Jalaei and Jrade, 2015; Clarke and Hensen, 2015). This enables the stakeholder to visualise the construction model, virtually, in the same way that the construction team builds the project. This is consistent with the findings by Redmond et al. (2012). Based on semi-structured interviews with eleven industries' stakeholders on the application of cloud-based BIM, they revealed that the cloud-based BIM process could create opportunity for the stakeholders to improve the decision-making process at an early stage. This reveals that BIM enables faster, more precise and more effective decisions by promoting data-driven to support the decision-making process.

The construction process involves vast volumes of graphical data and non-graphical information, which are generally stored in document formats. The type of information varies depending on the size, complexity and function. All reliable and accurate information can be captured and coordinated in the Common Data Environment (CDE) form. A study by Costin et al. (2014), reveals that by integrating BIM with Geospatial Modelling Technology (such as Radio-Frequency Identification (RFID), Ultra-Wideband (UWB), Global Positioning System (GPS) and Geographic Information System (GIS), it provides an effective sense of an early warning system to manage and eliminate potential risk and hazard in a construction site. BIM provides a novel methodology to ensure that the construction players are getting the right information, in the right format, at the right time, and at the right place. The information can be extracted and shared in real-time to support stakeholders' decision-making process, thus justifying the work through this rationale. By using a case study in assessing the effectiveness of integrating BIM to generate drawing that fits for a specific task in a construction project, Léon and van Berlo (2015) revealed that the integration provides an effective communication tool between the site office and manager. With this level of efficiency, it could improve the efficiency of the work by offering accurate and on time access of information for the construction workers. This shows that BIM provides the opportunities for organisations to drive good governance and transparency, while allowing real-time coordination across disciplines and reducing project risks as well as generating better outcomes through collaboration in the construction process. The stakeholders can visualise and understand the end product more comprehensively in order to determine the feasibility of project, before any huge investment is committed to the project. Moreover, by managing the information in a common environment, BIM allows better collaboration and communication between the stakeholders.

BIM provides a platform to produce a mock-up of the fully coordinated and integrated system design and this could be used to visualise the critical interfacing details accurately. It enables the design and construction team to recognise, assess and report the potential clashes during the design phase ahead of work starting on site. Ciribini et al. (2011) reveals that by comparing as-planned BIM designs with the conventional as-built design captured by laser scanning, the managers are able to effectively detect the missing safety components. The more recent study by Marzouk and Othman (2016) on the study to develop a framework for planning sustainable collection and treatment systems through the utilisation BIM has profess that BIM is useful to improve the sustainability of the system. The information model in BIM is able to give information to monitor the pipeline's performance and condition and at the same time, able to detect any failure in the system. This reveals that BIM enables the stakeholders to resolve complex coordination and human errors at an early stage, which in turn, would save a tremendous amount of money and time. The resulting benefits are time-saving and prevent unbudgeted changes.

BIM can be used to enhance the competitive advantage, through cost reduction strategy and a differentiation strategy (Son et al., 2015; Niknam and Karshenas, 2015). A cost reduction strategy emphasises employing BIM to improve the construction productivity and to reduce cost. The differentiation strategy emphasises on productivity improvement that opens up new business opportunities. Coming to similar conclusions, Aladag et al. (2016) suggests that BIM can provide sustainable competitive advantage for the Turkish construction industry at the national and international market. This further suggests that if the BIM adoption is effectively pursued, this will become a catalyst for the organisations to enhance their competitive advantage at a local and international level.

Ranging from the construction techniques to the project management solutions, BIM provides a transformational platform for the stakeholders to streamline the collaboration process, encourage efficient data exchange and empower the decision-making process at any time and any place. This reveals that BIM is becoming the next frontier for organisations to harness productivity and efficiency. Here lies the reason why construction organisation is bound to lead in the fourth industrial revolution. With all these great features, the organisations must realise that BIM is no longer merely a choice, but it is a must in order to survive the fourth industrial revolution.

RESEARCH METHODOLOGY

Due to the exploratory nature of this study, the qualitative research approach with structured interviews was employed. The structure method was employed due to the lack of a priori empirical research on BIM (especially on organisation and to capture the full richness of our respondents' descriptions of the adoption process in Malaysia.

The respondents of this study consisted of 975 housings and property developers that were registered with the Real Estate and Housing Developers' Association (REDHA), Malaysia from 2016 to 2016. An invitation to participate was personally sent to 975 organisations by e-mail on March 2016. In total, 170 organisations agreed to participate in this study, with a total response rate of 17 percent. Due to the reported low BIM adoption in Malaysia (Husain et al., 2018, Enegbuma et al., 2014; Harris et al., 2014), low response rate was expected. To mitigate reliability issues and to ensure the robustness of the finding, an assessment of the validity of the instrument was thoroughly conducted using psychometric analysis.

As an interview protocol, a 30-item list in measuring the organisation's propensity was developed by referring to the literature review and expert panel. All items used in this study were assessed on a four-point scale ranging from 1 (strongly disagree) to 4 (strongly agree). A content validity exercise was done with two industry practitioners and two academicians. This was followed by the instrument's pre-testing, conducted with a small convenient sample of fifteen respondents (n=15). The interview protocol was written in both English and Bahasa Malaysia. All of the feedback was taken into consideration and led to several minor improvements.

Prior to the interview sessions, the respondents were informed about the objective of the study and were briefed on their consent to meet ethical principles. Having agreed to be interviewed, the respondents were asked to sign consent agreements, which allowed the researcher to record the interview sessions on a digital tape recorder and to use their words anonymously. The interviews lasted between 45 to 90 minutes with an average time of 60 minutes. The interviews were digitally recorded. The recorded data was then transferred from the recorder and transcribed into written text. The interview transcripts were then manually grouped, coded and themed according to emergent themes as soon as the interviews ended. The WINSTEPS version of the 4.0 program (Linacre, 2015) was used to perform a psychometric analysis using the Rasch Measurement Model. The analyses were carefully examined based on acceptable criteria and guidelines from experts in the respected field of Rasch analysis, such as Bond and Fox (2015), Linacre (2015) Wright and Mok (2001) and Fisher (1992).

RESULT

Construct Verification Analysis

Table 1 shows the summary of psychometric properties of organisation's propensity towards Building Information Modelling (BIM) adoption in assessing the instrument's validity.

The internal consistencies of measures, Cronbach's Alpha (α) was registered at 0.90, which is a good internal consistency and reliable for further analysis of the instrument. With the mean defaulted at μ =0.00 *logit*, the adequacy and validity of sampling was tested. The organisation reliability index was at βn = 0.89 and items' reliability was at δi = 0.90. This shows that both respondents and items have excellent reliability and were sufficient enough to measure what it needed to measure. Based on the formula for calculating the number of Discernible Strata (DP), the DPorganisation = 2.80 and DPitem = 6.85 was computed into the Discernible Strata [(4G+1)/3]. The organisation separation index was at 2.80, indicating that the samples were sensitive enough to distinguish the organisations into 4 distinct groups. The item separation was registered at 6.85, indicating that the number of samples was sufficient to confirm the hierarchy of item difficulty of the instrument. The Raw Variance Explained by Measures of 66.9% has met the unidimensionality requirement of 40%1. Nevertheless, the unexplained variance in the first contrast of 3.4%, exhibited that the instrument was considered to be very good. This means that the 33 item-instrument used for the study met the unidimensional trait and was able to measure what it was meant to measure.

Table 1. Summary of Psychometric Properties of Organisation's Propensity towards Building Information Modelling (BIM) Adoption

	Organisations = 170		Items = 170
Cronbach Alpha (KR-20)		0.90	
Reliability	0.89		0.90
Mean	0.31		0.00
Standard Deviation	0.78		0.78
Standard Error	0.06		0.14
Max. Measure	1.82		0.12
Min. Measure	-1.25		-0.10
Outfit Mean Square (MNSQ)	1.00		-0.10
Outfit Z-Standard (ZSTD)	1.00		-0.10
Separation Index	2.80		6.85
Standardized Residual Variance (in Eigenvalue units)			
● Raw variance explained by measures		66.9%	
● Unexplained variance in 1st contrast		3.4%	

By applying log transformations and probabilistic equations (formula 1), the raw data was transformed into an equal interval unit of measure (log odds units known as *logit*). The items and organisations are assigned on the scale, according to how likely they are endorsed. Each person and item have a true Standard Error (S.E) as the precision of the measure and fit statistic (the statistical coherence of the measure). The Organisation ability mean of βmean = +0.31 logits (less than 1 S.D) indicated that the βn are comparatively having the same difficulty with the item. The maximum organisation measure is β_{max} = +1.82 *logit* (S.E 0.28) and the minimum measure is β_{min} = -1.25 *logit* (S.E 0.25), with the 3.07 *logit* length scale. The maximum item measure is δ_{max} = +1.05 *logit* and the minimum measure is δ_{min} = -1.45 *logit*, with the 2.50 *logit* length scale. Despite the very good reliability, the more difficult items, however, need to be introduced for the large gap of +0.12 *logit* to +1.82 *logits*. Nevertheless, there are sufficient items for the easy task where the β*min* is at -1.25 *logits* against the δ*min* of -0.10 *logits*.

$$Pr\ Pr\ \{X_{ni} = 1\} = \frac{e^{\beta n - \delta i}}{1 + e^{\beta n - \delta i}} \qquad \text{Formula 1}$$

Overall, the measurement instrument that was used for this study demonstrated strong psychometric properties to produce a robust measurement model and supports the validity of the instrument.

Analysis on the Organisation - Item Distribution Map

As shown in Figure 1, the output of a Rasch Measurement analysis is presented and established as the Organisation - Item Distribution Map (OIDM). The 170 organisations are plotted according to their ability on the left side, and the 33 items are plotted according to the level of difficulty on the right side on a continuum *logit* scale. OIDM is concerned by the likelihood of organisation (x) with the ability of β to endorse the item (i) with the difficulty of δ. The higher the location of βx from the mean (μ), the higher ability of the organisation, and the higher location of δi from μ, hence the item is more difficult, compared. Thus, μ serves as a threshold to discriminate organisation ability and item difficulty.

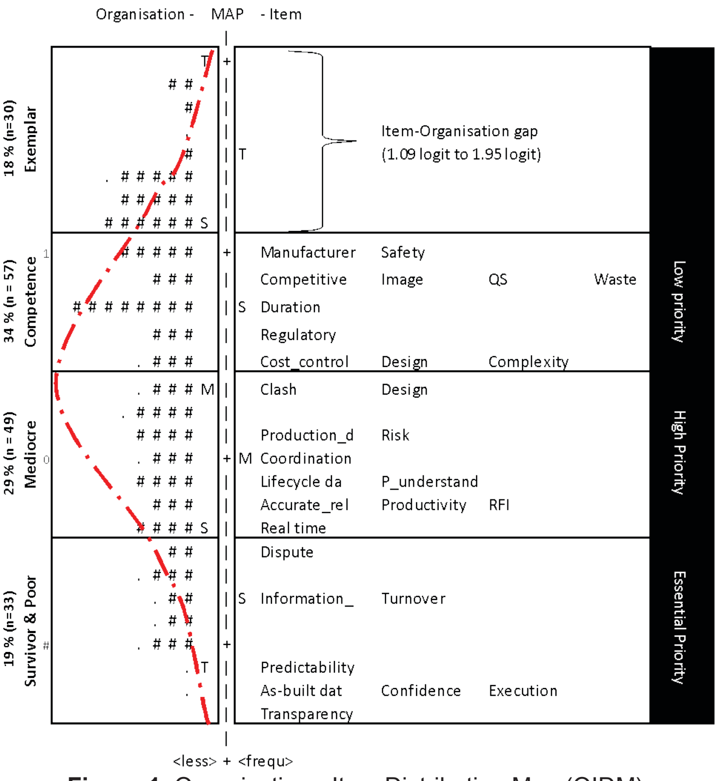

Figure 1. Organisation - Item Distribution Map (OIDM)

As depicted in Figure 1, the µ organisations = +0.41 *logit* (S.E = 0.25) which is higher than the threshold value of µitems = 0.00 *logit* (S.E = 0.11), reveals that the organisations ability is above the expected ability. More than half of the organisations (52 %, n = 87) were found above the µorganisations = +0.41 logit (S.E = 0.25). Furthermore, figure 1 shows the organisations spread at 3.15 *logit* along the continuum and the items spread at 2.44 *logit* along the continuum. The spread of the organisations which is bigger than the items demonstrates that there were insufficient items to gauge the level of organisations' propensity towards BIM adoption. There is a significant gap at the upper continuum of the scale, between δ_{max} and δ_{min} (from 1.09 *logit* to 1.93 *logit*). This gap which spanned about 0.84 logit, reflected insufficient items to challenge the ability of 36 organisations (20%).

Initially, by referring to µ*organisation* = 0.41 *logit*, the organisations can be divided into two categories, competent (exemplar and competence) and less competent (mediocre and survivor). Furthermore, by denoting by $\sigma_{\bar{x}}$ *organisation* = 0.41 logit, the organisation competency category can be classified under four groups which are Exemplar, Competence, Mediocre and Survivor. The most competent group is exemplar, and the poorest is survivor. Table xx depicts the matrix of categorisation for modelling the organisation's propensity towards BIM adoption.

Table 2. Matrix of Categorisation for Modelling the Organisation's Propensity towards BIM adoption

Categories	Position in normal distribution	Logit	N	%
Exemplar	∞ -2σ to $\bar{x}$ - σ	∞ to 1.18 *logit*	30	18
Competence	$\bar{x}$ - σ to $\bar{x}$	1.18 *logit* to 0.41 *logit*	57	34
Mediocre	$\bar{x}$ to $\bar{x}$ + σ	0.41 *logit* to -0.36 *logit*	49	29
Survivor	$\bar{x}$ + σ to ∞	-0.36 *logit* to ∞	33	19

Based on µitem = 0.00 *logit* and SDi = 0.75 as the threshold for the cut-off point, the benefits can be categorised into four categories, namely: essential priority, high priority, somewhat priority and low priority. Among these four groups, the item '*Coordination with manufacturer at early stage*' was at 1.09 *logit* (SE = 0.11), indicating the least preferred items. Moreover, '*to increase of the transparency of the construction process*' was at -1.35 *logit* (SE = 0.12), indicating the most preferred item. Table 3 further shows the matrix categorisation of the clients' expected benefits for BIM adoption.

Table 3. Matrix Categorisation of the Clients' Expected Benefits for BIM Adoption

Rank	Category of Items	Items	Measure (*Logit*)	S. E
1	Low priority	Coordination with manufacturer at early stage	1.09	0.11
2		Improved jobsite safety	1.07	0.11
3		Enhances organisational image	0.91	0.10
4		Better quality control of project	0.88	0.10
5		Reduce project waste	0.82	0.10
6		Increase organisation's competitive advantage	0.81	0.10
7		Reduce the overall project duration	0.74	0.10
8		Improve regulatory approval	0.64	0.10
9		Reduce project complexity	0.51	0.10
10		Better cost control and predictability	0.50	0.10
11		Design certainty	0.50	0.10
12	High Priority	3D/4D clash detections	0.40	0.10
13		Optimisation design at early stage	0.34	0.10
14		Mitigates risk	0.19	0.10
15		Better production of documentation	0.14	0.10
16		Improve coordination between client-consultant-contractor	0.00	0.11
17		Improve project understanding	-0.08	0.11
18		Better lifecycle data for whole life asset management	-0.17	0.11
19		Acquire accurate and reliable data	-0.22	0.11
20		Reduce RFI during construction process	-0.27	0.11
21		Increased productivity	-0.29	0.11
22		Acquire real time construction data	-0.32	0.11
23	Essential Priority	Dispute avoidance	-0.52	0.11
24		Increase project turnover	-0.70	0.11
25		Keep information consistent across the design and construction team	-0.81	0.11
26		Greater predictability of project	-1.06	0.12
27		Improve speed of execution throughout the entire project life-cycle	-1.22	0.12
28		Increase confidence in decisions making process	-1.26	0.12
29		Acquire comprehensive as-built data	-1.26	0.12
30		Increase the transparency of construction process	-1.35	0.12

In summary, the verification of the instrument produced acceptable values and reliability in justifying the validity of the instrument. This is illustrated through the accepted values of organisation reliability and item reliability. The OIDM illustrated that the organisations and items can be classified into four categories. Meanwhile, the OIDM has revealed the initial pattern of BIM adoption in Malaysia. Discussion on the findings will be presented in the next section.

DISCUSSION

As the proliferation of the fourth industrial revolution continues to shape the revolution across the globe and open up incredible opportunities, it carries new threats to organisations at the same time. At industry level, BIM is among the fourth industrial revolution's drivers to transform the global landscape of the construction industry.

To seize the advantages of the fourth industrial revolution, given the number of factors governing the propensity of BIM adoption in Malaysia, eight attributes were identified as the critical enablers to gear up and accelerate BIM adoption. The most preferred attributes are '*to increase the transparency of the construction process*', followed by '*to acquire comprehensive as-built data*', '*to increase confidence in the decision-making process*', '*to improve the speed of project execution*', '*greater predictability of project*', '*keeping of consistent information across the design and construction team*' and '*increase of project turnover', and 'to avoid dispute'*. The least preferred is '*to improve coordination with manufacturers at an early stage*'.

Being the most critical attribute for BIM adoption, the ability to increase transparency is the critical predictor to forecast the likelihood of the organisations to adopt BIM. This is consistent with the direction of BIM adoption by the UK Government - to promote greater transparency and collaboration between suppliers and thereby, reducing waste through all levels of the supply chain (HM Government, 2011).

Transparency implies openness, timely communication and accountability to access and acquire accurate and real-time information. Lack of transparency often leads to poor communication and coordination, ineffective decision making, stakeholders' dissatisfaction, unsafe working conditions, high levels of waste and unpredictability of the construction process.

Openness and effective communication are essential to a successful project. Correspondingly, BIM provides a methodology of practice to create, manage and collaborate the analytic construction information in a coordinated 3D environment. BIM promotes collaborative working for delivering project though a 'single source of truth' model. All project data are centralised in a single repository platform. Thus, the project stakeholders can virtually assess, manage and precisely predict any circumstances based on the reliable information gained throughout the project life cycle. This enables a greater exchange of accurate and better-informed decisions between stakeholders during the early stage. BIM enables design and construction teams to act based on up-to-date and accurate information in the common data platform. All parties involved are legally bound with a specific process protocol through the Employer's Information Requirements (EIR) and the BIM Execution Plan (BEP) in a Common Data Environment (CDE). All of this encourages the construction process to become more transparent and faster by considering all aspects of quality requirements.

Furthermore, the demographic profiling shows that organisations can be classified into four groups: Exemplar, Competence, Mediocre, and Survivor. The least competent group which represents 19 percent of the total organisations is the Survivor. As compared to other groups, the Survivor group would disregard and not be aware of the adoption of BIM and eventually, they would have to adapt to survive after BIM becomes a well-practiced methodology in the industry. Interestingly, the βmin (-1.22 *logit*, SE = 0.25) is higher than δmin (-1.35 logit, SE = 0.10), indicates that most of the organisations have a positive propensity towards BIM adoption. Furthermore, the analysis demonstrates that the Survivor group will start to merge and institutionalise BIM into their current practice to increase the transparency of the construction process, acquire comprehensive as-built data, and increase confidence in the decision-making process as well as to improve the speed of execution throughout the entire project life cycle.

The OIDM (Figure 1) illustrates the second group, which represents 29 percent of the total number of organisations is the Mediocre group. The Mediocre group has been regarded as the wait-and-see group. Initially, Mediocre was quite sceptical to adopt BIM and would institutionalise BIM after it has been well established in the industry. Thus, their adoption strategy will be based on what has been practiced by the industry as well as the directives by the local government.

The Competence group is the second fastest group that would adopt BIM. They represent 34 percent of the total organisations. Initially, this group acknowledged the benefits of BIM in the industry but were not willing to invest and take risks for the said adoption. The results suggest that, as compared to the groups Survivor and Mediocre, the Competence group is keen to explore the opportunity to gain benefits from BIM adoption. Regarding that, they closely observe the potential benefits that they will gain from the adoption process. The decision to adopt is based on the proven benefits and availability of assistance and initiatives from the Government.

The most competent organisation is the Exemplar group, which represents 18 percent of organisations and is located on the top of the map. What differentiates the Exemplar group with others is that the former relatively agrees to endorse all the items in measuring the organisations propensity towards BIM adoption. With their enthusiasm, this group has a higher likelihood to embrace BIM and to become a market leader in the industry. This demonstrates that the Exemplar group is relatively more resilient and are the ‘beta testers’ for the effectiveness of BIM. As a market leader, the diffusion of BIM in Malaysia is subject to the willingness of the Exemplar group to share their strategies and success stories in adopting BIM.

The explicit evidence from this study reveals that most of the organisations have positive propensity towards BIM adoption. In this continuum, 52 percent (18 percent of the Exemplar group + 34 percent of the Competent group) exhibits that most clients of organisations in Malaysia have a clear direction and desire to embrace BIM adoption. The success from early adopters in the industry has a substantial potential to accelerate further adoption among the other members. Towards that, the right policy and strategy on BIM adoption will create a bandwagon pressure, which has the potential to trigger the curiosity of another 29 percent of organisations (Mediocre Group) to join the bandwagon group. This result indicates that the awareness and readiness for BIM adoption has already existed, which in turn, provides evidence of the development of BIM at its embracing stage. This shows that the future of BIM in Malaysia is immense, and the level of adoption will increase as time goes by. This further suggests that BIM is inevitable and irreversible in transforming the Malaysian construction industry into a global presence with a competitive edge. In relation to that, the Malaysian construction industry is at its best position to embark into the fourth industrial revolution.

This study provides results from a developing country in Southeast Asia, where there is very little technical report and literature, and known to be an area where there is low BIM adoption. It is expected that this study will assist policy makers and stakeholders to design effective policies and strategies to direct the increase of the likelihood of diffusion of BIM in Malaysia and other late BIM adopter's countries. Theoretically, this research makes an original contribution by employing psychometric analysis for the purpose of profiling and modelling organisation's attributes towards BIM adoption. Eight critical attributes have been identified and the organisations have been classified into four groups. These findings provide useful information to explain and forecast the diffusion pattern of BIM. The methodology to derive the analysis will be able to guide future researchers to replicate, compare and benchmark findings in order to get more robust findings. The developed instrument can be adopted by future researchers to generalise findings into different research settings.

CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH

Drawing conclusion upon the findings, it is possible to envision what is in the pipeline regarding the future of BIM in Malaysia. In many ways, we are standing at the dawn of the fourth industrial revolution. To facilitate the drive, BIM is a catalyst to shape the future of the construction industry. Based on the structured interviews, this study employed a systematic examination on the factors of increasing the likelihood of diffusion of BIM in Malaysia. The most preferred attribute is to increase the transparency of construction process and least preferred is to improve coordination with manufacturers at an early stage. Furthermore, this study managed to profile the organisations into four groups (Survivor, Mediocre, Competence and Exemplar). Interestingly, 52 percent of organisations in Malaysia have a clear direction and desire to embrace BIM adoption. The findings reveal that most of the organisations have a positive propensity towards BIM adoption. At a large scale, the findings in this study provide insights to acknowledge the organisations' propensity and readiness to seize the opportunity to venture into the fourth industrial revolution.

Many interesting alternatives for future studies can be pursued.

At macro level, this study is limited to the shores of Malaysia. Despite this limitation, this study may also be valuable in the future to developing countries to provide a basis for comparative study. Future studies will be necessary to validate the developed propositions of this study by employing a case study approach. One interesting suggestion would be to use a case study to verify the ways to increase the transparency of the construction process that will affect the organisations' decision for BIM adoption. Since the fourth industrial revolution is about integrating human intelligence with machine intelligence, it is interesting for future research to explore the reason of *"to improve coordination with manufacturer at an early stage"* being the least preferred item. This will provide a deeper understanding on the current issues of the adoption of automation and mechanisation in the Malaysian construction industry.

On a different note, a few limitations should be kept in mind when interpreting the findings of this study. This study was confined to the client's organisations, and this has obviously limited the generalisation of the findings and conclusions into a broad spectrum. It would also be interesting to extend and generalise the findings with different contextual settings (such as within consultants and contractors). A larger sample size would have allowed for more advanced statistical analyses and generalisation. Since BIM is relatively new in Malaysia, the findings of this study represent a snapshot in time; but the effects of BIM adoption may not be static. Therefore, it would also be important to triangulate the findings of this study with opinions from the Government and the policy-makers. The findings from the triangulation process will provide several policy solutions and enable the mechanism to enhance the likelihood of BIM adoption as a strategy to embrace the fourth industrial revolution.

We hope this study would inspire more researchers to venture into the world of the fourth industrial revolution and Building Information Modelling (BIM) research.

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GUIDE TO AUTHORS

Aims and Scope:

The Malaysian Construction Research Journal (MCRJ) is the journal dedicated to the documentation of R&D achievements and technological development relevant to the construction industry within Malaysia and elsewhere in the world. It is a collation of research papers and other academic publications produced by researchers, practitioners, industrialists, academicians, and all those involved in the construction industry. The papers cover a wide spectrum encompassing building technology, materials science, information technology, environment, quality, economics and many relevant disciplines that can contribute to the enhancement of knowledge in the construction field. The MCRJ aspire to become the premier communication media amongst knowledge professionals in the construction industry and shall hopefully, breach the knowledge gap currently prevalent between and amongst the knowledge producers and the construction practitioners.

Articles submitted will be reviewed and accepted on the understanding that they have not been published elsewhere. The authors have to fill the Declaration of the Authors form and return the form via fax to the secretariat. The length of articles should be between 3,500 and 8,000 words or approximately 8 – 15 printed pages (final version). The manuscripts should be written in English. The original manuscript should be typed one sided, single-spacing, single column with font of 11 point (Times New Roman). Paper size should be of Executive (18.42 cm x 26.67 cm) with 2 cm margins on the left, right and bottom and 3 cm for the top. Authors can submit the manuscript:

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

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Abstract (Arial Bold, 9pt. Left and right indent 0.64 cm.)
Damage assessment …… ……(it should be single paragraph of about 100 – 250 words.)

Keywords: *Finite element analysis; Modal analysis; Mode shape; Natural frequency; Plate structure*

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Heading 2 (Arial Bold + Lower Case, 11pt)

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Body Text: Times New Roman, 11 pt. All paragraph must be differentiated by 0.64 cm tab.

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

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

Figures caption: Arial Bold + Arial, 9pt. should be written below the figures.

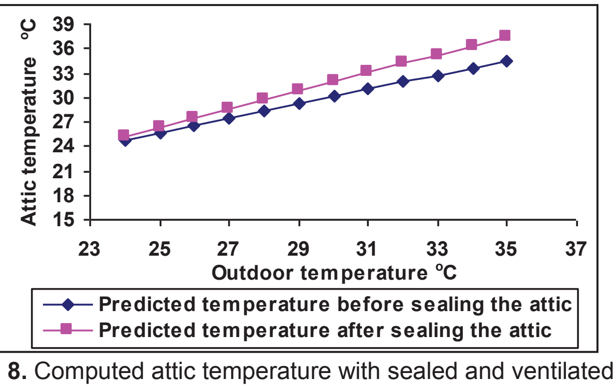

Figure 8. Computed attic temperature with sealed and ventilated attic

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

Table caption: Arial Bold + Arial, 9pt. Caption should be written above the table.

Table Line: 0.5pt.

Table 1. Recommended/Acceptable Physical water quality criteria

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

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

Reference: Times New Roman, 11pt. Left indent 0.64 cm, first line left indent – 0.64 cm. **Reference should be cited in the text as follows:** "Berdahl and Bretz (1997) found…" or "(Bower et al., 1998)". References should be listed in alphabetical order, on separate sheets from the text. In the list of References, the titles of periodicals should be given in full, while for books should state the title, place of publication, name of publisher, and indication of edition.

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