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Model BIM (2012)

Sebenar (2017)

Bangunan Pentadbiran Suruhanjaya Pencegahan Rasuah Malaysia (SPRM), Selangor

Kandungan

Perutusan
Ketua Pengarah Kerja Raya

Assalamualaikum Warahmatullahi Wabarakatuh dan Salam Negaraku Malaysia,

Syukur ke hadrat Ilahi kerana dengan izin dan kurniaNya, Jurnal JKR telah diterbitkan sekali lagi dengan jayanya. Tahniah dan syabas diucapkan kepada semua warga JKR yang telah menyumbangkan kertas kerja/artikel untuk dijilidkan ke dalam naskah kali ini. Tidak lupa juga kepada sidang redaksi yang saban tahun berusaha mengumpul kertas kerja/artikel dari warga JKR sehingga jurnal ini telahpun memasuki edisi kelima penerbitannya.

JKR memegang amanah yang diberikan oleh Kerajaan sebagai satu jabatan teknikal yang telah banyak membangunkan infrastruktur negara selari dengan visi jabatan untuk menjadi penyedia perkhidmatan bertaraf dunia dan pusat kecemerlangan di dalam pengurusan aset, pengurusan projek dan perkhidmatan kejuruteraan. Dengan usia yang telah melangkaui satu abad, JKR telah mempunyai pelbagai pengalaman dalam membangunkan infrastruktur negara dan sentiasa berusaha untuk meningkatkan mutu perkhidmatan dengan mengaplikasikan teknologi terkini bagi menyerahkan produk yang menepati masa, kualiti dan kos yang telah ditetapkan kepada para pelanggan.

JKR pada masa kini telahpun mula mengaplikasikan penggunaan *Building Information Modelling* (BIM) dalam melaksanakan projek-projek bangunan jabatan. Antara projek yang mendapat sentuhan teknologi BIM adalah Institut Kanser Negara, Bangunan Pentadbiran Suruhanjaya Pencegahan Rasuah Malaysia (SPRM) Selangor, Klinik Kesihatan Maran, Kolej MARA Banting, Blok Tambahan Hospital Putrajaya (Kompleks Endokrin), Hospital Parit Buntar dan lain-lain lagi. Kelebihan penggunaan teknologi ini ialah ianya membantu mempercepatkan anggaran kerja tanah, memudahcara kajian rekabentuk dan berupaya mengintegrasikan semua kerja perincian pakar termasuk elektrik, mekanikal, ICT dengan disiplin lain bagi meminimumkan percanggahan serta memberikan gambaran *visual* yang jelas tentang aset yang akan dihasilkan. Selain daripada itu, maklumat dan data yang tepat berkenaan aset tersebut juga dapat direkodkan di dalam model yang dibangunkan, sekali gus mampu menyumbang kepada pengoptimuman kos operasi dan penyenggaraan aset terbabit di masa hadapan. Menyedari manfaat besar yang diperolehi dari penggunaan teknologi BIM, JKR kini sedang berusaha untuk meluaskan lagi penggunaannya dalam pelaksanaan projek di jabatan ini.

Perkongsian pengetahuan berhubung BIM dan bidang-bidang yang lain melalui jurnal ini diharapkan mampu meningkatkan kompetensi pegawai-pegawai JKR. Saya juga berharap agar penerbitan jurnal tahunan ini mampu menyuntik semangat warga JKR untuk menghasilkan kertas kerja teknikal yang bermutu tinggi secara konsisten agar perkongsian pengetahuan ini dapat diteruskan.

Sekian, terima kasih.

DATO' SRI Ir. Dr. ROSLAN BIN MD TAHA

Kata Alu-Aluan
Pengarah Cawangan Dasar Dan Pengurusan Korporat

Assalamualaikum Warahmatullahi Wabarakatuh dan Salam Negaraku Malaysia,

Syukur Alhamdulillah, dengan limpah dan kurniaNya, Jurnal JKR Bil.5 (2017) telah berjaya diterbitkan. Tahniah dan ribuan terima kasih diucapkan kepada warga JKR yang telah menyumbangkan kertas kerja/artikel pada edisi kali ini dan sidang redaksi yang berusaha saban tahun untuk mengumpul kertas kerja/artikel serta semua pihak yang terlibat secara langsung mahupun tidak langsung dalam menerbitkan Jurnal JKR kali ini.

Seperti yang kita semua sedia maklum, Jurnal JKR ini merupakan satu medium atau saluran bagi warga JKR yang telah menghasilkan kertas kerja/artikel yang dibentangkan di persidangan/ seminar untuk berkongsi dan menyebarkan idea serta hasil penyelidikan mereka melalui penulisan tersebut. Penerbitan jurnal ini juga secara tidak langsung dapat menggalakkan percambahan minda serta memberi dorongan kepada warga JKR yang lain untuk menghasilkan kertas kerja/artikel dan penyelidikan yang lebih berkualiti, berinovasi dan selari dengan teknologi terkini pada masa akan datang.

Saban tahun, sambutan yang diberikan oleh warga JKR terhadap Jurnal JKR adalah amat menggalakkan, terutamanya dari kakitangan Kumpulan Pengurusan dan Profesional. Namun pada tahun ini, buat julung kalinya, Jurnal JKR telah berjaya memuatkan kertas kerja yang dibentangkan oleh kakitangan Kumpulan Pelaksana di persidangan antarabangsa. Ini adalah merupakan satu perkembangan yang amat positif dan membuktikan bahawa sesungguhnya warga JKR tanpa mengira pangkat dan gred adalah warga yang menghargai perkongsian ilmu pengetahuan. Pujian harus diberikan dan usaha ini harus dikekalkan pada masa akan datang.

Akhir kata, saya amat berharap agar jurnal yang diterbitkan ini akan memberi manfaat kepada para pembaca dengan menjadikannya sebagai salah satu bahan rujukan dalam memantapkan ilmu pengetahuan serta melaksanakan tugasan yang diamanahkan bagi melahirkan insan yang berilmu dan berdaya saing. Saya juga menyeru kepada warga JKR untuk berusaha dengan lebih gigih lagi bagi menghasilkan kertas kerja yang bermutu tinggi dan berkualiti.

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Tn. Hj. MEOR MOHAMED HARIS BIN MEOR HUSSEIN
Ketua Bahagian Pembangunan Skim Kejuruteraan
Menjalankan Tugas Pengarah Cawangan Dasar Dan Pengurusan Korporat

Visi
Jabatan Kerja Raya

Kami akan menjadi penyedia perkhidmatan bertaraf dunia dan pusat kecemerlangan di dalam pengurusan aset, pengurusan projek dan perkhidmatan kejuruteraan demi pembangunan infrastruktur negara melalui modal insan yang kreatif dan inovatif serta teknologi terkini.

Misi
Jabatan Kerja Raya

Membantu pelanggan dalam menyampaikan hasil polisi dan perkhidmatan melalui kerjasama rakan kongsi strategik

Pemiawaian proses-proses dan sistem demi penyampaian hasil yang konsisten

Menyediakan pengurusan aset dan projek yang berkesan dan inovatif

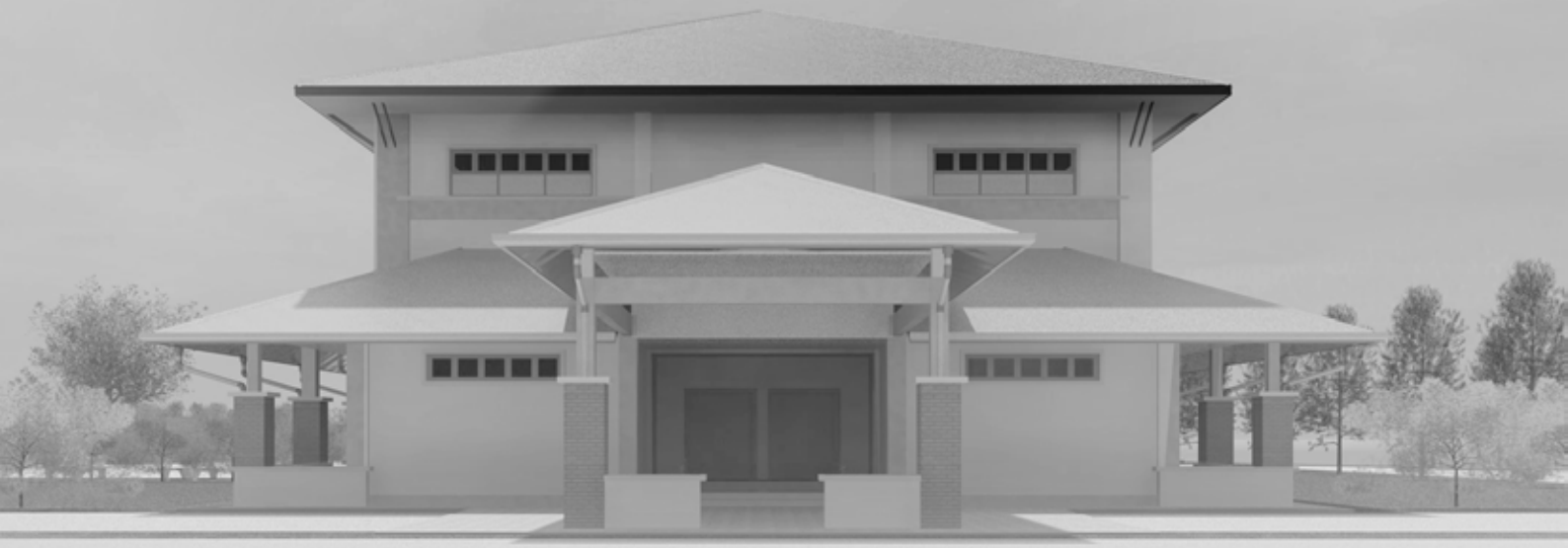
Memperkasa kompetensi kejuruteraan sedia ada

Membangunkan modal insan dan kompetensi-kompetensi baru

Berpegang teguh kepada integriti dalam menyampaikan perkhidmatan

Membina hubungan yang harmoni dengan komuniti

Memelihara persekitaran di dalam penyampaian perkhidmatan



Model BIM (Pandangan Hadapan) - Dewan Serbaguna Piawai

Optimising Time Performance of Public Building Sector Projects in Peninsular Malaysia

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ABSTRACT

The failure in estimating reasonable construction duration will jeopardize the successful completion of the projects. There are needs to establish a tool to estimate construction time performance. Thus, this study focused on developing a model to predict reasonable construction duration in order to accommodate and improve construction time performance for public building sector projects in Peninsular Malaysia. A document analysis method and quantitative approach were applied. Original contract duration and actual contract duration of 152 public building sector projects completed were used to assess the level of Time Performance Index (TPI). Independent variables had significant relationship to construction time performances were then regressed against TPI using multivariate analysis to establish time performance models. The regression model was successfully developed for public building projects with level of R^2 at 93.9%. The models were then validated via two approaches; first numerical validation using actual completed building projects, and second subjective validation using selected respondents by interview technique. Both numerical validation and subjective validation show the models developed were acceptable and would be regarded as valuable tool to predicted duration. The finding of this study is an important step in moving closer to a better understanding of construction time performance and also will provided statistical regression model available for public sector building projects.

Keywords*:* Construction Delay; Construction Management; Project Planning; Public Building Project.

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INTRODUCTION

The construction industry is large, volatile, and requires tremendous capital outlays. A unique element of risk in the industry is the manner in which disputes and claims are woven through the fibre of the construction process. The project which was delivered on time within the cost agreed and completed with acceptable quality are the benchmarking for projects to be categorised as successful (Naoum, 1994; Wright, 1997; William, 2003; Hasli *et al*., 2008). Delay in delivering project on schedule has become serious and expensive problems for parties involved. Late completion of projects can deny employers the benefits or profits potentially accrued through the use of the project. Delays may also expose them to serious financial and economic risks such as high interest rates and loss of market opportunities. On the contractor's side, delays in completion entails additional cost accrued from extended insurances, extended use of site office overheads, labour and equipment, standby costs and other intangible cost such as opportunity cost (Diekmann and Nelson, 1985; Semple *et al*., 1994; Kumaraswamy, 1997; Kumaraswamy and Chan, 1998).

Despite these effects, it is sadly all too common that most projects are not completed within the agreed contract period and according to price it was tendered for. Delays do not always result from a single catastrophic event as reported in studies by Wickwire *et al*., (1989); Kallo (1996) and Ahmed *et al*., (2003). Delay frequently develops slowly during the course of work. Minor delays are generally overlooked until their cumulative effect becomes financially apparent. Although timely completion is seen as one of the important criteria of the project success, late completion is a common problem in construction projects not only in Malaysia but worldwide as reported in studies by Chalabi and Camp (1984); Fereig and Qaddumi (1984); Arditi *et al*., (1985); Kaka and Price (1991); Al-Momani (2000); Georgy *et al*., (2000); and Chan and Kumaraswamy (2002). Notable recent examples in the UK include the British Library, the Millennium Dome, the Scottish Parliament Building, the Docklands Light Railway, The Brompton Hospital, and the West Coast Mainline Upgrade for Network Rail, the Jubilee Line Tube Extension, and the Wembley Stadium, which suffered huge time and cost overruns. Not surprisingly, many landmark reports on review of the United Kingdom (UK) construction industry (NEDO, 1983; Latham, 1994; Egan, 2002; OGC, 2003) identified delays and disruptions associated with project delivery as a major issues.

The statistics of the past six years show that Malaysia despite being one of the fast developing countries in South-East Asia, also faces delay problems in construction. As stated by MALBEX (2005), which reported that in the year 2005 about 31 numbers out of 417 government projects all over Malaysia were considered sick (MOF, 2009), which have more than two months delay or temporarily abandoned. BERNAMA (2006) further stressed that delays will cause losses and higher construction costs especially when funds for the project were borrowed from financial institutions, which carry a rather high interest rate. The government expenditures for infrastructure and utilities under the Eighth Malaysia Plan (2001-2005) was RM 38.7 billion while for the Ninth Malaysian Plan (2006-2010) the allocation was 46.8 billion (Prime Minister's Department, Ninth Malaysia Plan, 2006). The allocation was tremendously increased, so definitely an increase in the number of public project will be awarded. There has been a considerable and continued interest on the effects of construction delays. So that, there are needs to reduce the incidence of delays in the implementation of those projects.

Ahmad *et al*., (2006) stated that there is very limited empirical study available to be used as tools in identifying the time performance for public building project. Aware that the failure in estimating reasonable duration period and performance time in construction will jeopardize the successful completion of the projects. Despite the increased attention, delays continue to pose a great challenge for project owner and contractors at all levels of the supply chain (Pickavance, 2005; Pinnell, 2005).

In recognition of the previous background, this study was set out to develop a comprehensive time performance model to estimate reasonable construction duration in order to minimising delay in public building projects. In pursuit of this aim, the main task of this study is to identify the factor causes of delays determine the time performance of public building projects and to measure relationship between time performance and others independent variables. The time performance models for public sector building projects will be developed and validated. The recommendation to speed up the construction of public building project also will be summarised.

PREVIOUS STUDIES

Reviews on Construction Delay

The term "delay" in construction contracts has no precise technical meaning. It can be used in different sense to mean different conditions in project execution (Pickavance, 2005). The information related to construction delay and cost overruns can be obtained from various sources such as international journal, international conference, and published books. Many construction books (Halpin and Woodhead, 1980; Richard, 1984; Barrie and Paulson, 1992; Filcher, 1992; Harries and McCaffer, 1995; Render *et al*., 2006) have coverage on construction delay. Al-Momani (2000) considered delay as all extensions to the planned schedule describes and address the various elements cost with construction delays. Chalabi and Camp (1984) stated that delay considered as deviation from the original

bid or contract schedule. While, Semple *et al*., (1994) defined that all extension to the original schedule were considered delays. Delayed completion of projects is generally caused by the actions or inactions of the project parties including the employer, contractor, subcontractors, designers or supervisors and neither of these parties. Based on the responsibility and parties involved in contractual projects, Kraiem and Diekmann (1987); Arditi and Robinson (1995) classified delays into three categorized; compensable, excusable and non excusable.

Reviews on Factor Causes Delay

The importance reasons that contribute delays in construction project for pass two decade were studied by Arditi *et al*., 1985; Assaf and Al-Khalil, 1995; Ogunlana *et al*., 1996; Chan and Kumaraswamy, 1996; Kaming *et al*., 1997; Munns and Bjerirmi, 1996; Al-Momami, 2000; Elinwa and Joshua, 2001; and Murali and Yau, 2007. The reason in construction delays were due to variations in order, lack of coordination between projects team, inadequate construction planning and material shortage, under estimating project duration, slowness decision making by project owner, financial difficulties, poor site management, restriction of project location, and impractical design.

Review of Time Performance Index (TPI)

Construction time has been acknowledged by construction researchers and industry practitioners over the past three decades as one of the most important performance criteria of many successful projects. This raises an increasing global concern about benchmarking best practice measures of construction time performance for use by clients, consultants, contractors or analyst in the construction industry (Walker, 1995; Dissanayaka and Kumaraswamy, 1996; and Georgy *et al*., 2000). In this study Time Performance Index (TPI) was adopted, the underlying equation of: Time Performance Index (TPI) = Actual Duration/ Original Contract Duration. Where, Index > 1 (project delayed which exceeded original contract period), Index < 1 (project completed before original duration) and Index = 1 (project completion on time).

Reviews on Previous Statistical Model

A number of statistical models were previously developed for predicting the duration of a construction project; for instance in Australia (Bromilow, 1980; Ireland, 1985; Walker, 1995); in UK (Kaka and Price, 1991; Nkado, 1992; Khosrowshasi and Kaka, 1996); as well as in Hong Kong (Chan and Kumaraswamy, 1995; Chan and Kumaraswamy, 1996) has given the example of time-cost performance model being used to measure the construction cost for building contract. This model was based on the use of the project scope factors as the primary variable, some model incorporate either project complexity or project environment or management attributes element. Browmilow (1980), Ireland (1985) and Walker (1995) used project cost in order to integrate "Cost-Based Model Approach" for prediction construction duration of the building commercial and non residential building projects respectively. Assaf and Al-Khalil (1995) linked the contractor-related and labour-related causes to the probable time overruns in construction projects in Saudi Arabia. Chan and Kumaraswamy (1996) linked the consultant-related and client-related causes to the probable time overruns in construction projects in Hong Kong. Furthermore, Odeh and Battaineh (2002) linked the contract-linked causes to the probable disputes occurring in construction projects in Jordan. A difference approach was used by Al-Momani (2000) who had determined linear relationship between actual and original duration in his quantitative analysis to analyse construction delays in public projects in Jordan. Similarly, a study was study conducted by Ahmad *et al*., (2006) which aims to measure linear relationships between actual and original duration of civil engineering (irrigation and drainage; road and sewerage) projects in Malaysia in order to analyse the time performance for those three (3) types of civil engineering projects. The integrated approach and attempt as used by Al-Momani (2000) and Ahmad *et al*., (2006) were much more related and referred to in this study. Both studies were using a linear regression relationship in analysing construction period. Only the original contract duration stated in document contract were used as independent variable or predictor in order to estimate the actual construction period. This study will fill the gap and contribute to the body of knowledge by developing additional statistical models which focuses on public building projects.

Multiple Regression Models

Multiple regressions are a flexible method of data analysis to examine the relationship between one dependent variable y and one or more independent variables x_i. Cox *et al*., (2003) quoted that many practical questions involve the relationship between a dependent or criterion variable of interest (call it y) and a set of *k* independent variables or potential predictor variables (call them x_1, x_2, x_3,..., x_k), where the scores on all variables are measured for *N* cases. According to Render *et al*., (2006) in any regression analysis a relation between two or more observation is ascertained mathematically. The regression parameters or coefficients b_i in the regression equation with multiple predictors are estimated using the equation:

$$\hat{y} = b_0 + b_1x_1 + b_2x_2 + ... + b_kx_k + \text{e} \text{ (random error)} \quad (1)$$

where, $\hat{y}$ = predicted or fitted value and b_k = estimates of the population regression coefficients.

For this study, to estimate this value of coefficients the following equation is used:

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 \quad (2)$$

where, $\hat{Y}$ = predicted value (actual contract duration); b_0 = Y intercept; X_1, X_2, X_3, X_4, X_5, X_6 = independent variable (original duration; cost of project; complexity of project; and location of project); and b_1, b_2, b_3, b_4, b_5,b_6 = slope for X_1, X_2, X_3, X_4, X_5, X_6 respectively. In order to incorporate the complexity (i.e. less complex, moderate complex and highly complex) and the location of the project (i.e. northern region, southern region and western region) in the model equation, sees the categories are not quantities variables, so that dummy variable will be used.

Statistical Test - Pearson's Correlation

Pearson's coefficient of correlation *(r)* will be used to measure the degree of linear relationship between two variables. The correlation coefficient assumes a value between - 1 and + 1. If one variable tends to increase as the other decreases, the correlation coefficient is negative (Jonathan *et al.*, 2001. For the two variables x and y the formulation are as follow:

$$\rho = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{(n-1)s_x s_y} \quad (3)$$

where $\bar{x}$ sample is mean for the first variable, S_x is standard deviation for the first variable, $\bar{y}$ is sample mean for the second variable, S_y is standard deviation for the second variable, n is column length. Filcher (1992) quoted that the correlation coefficient is different from zero and that a relationship exists. Thus, it is common to reject the null hypothesis if the ρ-value is smaller than 0.05.

METHODOLOGY

In order to meet the objectives of this study, these seven (7) stages are mainly follows; sample selection stage, data collection stage, data analysis stage (including identify the causes of delay, evaluate the TPI, measuring the relationship between time performance with other independent variable for example project type, project cost, complexity of projects and project location, models development and validation stage by using actual completed public building project and selected respondent by interview technique, and followed by conclusion and recommendation. The sampling population were established by selecting the completed public building projects constructed in Peninsular Malaysia until period of 2011. Data collected will be based on the completed projects data which were obtain from main government agency department responsible for planning and implementation of those projects.

Data Analysis and Model Development

Time Performance Index (TPI) was used to compute current level of TPI of those public building projects. The measuring of relationship between TPI against independent variable (i.e. type of project, location of project, cost of project, and complexity of the project) were carried out. Pearson's Correlation was used, where the Pearson product moment coefficient represents the degree of the relationship between TPI vs. independent variable (Jonathan *et al.*, 2001). Time performance model for public building projects were then established by using the completed building projects until period of 2008. The variables that have been identified as having a significant relationship with construction time performances were then regressed against TPI. Model validation is an essential part of model development process if the models are to be accepted and used to support decision making (Macal, 2005). The model therefore was validated via two (2) approaches; firstly, numerical validation by using actual completed public projects, and second, subjectively validation by using selected respondents through interview technique.

RESULT AND DISCUSSION

Project Information Data

The sampling was established by selecting 197 public building projects constructed in different regions in Peninsular Malaysia during period of 1995 to 2011. Out of 197 projects selected, about 152 projects were used to develop full regression models (i.e. project completed until period of 2008), and 45 completed projects used as split-sample for numerical validation (i.e. projects completed during period of 2009 to 2011). The data collected was referring to contract files, progress reports, and final projects report from the various related technical departments. The information gathered during data collection includes; reasons related to construction delay and overruns: i) planned duration of contract; and ii) actual completion date; iii) cost of the projects; iv) location of the project, and v) scope of the project.

Evaluate of Project Complexity

In order to quantify the level of the complexity of the projects, public building projects were categorised into three (3) categories, namely less complex, moderately complex and highly complex. A project that has only one component was categorized as fewer complexes. A moderate complex project consisted of 2 or 3 components while highly complex one comprised of more than 3 components. Out of 152 public building projects, about 26 projects (17.1%) were categorised under high complex, 55 projects (36.2%) stated as moderately complex, while 71 projects (46.7%) was grouped under less complex of complexity level.

Distribution of Project Location

The public projects in Peninsular Malaysia were categorised into three (3) regions. The regions consist of the northern region (N), western region (W) and eastern region (E). The northern region includes Perlis, Kedah, P.Pinang, and Perak. The western region is represented by Selangor, N. Sembilan, Melaka, and Johor. Kelantan, Terengganu, and Pahang were grouped under Eastern Region.

Evaluation the Time Performance Index

From the 152 public building projects completed, the level of time performance index (TPI) was calculated. TPI value describes the average level of delay public building project to be 1.235. This indicates that the average of delay for public building project was 23.5% or 36 out of 152 public building projects were slippage in the completion.

Relationship between Time Performance Index (TPI) vs. Independent Variable

The relationship between TPI and four (4) independent variables (i.e. type of the project, location of the project, cost of project and the complexity of the project) was done. Pearson product moment coefficient (ρ-value) was used to measure the strength of relationship. A small ρ-value is an indication that the null hypothesis is false. Filcher (1992) quoted that the correlation coefficient is different from zero and that a linear relationship exists. Thus, it is common to reject the null hypothesis if the ρ-value is smaller than 0.05.

From analysis it was found that the relationship between TPI and cost of project was ρ-value = 0.001, TPI and complexity of project was ρ-value = 0.002, and TPI and location of project was ρ-value = 0.002. In these cases, the ρ-value is lesser than the alpha value of 0.05, thus the null hypothesis no significant relationship can be rejected. Hence it failed to reject null hypotheses and concluded that there is no significant relationship between TPI and type of project. It can be concludes that cost of project, location of the project and complexity of project have significant relationship with TPI. The finding from this study is similar compared to the finding by Kaka and Price (1991) who reported that the cost and complexity of project had a significance effect on the duration of project. Walker (1995) further supported that there was only a slight association between complexity of project and construction time performance.

Development of Multiple Regression Model

Regression analysis is predictive approach. It a statistical method to predict the changes in the dependent variable based on several independent variables (Hair *et al.*, 1995). A probabilistic model was developed to predict the risk effects on time awarded of public sector building projects based on the independent variable: i) original duration specified in contract, ii) cost of the project, iii) complexity of the project, and iv) location of project. The research goal is to utilise a real historical data in estimating project duration. The model will be used as tool to provide the estimated construction duration before the project tender. In this study, statistical regression models were developed using real data of completed 152 public building projects for year 2008. This study incorporated cost of the project, complexity of the project (i.e. less complex, moderate complex and highly complex) and the location of the project (i.e. northern region, southern region and western region) in the model. Since complexity and location are not quantities variables, so that dummy variables were applied.

Model for Public Building Project

The regression model was developed by using out of 152 public building projects completed on 2008. Equation (4) shows the regression model equation developed for public building projects.

$$TP_{Public} = 77.798 + 1.096\,X_1 - 0.284\,X_2 - 25.471\,X_3 - 18.568\,X_4 - 22.035\,X_5 - 2.738\,X_6 \quad (4)$$

where, X_1 – Original contract duration; X_2 – Cost of projects, $X_{3,4}$ – Complexity of project, and $X_{5,6}$ – location of project.

Model Summary:

The ρ-value in the ANOVA table (ρ = 0.000) shows that the model estimated by the regression procedure is significant at 95% level of significant (α-level of 0.05). This indicates that at least one coefficient is different from zero. The model summary for public building is shown as in Table 1.

Table 1: Model Summary for Public Building

Model Summary										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.970	.941	.939	80.467129	.941	386.385	6	145	.000	1.913
a. Dependent Variable: TP										
b. Predictors: (Constant), X6, X4, X2, X3, X5, X1										

The R^2 value in Table 1 indicates that the predictors explain 94.1% of the variance in time performance duration (TP). The adjusted R^2 is 93.9%, which accounts for the number of predictors in the model. Both values indicate that the model fits the data well. The R^2 value is close to the adjusted R^2 values, indicating that the public building model does not appear to be over fitted and has adequate predictive ability. The Durbin-Watson (DW) statistic shows whether the assumption of independent error is tenable, as a general the residuals are not correlated if the Durbin-Watson (DW) statistic is approximately 2, and an acceptable range is 1.50 to 2.50 (Cohen and Aiken, 2003). For public building model DW value is 1.913, which is so close to 2 means that the assumption has been met and the model falls within the acceptable range.

ANOVA Table:

Table 2 shows whether the model is significantly better at predicting the outcome than using the mean as a best guess. Specifically, the F-ratio represent the ratio of the improvement in prediction that results from fitting the model, relative to the inaccuracy that still exist in the model.

In order to improve the model by fitting the regression model, the value of F-ratio must be greater than 1 (the exact probability of obtaining the value of F by chance). For public building the F-value is 386.385, which is highly significance ($\rho = 0.000 < 0.001$). Thus, the public building model is interpreted as being able to significantly improve the ability to predict the outcome variables.

Table 2: ANOVA Table for Public Building

ANOVA (a)						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15010949.801	6	2501824.967	386.385	.000
	Residual	938869.041	145	6474.959		
	Total	15949818.842	151			
a. Dependent Variable: TP						
b. Predictors: (Constant), X6, X4, X2, X3, X5, X1						

Model Parameter

Multi-collinearity is not a problem in public building regression analysis, where collinearity tolerance values is larger than 0.10. The tolerance values for all of the independent variables are larger than 0.10 is acceptable (Hair *et al.,* 1995; Cohen and Aiken, 2003). The detail model parameter for public building is shown detail in Table 3.

Table 3 shows that the ρ-value (sig.) for the estimated coefficients for planned duration (X_1) is 0.000, indicating that they are significantly related to time performance at α-level of 0.05. The ρ-value for cost (X_2) is 0.279, for location (X_3-northern region) is 0.279, for location (X_4-western region) is 0.229,for complexity (X_5-less complex) is 0.203, and for complexity (X_6-moderate complex) indicating that it is not related to time performance at α-level of 0.05. The sequential sum of squares indicates that the predictor X_2, X_3, X_4, X_5 and X_6 does not explain a substantial amount of unique variance does not contribute any effect on the duration of time performance for public building projects. The dummy representing the location (East region) and complexity (highly complex) may significantly relate to time performance of this type of projects.

Validation of Regression Models Developed

Validation using actual completed public building projects

The processes were carried out by compute the mean duration of 152 public building projects completed until the year of 2008 using the model and then the results were compared with the actual duration of 45 public building projects completed during the period between 2009 to 2011. The actual mean duration recorded from 45 completed public building projects was 384.067 days, while the mean of duration calculated using the developed model was 387.934 days. The difference between the means was ±0.049%. Thus, the models were validated at a probability of 95%, which the proposed models predict the project duration at an error margin of ±0.049% of the duration. Furthermore, Pearson Correlations was used to measure the relationship between two results (actual duration versus model duration). The value of correlation is at 97.2%, which indicates a strong relationship. Scatter Plots were used to view the distribution of 45 public building projects in term of actual duration (TP-Actual) versus duration predicted by model (TP-Models). The distribution is shown in Figure 1.

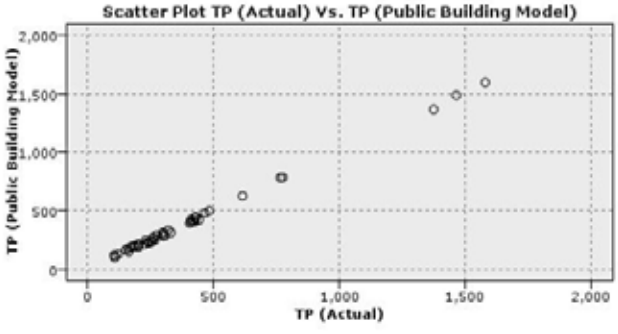

Fig. 1: Distribution of Actual Duration versus Public Building Model

Table 3: Model Parameter for Public Building

Coefficients(a)								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	77.798	22.245		3.497	.001		
	X1	1.019	.043	.987	23.444	.000	.229	4.369
	X2	-.284	.261	-.042	-1.086	.279	.274	3.653
	X3	-25.471	21.098	-.030	-1.207	.229	.675	1.482
	X4	-18.568	16.287	-.028	-1.140	.256	.695	1.438
	X5	-22.035	17.244	-.031	-1.278	.203	.687	1.455
	X6	-2.738	15.975	-.004	-.171	.864	.685	1.460
a. Dependent Variable: TP								

It was observed in Figure 1 that the durations calculated by public building model were similar to the actual recorded durations. Considering the different sets of data were used in the validation process, differences of means between -1.007% to +1.007% can be considered satisfactory (Ronald, 1977; Gass, 1983; Macal 2005). Therefore, the public building model developed is appropriate model.

Analysis of Selected Respondents

Out of the 10 selected respondents contacted, 7 selected respondents were favourable to interview. A respondent was selected regarding to their organization, job designation, area of expertise, qualifications and years of experience in delay analysis. The selected respondents are all actively involved in delay analysis within implementation agencies' specialising in this area of construction discipline. They possess relevant qualifications and their total combined construction industry experience is over 136 years. The respondents were interviewed in a structured, semi-closed questionnaire to comment on the model. Most of the experts agreed that the model addresses an important problem in the field of delay analysis. Concerning its capability in performing its intended function accurately, most of the experts were of the opinion that it is capable. This suggests that the model would be regarded by practitioners as a very useful tool for time performance analysis. In terms of the model's completeness, most selected respondents felt that the model is comprehensive and detailed. With regard to comprehensibility, most selected respondents found the model is clear and simple to understand. Most selected respondents also felt that the model would not be too costly to implement at current resource level. The attributes of model defined were found to suitable. This respond represents the model developed having a positive contribution to construction organisations.

CONCLUSION AND RECOMMENDATION

In general, the mean time performance index (TPI) value for public building projects was found to be 1.235, which described that the overall average of delay in public building project is 23.5%. The results of correlation analysis show that there were a significant relationship between TPI with the cost of project (ρ-value 0.001), complexity of project (ρ-value 0.002), and location of project (ρ-value 0.002). However, there is no significant relationship between TPI and type of project (ρ-value 0.210 greater than 0.05).

The regression model were developed appears tenable and may use as decision making tools in predicting construction duration for future awarded public building projects. The model estimated at a 95% level of significant (α-level of 0.05). The R^2 value indicates that the predictors of the variance in time performance duration for public building model was at level 93.9%. The R^2 values were indicated that the public building models developed were significant and appropriate models to use. The models were validated at a probability of 95%, at which the proposed models predict the project duration with an error margin of ±0.049% of the duration. The value of the Pearson Correlation is 97.2% indicating a strong relationship between actual duration recorded versus duration computed by the two models developed. By and large the opinions of the selected respondents were in favour of the model suggesting that the model would be regarded as valuable tool for analyze time performance of public building projects. This represents a positive contribution to the body of knowledge and practice of delay analysis within construction organizations.

Based on the factor identified as significant from this research, the strategies for speed up the duration of public building construction was summarised. The recommendation should be given attention in order to minimising the occurrence of delay.

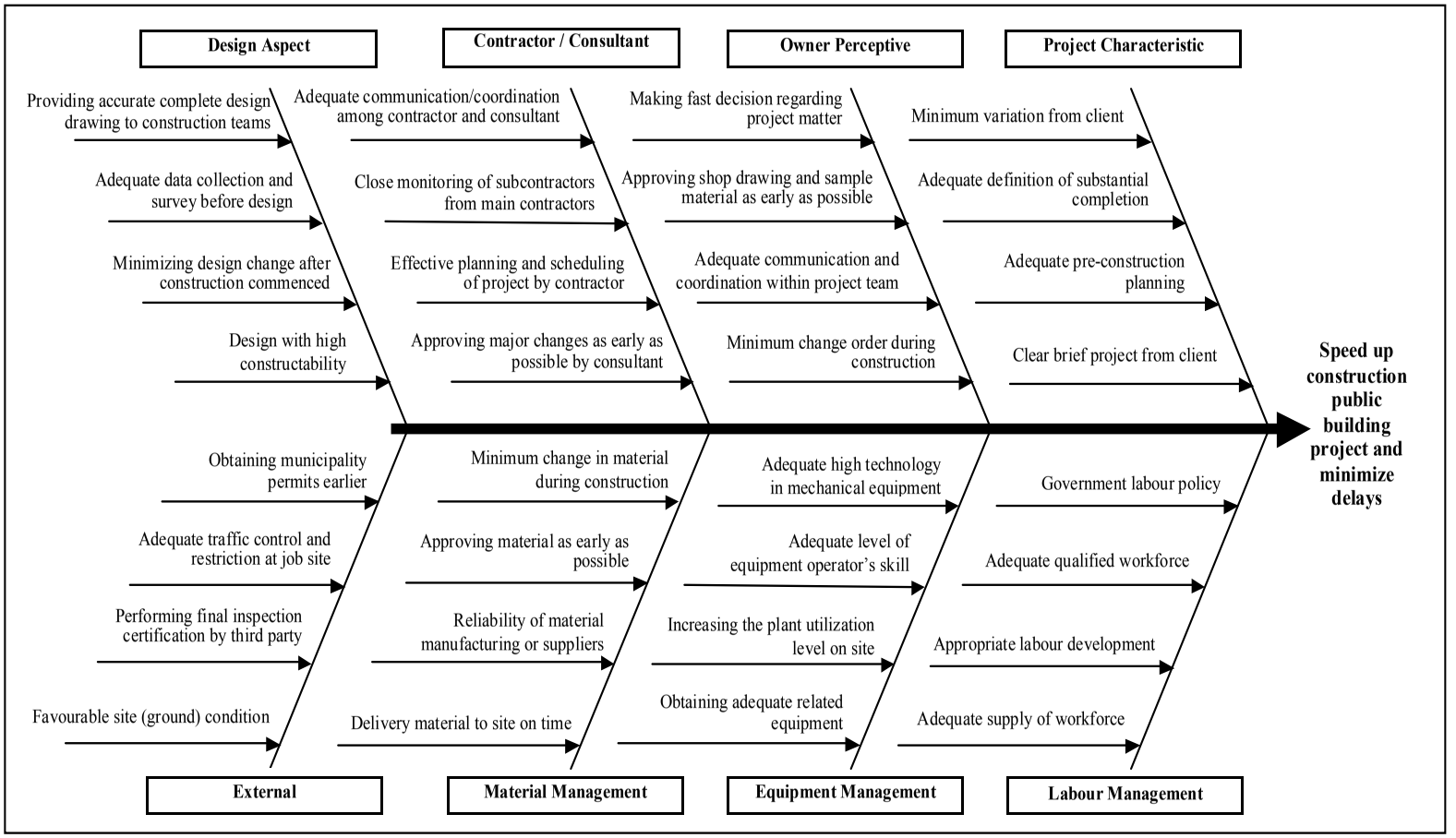

Fig.2: Fish Bone Diagram - The significant factors in refining time performance of construction public building projects in order to speed up construction of public building projects and minimize delay

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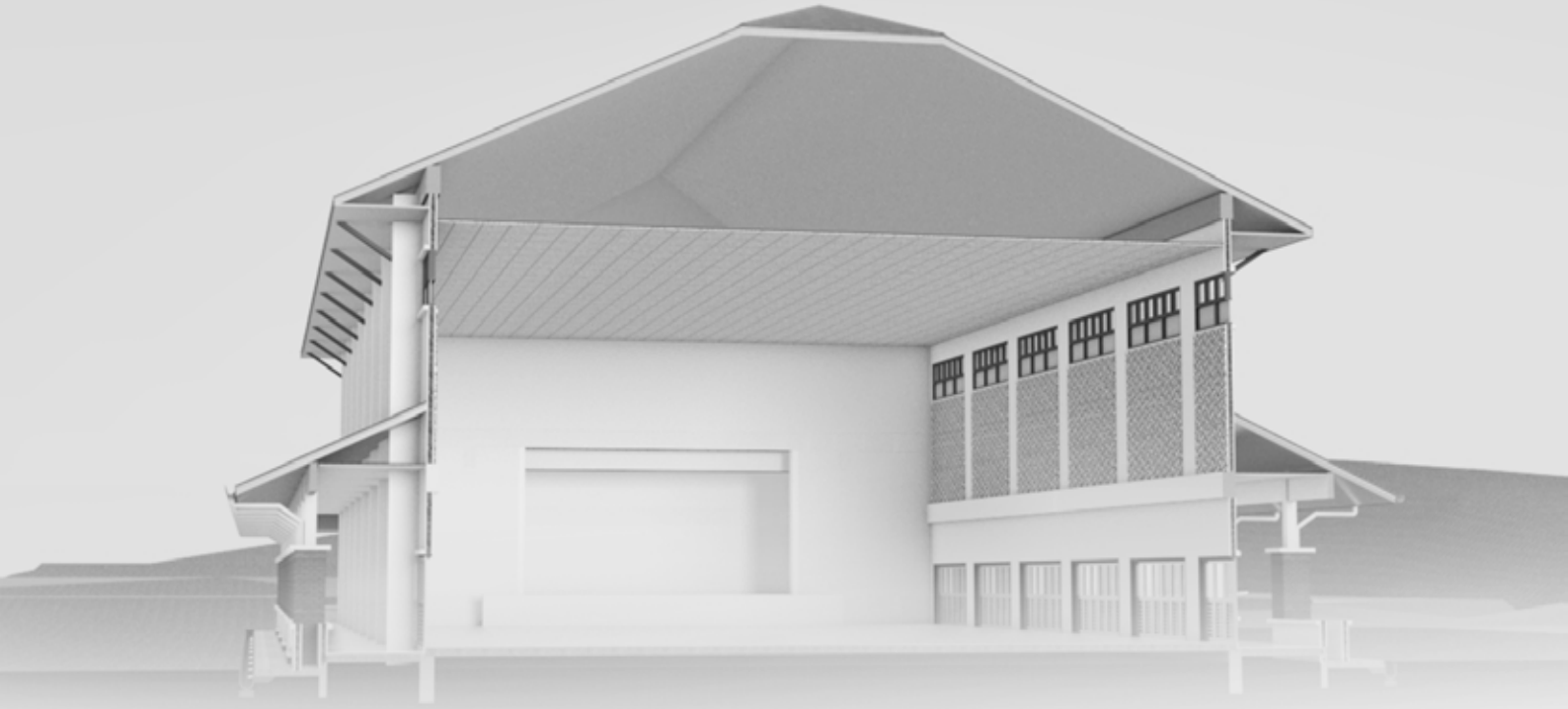

Model BIM (Keratan Perspektif 3D) - Dewan Serbaguna Piawai

Perceived Outcome of Project Success on Applying Islamic Leadership Principles – The Use of Thematic Analysis

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ABSTRACT

Islam is way of life that provides comprehensive guidance for all facets of people activities including project management. Islamic leadership has a great success history from the past and it was a paragon of excellence from the Prophetic period, to the golden age of Andalusia in Spain until the rise of Umayyad Caliphates in Istanbul, that ruled major parts of Europe, Northern Africa and Arabs and established Islamic States. The all-encompassing and success of Islamic leadership principles is even acknowledged in the Western literature that the Prophet S.A.W. is ranked number one by Michael Hart in his book; entitled 'The 100 Most Influential Persons in History'. Strong leadership by project manager is fundamental to achieve project success. Empirical studies on the positive outcome that Islamic leadership brings has been conducted in previous research however not in construction projects. Project management that is conventionally driven separates religious principles from its practice that indicates there is a gap on divine guidance in the present project management including on Islamic leadership principles. To fill this gap of lacking empirical data, a qualitative survey with project managers in Public Works Department Malaysia (PWD) on how they perceive the outcome of project in terms of time, cost and quality when applying Islamic leadership principles in their projects. Data collection was conducted via face to face interview and analysis was done by using thematic analysis. The findings of this research strongly supports the previous studies on the positive impact of Islamic leadership in organoisation that Islamic leadership principles will bring better chances of project success. This paper seeks to outline and discuss the methodology and findings of this survey and forms part of an ongoing postgraduate research.

Keywords*:* Islamic Leadership Principles, Project Management, Project Success, Thematic Analysis

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INTRODUCTION

Conventional leadership theories are lacking of spiritual, god-consciousness, ethics and moral values that are attached religion or faith (Beekun and Badawi, 1999; Toor, 2007; 2008; Groves and LaRocca, 2011; Dubrin, 2012; Beekun, 2012; Moten, 2011; Naji et. al, 2014). Islam provides the most comprehensive understanding of leadership through its highly developed and modern ethical system that seek guidelines from the Qur'an and the Sunnah of the Prophet S.A.W. (Ali Jubran Salleh, 2007; Syed Fayyaz, 2007; Toor, 2008).

The positive impact of Islamic leadership in various organisational types and settings has been proven empirically in previous research, that it is positively related to and it can increase organisational performance (Abbasi et. al, 2010; Majeed et. al, 2011; Nayal Rasyed, 2007; Gholamreza et. al, 2013a; Gholamreza et. al, 2013b; Hakim, 2012; Wan Norhayate et. al, 2014; Kriger and Seng, 2005). There is, however, no enough evidence to support that the same research has been conducted in construction projects environment or in project management (Muhamad Rosdi et. al, 2013a; 2013b; 2014a; 2014b, 2014c and 2015b).

Islam is not merely a religion but a way of life and the divine revealed and sources of the Qur'an, the Sunnah Prophet S.A.W. and other non-revealed sources of Islamic teachings are the complete and comprehensive guidance for mankind covering all aspects of human life including business transactions and project management which is part of muamalat (transactions or dealings according to Islam), (Khaliq Ahmad and Fontaine, 2011; Akram Laldin, 2011).

The completeness and comprehensiveness of Islam that provides the best guidance and as a way of life, to regulate the whole life of mankind and to resolve and fulfil all the needs of men and women, in totality is also confirmed in the following verses of the Qur'an: "This day, I have perfected to you your religion, completed My Favour upon you, and have chosen for you Islam as your religion" (Qur'an, al-Maidah: 3,translation of Tafsir Ar-Rahman, JAKIM, 2007).

In another verse Allah Says: "And there is no creature on [or within] the earth or bird that flies with its wings except [that they are] communities like you. We have not neglected in the Register (Book) a thing. Then unto their Lord they will be gathered" (Qur'an, al-An'am: 38, translation of Tafsir Ar-Rahman, JAKIM, 2007).

Infact, Muslims are obliged to follow Islamic teachings that is also clearly mentioned in the Qur'an as follows: "To each among you, We have prescribed a law and a clear way" (Qur'an, al-Maidah: 48,translation of Tafsir Ar-Rahman, JAKIM, 2007).

This commandment is all-encompassing to all human affairs and not to exclude matters pertaining to leadership in project management. Moreover, infact it is obligatory (for Muslims) as part of obligations towards Allah to identify the lawful (halal) and otherwise those prohibited in our daily dealings (Siti Nora and Khairuddin, 2008a and 2008b; Bilal et. al, 2010; Khaliq Ahmad and Fontaine, 2011). For non-Muslims, although it is not obligatory, Islamic system, values and principles, as such, Islamic leadership will provide one best alternative to practice, since Islam will brings benefits to the whole ummah and it is not only meant for Muslims, and one best example of this is the great success of Islamic banking system. Allah says in the following verse of the Qur'an: "And We have not sent you, [O Muhammad], except as a mercy to the worlds" (Qur'an, al-Anbya': 107, translation of Tafsir Ar-Rahman, JAKIM, 2007). In this regard, the success of Islamic finance and banking system as well as Islamic insurance (Takaful) have provided sufficient proof that Islam benefits all and the brings the best to mankind as stated in the surah al-Anbya.

Despite, this development, as stated earlier and the potential of Islamic leadership, and the fact that there is no evidence and none of its kind of initiatives have been introduced into construction project management in particular the public sector projects until recently, that some early indications inclining towards this direction is seen. An acknowledgement of Islamic principles is stated in project management guidance for public projects that project manager imbuted with faith (iman), taqwa, trustworthy, high quality, etc would have better control on projects and therefore can manoeuvre their project to success (ICU, Prime Ministers Department Malaysia, 2015; Ali Hamsa, 2016). They have internal control mechanism that can much influence their ways and behaviour towards their projects and the people involved that is oftenly neglected in the vast majority of project management literature. Nevertheless, there is still no evidence of empirical studies conducted with respect to imbuting Islamic leadership principles into the practice of project management.

Project success is commonly viewed as the successful achievement of completing a project within the agreed budget, within the specified time, expected quality and satisfy the client (Samiaah et. al, 2011; Jugdev and Müller, 2005; Wan Maimun and Ahmad Ramly, 2006; Pinto; 2008). Successful projects demand strong leadership capability by the project manager (PMBoK, 2013). Thus, improving their leadership can influence the project outcome and increasing the chances of meeting project success that is obviously the ultimate goal of any project endeavour.

This research was undertaken in project management of PWD (Public Works Department), Malaysia. PWD Malaysia is also known as JKR (Jabatan Kerja Raya).

The scope of this paper focuses mainly on two (2) parts, firstly on the opinions of the project managers on Islamic leadership principles, its application and project success and secondly the reasons for

their (project managers) choice on the first part. This paper will also discuss the steps taken in the data analysis and the findings of this as a qualitative research employing thematic analysis. This is part of an ongoing postgraduate research.

The purpose of this paper, therefore, is to investigate whether applying Islamic leadership principles will have impact on the project outcome ie. project success. This is based on the perceived opinions of the selected respondents.

The resulting research question follow:

Research question: Opinion on whether applying Islamic leadership principles will have positive impact on JKR project success in terms of time, cost and quality?

PROJECT MANAGEMENT AND DEFINITION OF PROJECT SUCCESS

Project management for public projects in Malaysia is best represented by JKR as the main technical department for implementing physical and infrastructure projects (Judin, 2010; Hazimul-Din, 2010; Hannerita Zainal, 2012; JKR Strategic Framework, 2012-2015). In this respect, JKR has long been leading other government agencies on technical guidelines for buiding, road, and maintenance projects, construction contracts and project management. Project management in JKR is divided into five (5) project phases ie. planning, design, procurement, construction and handing over (JKR Project Managers' Practice Manual, 2007). As the premier technical agency, it has all the in-house technical expertise comprising of all main disciplines that makes the department capable of handling a project from sketches to until it is ready to be handed over to client and users. Planning is project inititation, that the need for having a project is established by the client with preliminary indications on budget, time and expectation of end products. Project manager and initial team members are appointed to define and obtain the client's ideas in his mind to technical documentation.

Planning is crucial to decide whether to 'go or not' with a project. In design phase, details design will be prepared taking the inputs from planning as the client's needs and wants. Revisions will be done for example if there are constraints with regard to technical guidelines, as more and full information are revealed at this stage. Procurement phase is to prepare documentations for the project to be procured and the best contractor that meets various evaluation criterias can be selected. Construction is the implementation phase to make the paper planning, design to reality.

This is the real test is for the project manager, his team and stakeholders involved in any project as full team comes into and interfacing project activities running concurrently. Project fate mostly is determined in this phase. Handover is closing phase that physical components are approaching completion and testing and commissioning of deliverables items are performed. This phase is to ensure that a project accomplishes its missions, meets its main objectives and fits for purpose to the client and satisfy him.

Project management literature has evolved on the meaning of project success from the 'Iron Triangle' of Cost, Time and Quality (Atkinson, 1999, De Wit, 1988) to include more of recent criteria that reflects the increasing in clients' requirements and demand and project complexity ie. client's satisfaction and stakeholder's satisfaction or requirement (Samiaah et. al, 2011; Jugdev and Müller, 2005; Pinto; 2008). Nonetheless, JKR project management is still basically focusing towards achieving and fulfilling the three(3) traditional and commonly accepted criteria of project success which are Time, Cost and Quality. One of the reasons is that these criteria are measurable and quantifiable leading to direct evaluation on its achievement and progress. On the contrary, client's satisfaction is not directly observable and interpreted that is also known as latent variable, although scale can be suggested to represent it. These three(3) criteria are the traditional success criteria that are widely used and accepted in literature thus being the norms of measuring project success or failure in the construction industry. The essence of the project success in terms of time, cost and quality is to meet the needs and satisfy the client on which projects are constructed for.

ISLAMIC LEADERSHIP PRINCIPLES

Islamic leadership principles are enormously discussed in literature of Islamic studies (for example in Ismail Noor, 2000; 2002; Adnan, 2006; Adalat Khan, 2007; Syed Omar et. al, 2007; Dahlena Sari, 2013; Khanittha, 2015; Mohd. Sani and Nor Hartini, 2016). There are six (6) main Islamic leadership principles have been appraised and identified; leadership is a manifestation of human role as His Khalifah; leadership is a knowledge acquisition and translation-leading with knowledge; leadership is a responsibility; leadership is a team working; leadership by example and leadership is vision and the will to achieve the vision.

Al-Qur'an and al-Sunnah form a principal source of deriving Islamic leadership principles (some of it been mentioned under the Introduction i.e. Al-Ahzab:72, Al-An'am:165 and Al-Zukhruf:32), followed by practices of Companions that immediately upon their appointment would address clearly the followers and stating what leadership principles in Islam are.

Upon the occasion of his first speech once appointed, as first Caliph, Abu Bakr (ra) stated: O people! I have been selected as your trustee although I am not better than anyone of you. If I am right, obey me.

If I am misguided, set me right". Similarly, 'Umar (ra) was quoted as saying to the people: I have appointed over you governors and agents not to beat your bodies, but rather to teach you and serve you (Jabnoun, 2012). The six (6) principles will be discussed in the following paragraphs.

Firstly, The purpose of creation of men by Allah as His Khalifah (Vicegerent) or leaders on earth is repeated in the Qur'an such as in al-Baqarah, 2.143, al-Baqarah, 2:30; al-Hajj, 22.041; al-Anaam, 6.165; az-Zukhruf, 43:32; al-Maida, 5:8; al-Yusuf, 12:55; al-Yusuf, 12:56, In one verse Allah Says: "And (remember), when your Lord said to the angels, "I am about to place a vicegerent on the earth…" (Qur'an, *al-Baqarah*: 30, translation of Tafsir Ar-Rahman, JAKIM, 2007). This indicates that leadership principle already embedded in us and came from the very first moment men were created. Being Khalifah is to live by upholding the divine guidance of the Qur'an and Sunnah ie. performing good deeds and preventing from wrongdoings (amal maaruf wahna anil munkar) among fellow men, taking care of other creations, in all aspects of life including matters relating to works, in this regard, project management. Realising this principle, all activities are actions of ibadah with the inner admission as servant to Him that counted for in the Hereafter, thus men will always strive for optimisation and there is no room even as small as seed, for corrupted doings in all dealings.

Secondly, being a knowledgeable person is very demanded in Islam. Many verses in the Qur'an shows how importance Islam views the seeking of knowledge on individual Muslim and what more important to lead and to become leaders. The first verse of the Qur'an is talking about reading in verse al-'Alaq, and in al-Zumar:09, Allah SWT asks "…Are those who know equal to those who know not?"… (Qur'an, az-Zumar: 9, translation of Tafsir Ar-Rahman, JAKIM, 2007); Truly none will take heed but men of understanding". Infact, seeking knowledge and acting with knowledge is synonymous to religious duty (obligatory) as it is repeated so many times in the Qu'ran and in the hadith of the Prophet S.A.W. For example, when Mu'awiyah (ra) reported the Prophet SAW as saying, "When Allah wishes good for someone, He bestows upon him the understanding of Deen."[Al-Bukhari and Muslim]. In another hadith, that shows the great impact and lasting benefits (of rewards from Allah) not only in this world but in the next 'world', for knowledge seekers and spreading it to others, who then practice: Hadith: 'Abu Hurairah reported, the Prophet S.A.W. said, 'When a person dies, his deeds come to an end except for three things: Sadaqah Jariyah (ceasely charity); a knowledge which is beneficial, or a virtuous decendant who prays for him (for the deceased),' (Muslim) in Collection of Hadiths from Riyad-us-Saliheen by Imam An-Nawawi; 2002. For leadership, this is very true, when leading their followers, leaders must provide useful and truthful guidance to do the right things, continuously, so that they succeed the hurdles and hardship and to be able to do this, it must be accompanied with knowledge. The knowledge pass down to followers and continuously spreading to others so long they live.

Thirdly, leadership in islam is a divine trust (amanah), not an honour or previllege, neither for self fulfillment and thus it becomes a religious duty to accomplish in the best manner and in full commitment. The principle that leadership is a trust comes at the highest rank above all other reasonings. In the same notion, a leader is accountable for all his actions and endeavours towards God more than people who have vested interest in project ie. the stakeholders. Allah Says in surah al-An'am of the Qur'an that some of us will be appointed to be leaders to lead the others and in the verse of Al-Hajj, leaders are to lead himself and to serve and guide followers to do good deeds and prevent committing those that are prohibited. Allah says: "It is He Who hath made you (His) agents, inheritors of the earth: He hath raised you in ranks, some above others: that He may try you in the gifts He hath given you: for thy Lord is quick in punishment: yet He is indeed Oft-forgiving, Most Merciful. (Qur'an, al-An'am: 165, translation of Tafsir Ar-Rahman, JAKIM, 2007). (They are) those who, if We establish them in the land, establish regular prayer and give regular charity, enjoin the right and forbid wrong: with Allah rests the end (and decision) of (all) affairs. (Qur'an, al-Hajj: 41, translation of Tafsir Ar-Rahman, JAKIM, 2007). Being trustworthy and responsible is also to be just ie. to practice justice (ad'l). Justice is a fundamental principle in Islamic religion that Islam promotes just society and against any actions of oppression and manipulation of rights (haq) and that justice ensures properity and peaceful of ummah (society) (Jabnoun, 2005; Norfazila , 2012; Khaliq and Fontaine, 2011; Amrozi, 2014; Muhamad Rosdi et. al, 2015b; Pahrol Mat Joi, 2015).

Fourthly, leadership is indeed by all perspectives is about establishing and maintaining teamwork because leaders cannot accomplish anything alone without teamwork and their followers and the very fundamental fact of the meaning of leadership itself refers to a concerted group efforts between leaders and their followers energised by influence to achieve a desired goal (Verma, 1995; Fellows et. al, 2003; Lussier and Achua, 2007; DuBrin, 2010; Beekun, 2012; Yukl, 2013). This means, leadership fails without teamwork or the the result of good leadership is the existence of teamwork. In Islamic teaching, the six pillars of *iman* and the five pillars of Islam form a catalyst of unity. Everybody is heading towards one direction under the notion of religiosity. Islam is very much synonemous with teamworking ie. the principle of collective efforts rather than individualism that is manifested for example in the performance of daily prayer in congregation (*jemaah*) and the striving for social justice and sharing the burden of those less fortunate people in the community through the giving of charity (sedekah) and zakat. In this respect, Islam instills the practice of mutual consultation or shura for maintaining the group teamworking and cohesiveness in solving problems or facing challenges. It is also a famous tradition of the Prophet S.A.W. as well as it is a fundamental construct of leadership from the Islamic perspective (Haddara and Ennany, 2009; Khaliq and Fontaine, 2011; Handoko and Kayadibi, 2013).

Fifthly, being at the front line of the people, leaders must be an exemplary icon ethically, morally and charismatically and free from all degradations, and live with what they preach to followers or in modern term it is called 'walk the talk' as Allah clearly Reminds this in the Qur'an, in the Surah as-Saff, "O believers! Why do you say what you never do?" (Qur'an, as-Saff: 2, translation of Tafsir Ar-Rahman, JAKIM, 2007). The emphasis on having leaders with the correct and exemplary models for the followers are also highly important because it is seen that not all those who occupy leadership roles or positions by birth, election or appointment have the personal ability and knowledge of how to lead (Adair, 2010), thus resulting in leadership paranoia and disaster to organisation they lead in the end. Islam has bestowed upon the believers, the best leadership role model that to be exemplified that is the leadership of Prophet S.A.W., followed by the subsequent Caliphs of Abu Bakar, Uthman and Ali. Allah Testifies in the Qur'an on the Prophet S.A.W. as the noblest example of leadership; "Indeed in the Messenger of Allah, you have a good example, for anyone who looks forward to (please) Allah and the (reward of the) Last Day and remembers Allah much (whether in times of hardship or comfort" (Qur'an, al-Ahzab: 21, translation of Tafsir Ar-Rahman, JAKIM, 2007).

Finally, leaders articulating visions for the people and organisation they lead and make them achieving it and this distinguishes a leader with a routine manager or even a normal person (Maxwell, 2005; Lussier and Achua, 2007; DuBrin, 2010; Pinto, 2010; Yukl, 2013). Although, leaders set visions for followers and organisation they lead, in both conventional and Islamic leadership, however, Islam sets a far wider dimension of visions that is comprehensive and all-encompassing ie. to include spiritual visions (Jabnoun, 2005; Ali Jubran, 2007; Syed Fayyaz, 2007; Syed Omar et.al, 2007; Syed Othman al-Habshi; 2007; Toor, 2008b). The Prophet S.A.W. had exemplified that leadership in Islam is farsighted and encompasses the visions of both worlds ie. not only to succeed in this world but in to achieve the real and utmost level of success (al-Falah) in the Hereafter.

The leadership principles from Islamic perspective that have been herein discussed are divinely sourced leadership guidance that is in general meant for all mankind in all walks of life including project management as stated earlier in this paper. It is anticipated that the principles that bring elements of faith and religion of Islam would have positive impacts because it strives for true purpose of life and so be it in projects, correctness of behaviours, strong internal control and inner feelings that guide such correct actions, culture of transparency, perfection and excellence as well as putting justice at the right place, to the leaders and followers eventually projects are manoeuvred as it suppose to be.

THEMATIC ANALYSIS

Thematic analysis is a widely and most commonly used qualitative data analysis that involves identifying, interpreting, analysing, developing and reporting patterns across a data set that leads to themes that eventually provides the answer for the research questions being asked (Gibson, 2006; Braun and Clarke, 2006; Thomas and Harden, 2007; University of Auckland, 2016). Qualitative approach is complex, subjective, diverse but yet rich and deep that deals with opinions, latent variables and words that are not directly measurable (Sarantakos, 1998; 2005; Braun and Clarke, 2006; Klanke, 2008). Thematic analysis provides the first avenue or foundational method for qualitative analysis that researcher should learn that provides the core skills for conducting many other forms of qualitative analysis since the fact that qualitative study normally requires and results in identifying patterns and themes from the raw data that is analysed (Ryan and Bernard, 2003; Braun and Clarke, 2006; Bloomberg and Volpe, 2008; Ruggunan, 2013). Thematic analysis is 'not another qualitative method but a process that can be used with most, if not all, qualitative methods…' (Boyatzis, 1998 in Thomas and Harden, 2007).

Indeed, themes discovery is the basis of social science research that without thematic categories, researchers have nothing to describe, nothing to compare, and nothing to explain eventually have nothing to research and discuss (Ryan and Bernard, 2003).

This method of data analysis is also applied in previous project management research (Wang, 2012; Hannerita Zainal, 2012; Berggreen Ramsing, 2013; Davies, 2014; Lippe and Vom Brocke, 2016).

There have been no concise and precise standard method for thematic analysis (Braun and Clarke, 2006; Thomas and Harden, 2007). However, it is observed that typically the followings are the main steps or processes for data analysis employing thematic analysis (Gibson, 2006; Braun and Clarke, 2006; Thomas and Harden, 2007; Bloomberg and Volpe, 2008; University of Auckland, 2016):

1. Familiarisation with the data – this involves many times read and reading, a repetition activities to make the researcher immerse in the data to the extent he or she is familiar with the depth and breadth of the content and searching for meanings and patterns;
2. Coding - it refers the process of describing and labelling data patterns or creation of categories or grouping same patterns together enabling them to be known as the same type, this allows researcher to view the different patterns;
3. Searching and reviewing themes
4. Defining and naming themes
5. Presenting results and discussion

The steps are meant for showing the sequences but these can be overlapped and done simultaneuously. Thematic has several advantages such as flexibility and an easy process to practical approach to be conducted.

METHODOLOGY

The objective is to investigate whether applying Islamic leadership principles will have impact on the project outcome ie. project success. This is based on the perceived opinions of the selected respondents ie. project managers in JKR. The following are the key activities involved:

1. Literature review for obtaining adequate information on Islamic leadership principles and method of data analysis using descriptive statistics and thematic analysis
2. Two (2) rounds of face to face structured interview with respondents (project managers)
3. Descriptive analysis using frequency distribution (percentage) to obtain level of agreement on whether applying Islamic leadership principles will have impact on the project outcome ie. project success
4. Thematic analysis to analyse the open-ended question to develop the main themes as the reasons or justification for the respondents' answer of 3. Above.

The respondents were thirty seven (37) project managers that were the Head of project team in JKR project organisation that were based at the JKR Headquarters. They were experienced project managers as each of them had more than twenty five (25) years involvement in project management. A person with twenty five (25) years project management experience is considered an expert project manager (Berggreen Ramsing, 2013). They involved managing various projects that run parallel and their involvement was from planning phase until project completion.

They were asked a combination type of question consisting of multiple choice and open ended on the followings: Please give your opinion on whether applying Islamic leadership principles will have positive impact on JKR project success in terms of time, cost and quality. They were given the choice between Yes, No or Not Sure and an adequate space for them to state the reasons to support their answer. All respondents answered the questions. Data was analysed using frequency distribution or percentage for the multiple choice question and thematic analysis was employed to analyse the open-ended question response on the reasons supporting their choice. In thematic analysis responses from respondents are categorised and organised according to the different themes and subsequently summarise (Hannerita Zainal, 2012; Khalidah Haron, 2014; Lokman Hakim, personal communication, 7 May 2015; Shamsulhadi Bandi, 2016). The main themes resulted from thematic analysis were coded and listed randomly and subsequently became the basis instrument for the second round interview whereby the respondents, based on their opinion, were asked to rank those themes according to the level of significance or importance. However, the number of respondents participated in the second round interview were only thirty four (34) respondents because three (3) respondents that involved in the first round interview had retired from their service in JKR.

RESULTS AND FINDINGS

Table 1: Frequency Analysis

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	37	100.0	100.0	100.0
	No	0	0.00		
Missing		0	0.00		
Total		37	100.0		

The results were overwhelmingly positive that all thirty seven (37) respondents responded 'Yes' which indicates they agreed that Islamic leadership principles will have positive impact on JKR project success in terms of time, cost and quality. This shows their strong agreement and support on Islamic leadership and also on the possibility of bringing and applying these principles into the practice of project management in JKR projects. As JKR is the main technical department for implementing government physical and infrastructure projects, this can also be regarded as an initial step for introducing and imbuting the principles of Islamic leadership into public projects implementation that are undertaken by other government agencies in Malaysia in the future.

This idea is indeed in line with the several recommendation that have been made in the newly published book on project management guidance for public projects in Malaysia published by Implementation and Coordination Unit (ICU), under the Prime Ministers Department Malaysia, that calls for project managers and other stakeholders involved in public projects, to apply and practice faith (iman) and religious values from Islam such as taqwa, trustworthy, justice, transparency etc. in project management to ensure transparent and quality projects are implemented and eventually ensuring the success of public projects (ICU, Prime Ministers Department, *Public Project Management – Concept, Practical and Reality*, 2015).

The open-ended part has generated various responses from all the thirty seven (37) respondents. Through the thematic analysis, finally those responses were categorised into seven (7) main themes. The themes were then listed randomly and in the second round interview, the respondents were asked to rank the themes. The results are as follows:

Table 2: The Seven Themes from Thematic Analysis and after Ranking

Rank	Themes
1.	Islam is a way of life that is the best and perfect guidance
2.	Islamic leadership principles for all involved in project, the whole organisation
3.	Enhancing trustworthiness, integrity, humbleness, taqwa and positive characters as His servants
4.	Islamic leadership principles leading to best practice project management
5.	Best leadership practice for JKR
6.	Trainings on Islamic leadership for JKR staff
7.	Enhancing project success

The results indicate an acknowledgement and acceptance of the respondents on the big scale view that Islam provides the perfect and comprehensive guidance not only for religious or ritual matters but they also view it for the whole life guidance to include and not to set aside project management and its human resources ie. the people. This is indeed very important for any individual Muslim as a believer to have the right perspective on this life, on ourselves with the clear understanding on the purpose of our creation and the direction we are going to with the correct path to follow, as Islam has set completely in the Qur'an and Hadith. It is known as Islamic worldview or tasawwur Islam (Azimi et. al, 2007; Ang et. al, 2012) and in Malay it is called 'pandangan alam' (Mohd. Farid, 2016; Nik Mustapha, 2016).

Respondents believe that applying Islamic leadership principles will enhance those oftenly viewed important and crucial behaviourial elements in projects and in all people affairs such as trustworthiness, integrity, humbleness and taqwa (being obedient servant of Allah) that having these in place will lead to best practice of project management in JKR. With adequate awareness and continuous trainings on this subject to the project people in JKR to really understand and embrace Islamic leadership and how it can be well accustomised to the ways and methods projects are managed, the chances of achieving project success overall will also be enhanced.

CONCLUSION

This paper further contribute to the studies on Islamic leadership and has extended it to project management that the application of Islamic leadership principles would benefit various type of organisational settings including project-based organisation. Project management has long been awaiting for a comprehensive modul and model of leadership to produce robust, coherent, highly resilient human resources of project managers and the project team that are built upon external technical competencies and internal emotional and spiritual strengths based on divinely guided religious principles, to steer project to success. This study also sets the preliminary tone for the applying Islamic leadership principles into project management and supports the recent calls from the government for more efficient and transparent public project in Malaysia and in line with the continuous efforts to instill and bring Islamic principles and values into the public sector in Malaysia. Using qualitative approach of thematic analysis gives the advantage to data richness. As this study was conducted in JKR as the lead technical department for public projects in Malaysia, similar concept as indicated by the findings can be emulated by other technical agencies in the public sector in Malaysia in particular that involve in project management.

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External Networking on Innovation in Malaysia's Construction Industry

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ABSTRACT

This paper aims to discuss the impact of external networking on innovation in construction industry. In Malaysia, the construction industry is known to be one of the industries that contribute significantly towards her economic growth. The industry is described as a fragmented and complex product system as construction projects implementation requires involvement of varying combination of large and small organizations across the supply chain spectrum. The innovation in construction industry is reported to be at underachieving and efforts for its improvement have inspired this study initiative. External networking among industry players is capable in bringing them to work together as a team, reducing the adversarial relationships among them for innovation effort. The instrument in measuring innovation specific to the construction industry was developed by adapting measures introduced by several scholars in these fields. Contractors and consulting companies were the sampling frame of this study representing the construction industry in Malaysia. The population lists were developed from the lists provided by CIDB, BEM, BOA and BQSM. The samples were selected based on a stratified sampling method to gauge representation of the different groups in the population. Regression analysis was performed in this quantitative study to assess relationships amongst variables. The results revealed that only external networking with government agencies and academic institutions is significant on innovation.

Keywords*:* Advanced Technology Utilization, Project Players, Fragmented

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INTRODUCTION

In Malaysia, the construction industry has contributed significantly in establishing the infrastructure required for socioeconomic development and contributing directly to economic growth. Ibrahim et al. [1] reported that the essential elements of a healthy, functioning economy that are driven by the educational institutions, government offices, tourist attractions, transportation infrastructure, housing, commercial property are built and maintained by the construction industry.

Malaysia's construction industry registered a growth of 18.1 percent in 2012, and subsequently 10.1 percent in 2013 and recently at 11.6 percent in 2014. When translated these percentages into projects awarded in the 9th Malaysia Plan, around 26,300 projects were awarded valued at RM380 billion compared to the 8th Malaysia Plan which registered 25,700 projects valued at RM255 billion. In addition, Malaysia's construction industry has established about 75,000 contractors and employs 1,200,000 workforces that include the professionals, supervisors, skilled and unskilled workers [2].

In terms of Malaysia's GDP, construction industry only accounts for less than 5 percent; albeit its performance has great influence on the overall economic growth. Ibrahim et al. [1] portrays the construction industry as an "essential growth enabler" due to its extensive linkages and integration with other industries namely the manufacturing industry that supplies construction materials such as basic metal, cement, electrical machinery etc. For example in 1998, when the construction industry experienced a sharp downturn, the metal industry in Malaysia saw a 35.6 percent drop in output [1]. Therefore, it is fundamental for the industry to sustain its growth and attain greater performance as it has spillover effect on other industries.

Malaysia has strategically emphasized innovation as the key factor for greater growth and recognizes the importance of innovation as the catalyst for the country's long term success. The Construction Industry Development Board (CIDB) echoed this notion by underlining innovation as one of the strategic thrust in the Construction Industry Malaysia Plan (CIMP) aiming for industry's superior performance [2]. The CIMP that strategizes industry's goals for the year 2006 to 2015 denotes the importance of innovation through research and development and through adopting new construction methods. The recently published Construction Industry Transformational Plan (CITP) continues on emphasizing and promoting mechanization and advanced technology utilization.

While there are many researches on the field of innovation available, study within the perspective of the construction industry are limited. In fact, according to Sexton and Barrett [3], the study of innovation has been perceived as being at the nascent stage in the construction and build environment field. A study was conducted by Panuwatwanich et al. [4] on the determinants of innovation and business performance in Australian architectural, engineering and design (AED) firms. In the study, they claimed that there were no known study on an empirical investigation of the cause-and-effect relationships between innovation determinants and the innovation outcome within the AED firm context. On the local ground, despite the attentiveness on the importance of construction industry to the economy and the significance of innovation in contributing to the competitive edge of an organization, study on this subject is still at its infancy stage where the only known studies were conducted by Ismail [5] and Jaafar et al. [6]. Ismail [5] examines the determinants (learning organizational culture and organizational creative climate) for innovation in local organizations and multinational corporations (MNCs) in Malaysia. Jaafar et al. [6] explores on the technology readiness among managers of Malaysian construction firms particularly in the aspect of technology innovation. The fact that there are gaps and concerns in the construction industry particularly in the context of innovation, an empirical study on the subject matter is mooted.

INNOVATION IN CONSTRUCTION INDUSTRY

In the current global economic environment, it is vital for the construction industry to keep pace with the rapid changes of the technology and economic model that the world is heading towards. However, literatures in innovation indicate that construction industry has often been criticized for resisting change and for failing to adopt innovative approaches to improve performance [7]. According to the National Endowment for Science, Technology and the Arts (NESTA) [8], the construction industry is among the six "low innovation" sector along with oil production, retail banking, legal aid services, education and the rehabilitation of offenders sectors. In addition, the Third UK Community Innovation Survey conducted in 2004 revealed that construction was the worst performing industry in innovation in comparison with 11 other industries [9]. A survey conducted by the Australian Bureau of Statistics on innovation in Australian industries indicates that the construction industry had one of the lowest proportions of innovating businesses comparable to mining businesses and had fallen behind other industries such as manufacturing, electricity, gas and water supply and communications [10].

Nevertheless, the indicative low innovation level of the construction industry by past researchers is considered not conclusive and demands for more in-depth studies. This is contributed by diverge views of scholars in defining and identifying innovation, which are distinct and in some cases irrelevant across different industries. For example, in dynamic industries such as pharmaceuticals, electronics, biotechnology and IT, product innovation is essential which demands

organizations for continuous product development in order to succeed in the intense competition and fast product evolution environment. These types of industries are considered as research intensive industries that adopt indicators such as Research and Development (R&D) expenditures and capital investments, publications and patents as the common measures for innovation [11].

On the contrary, construction industry is regarded as a highly fragmented, loosely coupled, complex and non-research intensive industry and innovation is established within a project implementation that require involvement of varying combinations of large and small organizations from across the supply chain spectrum [12]. This includes a broad representation of key players in the industry particularly among manufacturers and service providers in the process of transforming materials, knowledge and processes into buildings and infrastructures. Adopting the traditional measures of innovation in a dynamic industry such as manufacturing will not reflect the actual representation of the construction industry. This is because innovation in construction usually does not involve R&D investments and introduction of new products and processes in the form of publications and patents. Hence, if such measure were used in the construction industry, the outcome might result in low level of innovation. This view is supported by Aouad, et al. [13] who argues that innovations in construction industry are project based and not able to be indicated as formal R&D expenditure and innovations are neither patented nor trademarked. Hence, employing the appropriate measures for assessing innovation will provide the real depiction of innovation in the construction industry. In addition, while manufacturing innovations for example, involve resources within the organization itself for both product and process innovation, construction innovations requires involvement of different parties from various organizations engaged directly in the construction projects. For these reasons, much of the innovation in construction remains “hidden”, as it is co-developed at the project level and not at the organizational level. Project teams disband upon completion of projects whilst innovation typically remains within the project per se. Hence, in the construction industry, evaluating innovation at project level will provide a more objective measurement as compared to the innovation at organizational level.

The organizational context of construction innovations as Slaughter [14] pointed out differs significantly from a great portion of manufacturing innovations. This is supported by Blayse and Manley [15] who state that construction is partly manufacturing (materials, components, and equipment) and partly services (engineering, design, surveying, consulting, and management). Similarly, Peansupap [16] categorizes innovation in construction industry into three; (1) Innovation in materials, equipment and methods (2) Management innovation and (3) Information Technology (IT) innovation. The first category refers to technical innovation, which can be either technical product or technical process innovation. Technical product innovation includes concrete materials, construction techniques, Industrialized Building System (IBS), robotics construction equipment etc. This type of innovation can be either adopted by organizations or created within a particular construction project. For example, a technical project setback in construction installation has triggered a construction organization to develop an innovative construction method. A project delay may generate an innovative and efficient technique devised from existing resources.

Management innovation on the other hand is reflected by techniques and principles that are adopted to facilitate the process of management and administration of construction organization and construction projects. Value engineering, Total Quality Management (TQM) and Lifecycle Costing are some of the examples of management innovation. Finally IT innovation is characterized by the adoption of hardware and software that are used to facilitate for a more effective and efficient construction project implementation such as the Building Information Modeling (BIM), online project procurement system, project management application, RFID material testing, etc.

Evidences from past researches indicate that construction innovation is process and organization based and often characterized by the widespread adoption of new practices as a result of advances in technological and business processes [14]. This is supported by the case study conducted by Gil, Miozzo and Massini [17] on Heathrow airport’s Terminal 5 project, which stress that innovation hinges on technology adoption decisions. Panuwatwanich et al. [4] adopted innovation diffusion outcomes namely innovative design products, innovative design practices and advanced technology utilization as the measurement for innovation in the architectural and engineering design sector. The innovative design product is measured by elements like recognitions and awards received, flexibility for change, and minimum environmental impact. The innovative design practices elements include value management, value engineering, life cycle costing and sustainable design. Examples of the elements for the advanced technology utilization dimensions are design drafting and development, integration of design information and remote collaboration.

EXTERNAL NETWORKING ON INNOVATION

External networking is defined by Zeng et al. [18] as the interaction between external actors and sources which can be realized in many forms or terms namely collaboration with external parties, inter-organizational cooperation and partnering. Bresnen and Marshall [19] describe partnering as integration and cooperation between contractual partners. Beach et al. [20] suggests that partnering can be described in two forms – strategic partnering (long term) and project

partnering (short term). Strategic partnering focuses on long term benefits and the relationship involved several projects and commits for a significant period of time. Such relationship typically develops collaborative relationship that aims for continuous improvement of the effectiveness of the system and operations over time. Project partnering on the other hand, establishes only for a specific project life cycle and seek for short term benefits.

Past studies [20, 21, 22] have demonstrated that external networking in the form of inter-organizational relationship or partnership has great influence on innovation in organizations. In the construction industry context, networking improves communication, promotes knowledge sharing among project participants and provides ease of access to expertise and resources which in turns facilitates problem solving and reduces conflicts. According to Beach et al. [20] organizations may enter into partnership as a form of networking in order to innovate, access new markets, overcome local market restrictions, raise entry barriers and share risk for mutual benefits. For instance, collaboration with suppliers is critical as they have greater expertise and more comprehensive knowledge on materials, parts and component for product development. In his research in a technological firm in Taiwan, Tsai [23] suggests that customer involvement in the early development stages may contribute to product development advantage since it may reduce the likelihood of poor design and organization may gain new ideas about the latest customers' demands and trends.

According to the study, partnering relationship improves communication that provide underlying beneficial effects such as improved problem resolution, the development of inter-organizational and inter-personal trust, and the promotion of an innovation culture. As Hartman [24] suggests innovation derives from the efforts of people who interact organizationally. This triggers the need for all members to be involved in the innovation process for it to succeed. It is suggested that networking play a crucial role in accomplishing this especially in the project-based environment such as the construction industry.

Many researchers have endorsed the valuable impact of cooperation with different partners on innovation [13, 18, 22, 25]. Zeng et al. [18] in his study on SMEs in China defined "partners" as the government agencies; other related firms in the industry; intermediary institutions and research organizations. Ojasalo [25] further explains that networking involves cooperation, coordination and communication which in turn reduce the level of chaos in an innovation process and, thus increasing the probability of developing successful innovations. A research by Rutten et al. [26] observed that the construction industry's poor inter-organizational cooperation combined with industry's fragmentation hinders innovation. They elaborate that the organizational dynamics, shaped by the project-based nature of production complicates the flow of knowledge and innovation between organizations. The fragmented characteristic of construction industry that insists on bringing together various organizations whose members from different set of skills, experiences, background and management requires an effective coordination and cooperation for a successful completion of a construction project.

Networking provides an efficient communication channel that allows for better knowledge transfer and diffusion of innovation in a social system. This is supported by Fukugawa [27] that describes networking as a mean of speeding up innovation by providing access to expertise and resources. As mentioned by Aouad et al. [13], innovation in construction is usually at project level, thus it shall encompass a wide range of participants within a 'project system'. Blayse and Manley [15] lists participants within a 'product system' in construction projects as governments, building materials suppliers, designers, general contractors, specialist contractors, the labor workforce, owners, professional associations, private capital providers, end users of public infrastructure, vendors and distributors, testing services companies, educational institutions and certification bodies.

Miozzo and Dewick [28] further describe the construction industry as a complex system industry in which firms must rely on the capabilities of other firms to produce innovations. Aouad et al. [13] explains that each stakeholder within the construction value chain has a different responsibility and role in stimulating and achieving innovation. Clients can act as a catalyst to foster innovation by exerting pressure on the supply chain partners to improve overall performance and by demanding high standards of work, and identifying specific novel requirements for a project [29]. Contractors, on the other hand, play a mediator role in the interface between the institutions that develop many of the new products and processes (materials and components suppliers, specialist consultants, and trade contractors) and those which adopt these innovations (clients, regulators, and professional institutions). Hence, superior collaborative relationship among these stakeholders ensures successful implementation of an innovation initiative.

Alternatively, Gadde and Dubois [22] argue that the effect of networking on innovation depends on the terms of such relationship. They differentiate partnership into two distinct relationships. One is a short term, project based relationship within a specific project period. The other type of relationship is the strategic partnership that is intended "*to last for significant period of time, include several projects and seek gains for long term*". Nevertheless, Larson [30] argues that most of the relationships in construction are short term and project based which over time may or may not lead to a strategic partnership. Such relationship that is the form of one-off contract and short-term gains restricts innovation which usually develops and diffuses over a period of time. Such characteristic of the construction environment is questioned on whether it is capable of supporting the long-term collaboration concept hence creating doubts on its impact on innovation.

RESEARCH METHOD

A. Research Objectives and Research Framework

Given the above reviews, it is crucial to gain better understanding in the aspect of enhancing innovation in construction industry through external networking. The fact that there are gaps and concerns in this particularly context, an empirical study on the subject matter was proposed. In order to do so, external networking as the indicative determinants for innovation was explored and examined. The proposed framework (Figure 1) illustrates the logical relationship between the independent and dependent variables. The dependent variable - innovation is described by three dimensions – innovative design solutions, innovative project practices and advanced technology utilization. In this study, external networking is the independent variable and is represented by two dimensions namely external networking with project players and external networking with government bodies and academic institutions.

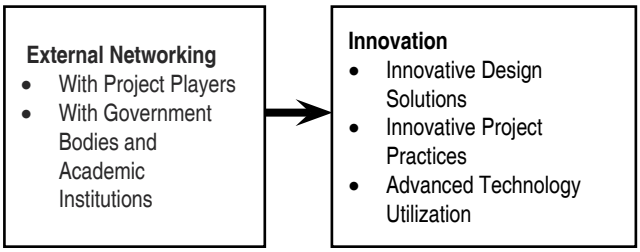

Figure 1: Research Framework

B. Sample Data

In Malaysia, organizations that involve in this industry are mainly contractors and consulting companies. Currently, there are 75,000 registered contractors in CIDB and since registration with CIDB is a compulsory requirement for the contractors to legally practice in Malaysia, these numbers can be considered valid to represent the population of contractors. The registered contractors are categorized into seven grades which represent the value of construction contracts they are eligible to participate in. The eligibility is based on certain technical and financial criteria set by CIDB (Table 1).

Table 1: Contractor's Grade

Grade	Maximum Contract Value
G1	Not exceeding 200,000.00
G2	Not exceeding 500,000.00
G3	Not exceeding 1 million
G4	Not exceeding 3 million
G5	Not exceeding 5 million
G6	Not exceeding 10 million
G7	No Limit

Source: CIDB, 2014

The scope of this research is confined to contractors in grade G7, G6 and G5 only as they are involved in projects having a contract value of more than RM3 million. Projects below RM3 million are categorized as small projects and have limited scope and complexity [31] and are excluded in this study. This reduces the population list to 9,788 contractors. Table 2 below provides the summary of the population frame.

Table 2: Population Frame

Organization	Source	No. of Registered Organizations
G7 Contractors	CIDB	4,573
G6 Contractors	CIDB	1,398
G5 Contractors	CIDB	3,817
Engineering Consultants	BEM	2,198
Architectural Consultants	BOA	1,609
Quantity Surveyor Consultants	BQSM	339
TOTAL		**13,934**

Source: CIDB (2014)

On the other hand, the list of the Board of Engineers of Malaysia (BEM), reported 2,198 registered private engineering consulting companies in Malaysia. These companies are categorized based on their engineering disciplines namely civil, mechanical and electrical engineering. Board of Architect (BOA) registered 1,609 architectural consulting companies and 339 quantity surveyors consulting companies that are currently in the list of the Board of Quantity Surveyor (BQSM). The organizations mentioned above will be the population of this research.

A set of questionnaire survey was developed to elicit the responses of the respondents of this research. The data collection was conducted in the traditional personally administered approach whereby respondents are given a hard copy form of questionnaire and monitored face to face during the survey sessions. Selections of respondents among the stratified groups were then based on a simple random sampling method and a total of 378 responses were received.

C. Variables and Measures

i. External Networking

The construct in measuring external networking is adapted from the study by Zeng et al. [18] but is adjusted to include the relevant partners in the industry. The selection of these partners is based on studies by Gann and Salter (1998) that categorizes stakeholders in the 'building and construction project system' into the following categories:

i) Regulatory framework (government and professional bodies)
ii) Supply network (building materials suppliers)
iii) Project-based firms (consultants, contractors)
iv) User (clients, owners)
v) Technical support infrastructures (academic institutions, certification bodies).

This section of the survey include a question that rate the perception of the respondents on the level of the cooperation and interaction with those partners for a project implementation.

ii. Innovation

The instrument for measuring innovation in this study combines dimensions from several studies in the field of innovation specific to the construction industry environment. They were adapted from Bossink [21], Gadde and Dubois [22], Blayse and Manley [15], Dewick and Miozzo [33], Peansupap [16], Panuwatwanich et al. [4], and Qi et al. [34]. The instrument mostly adapted the constructs by Panuwatwanich et al. [4] which categorizes them into three dimensions which are (1) Innovative Design Solution, (2) Innovative Project Practice and (3) Advanced Technology Utilization. The dimensions included the whole aspects of construction project implementation that is not only the design aspect. The innovation design solution refers to the degree of the design innovativeness of the construction project. Although it relates much to the construction design aspects, it is adapted to include the involvement of contractors during the implementation stage. The innovative project practice dimension refers to the value-added process, which aims to enhance the project performance. The advanced technology utilization dimension refers to the adoption of advanced technology during the project implementation. Table 3 summarizes the variables represent every dimensions along with the associated adopted reference.

Table 3: Summary Of Innovation Measures

Dimension	Elements	Adapted From
Innovation design solution	Recognition and awards Flexibility of the design Environmental sustainability New and established recognizable design	Panuwatwanich [4] Qi et al. [34] Peansupap [16]
Innovative project practice	Value management Value engineering Life cycle costing Constructability review Sustainable design/construction Total Quality Management	Panuwatwanich [4] Qi et al. [34]
Advanced Technology Utilization	Advanced design drafting techniques Advanced project procurement system Advanced project monitoring tools Advanced technical products Advanced construction techniques Environmental friendly equipment and products Advanced ICT application	Panuwatwanich [4] Peansupap [16] Blayse and Manley [15] Dewick and Miozzo [33] Gadde and Dubois [22] Bossink [21]

ANALYSIS AND FINDINGS

Regression analysis was performed on the data collected from the surveys to analyze the relationships between two or more variables with dependent variable (multiple regressions), in this case, the relationships between external networking and innovation.

The underlying assumptions of the linear regression, which are linearity, normality and homoscedasticity were tested in continuous data used for the regression analysis. Linearity was assessed by analyzing the scatterplots of the variables, whilst histogram and skewness data were used to detect the normality of the variables. Consistent variance of the error term is associated with homoscedasticity. Homoscedasticity assumes that the dependent variable exhibits equal levels of variance across the range of predictor variables [35]. The scatter plot of the variables on the x-axis and the variable's residual on the y-axis is analyzed to determine if a relationship is homoscedastic. The scatter plot that displays a specific pattern indicates homoscedasticity were met.

Analyses on the relationship of external networking and innovation were separately conducted based on the two defined dimensions of external networking and three dimensions of innovation. The r^2 value and the Beta coefficient as well as its significance were analyzed and examined on all of the dimensions relationships as indicated in Table 4.

The results show that external networking with project players is insignificant influencing innovation. However, external networking with government and academic institutions positively significant in influencing all three dimensions of innovation.

Table 4: External Networking On Innovation

	Innovative Design Solution			Innovative Project Practice			Advanced Technology Utilization		
r^2	0.123			0.149			0.066		
	Std. Error of the Estimate	Sig. F Change	Durbin-Watson	Std. Error of the Estimate	Sig. F Change	Durbin-Watson	Std. Error of the Estimate	Sig. F Change	Durbin-Watson
	0.93396	0.000	1.870	0.937852	0.000	1.741	0.96935	0.009	1.789
Variable	B	Std. Error	Sig.	B	Std. Error	Sig.	B	Std. Error	Sig.
(Constant)	-0.007	0.050	0.894	-0.012	0.050	0.805	0.008	0.052	0.870
External Networking with Project Players	-0.011	0.052	0.834	0.120	0.053	0.653	-0.033	0.054	0.547
External Networking with Government & Academic Institutions	0.105	0.051	0.042	0.120	0.052	0.021	0.162	0.053	0.003

External networking is posited by many scholars [13, 18, 22, 25, 28] to have a positive influence on the innovation of an organization. The findings of this research partially support this notion which indicates that networking with government bodies and academic institution is positively significant in determining innovation in construction industry. However it is not supported in the case of networking with project players.

The positive outcome on the influence of external networking with government bodies and academic institutions on innovation can be explained by the fact that construction industry is not a research intensive industry [12, 13]. As compared to a research intensive industry like pharmaceutical, where research is conducted within the organization, construction organizations are less likely to perform their research within their own organization. In PWD for example, formal research and development initiatives depends highly on the collaboration with higher education institution as well as with research agencies such as SIRIM and IKRAM. This trend is supported by the study undertook by Kamar [36] that denotes most construction related R&D activities in the Malaysia were performed outside of the construction organizations and mostly by the academic institutions. Furthermore, it is also posited that most companies did not conduct their own R&D but would rather purchase and adopt technology they require.

The outcome of this also study implied that the current progress of innovation in construction organizations in Malaysia is more due to government initiatives rather than the effort by the construction organization. In Malaysia, such efforts in promoting innovation can be observed by the consistent calls by government bodies such as CIDB. A good example would be the CIDB's request for the industry players to enhance mechanization through utilization of advanced technology in reducing high dependence on low skill foreign workers. In addition, two of the strategic thrusts in CIMP aim to promote innovation by calling the construction industry players to innovate for new construction methods by investing in research and development efforts and leveraging on the information and communication technology in automating design and construction process.

Moreover, the current widespread adoption of the innovative Industrialized Building System (IBS) in most construction project implementation in Malaysia is not due to industry push but rather by the guidelines produced by CIDB and enforcement in PWD's projects that requires 70% IBS components in all of government project [2]. The report by CIDB [2] that illustrates 67% of IBS projects were government funded further justifies this outcome.

On the other hand, although various scholars supported the positive relationship between external networking with project players and innovation, the outcome of this research indicates otherwise as it is revealed that external networking with project players is insignificant in influencing innovation. This may be contributed by the fragmented nature of the construction industry which requires the participation of the various organizations in a project team for an innovation initiative to be implemented in a construction project. While an innovation requires a certain period time to develop and diffuse, the networking established among project players is project-based and short term which may not sufficient for a full collective adoption of an innovation. In addition, according to Diffusion of Innovation Theory [37], the time required for innovation adoption is determined by the innovation decision process and the innovativeness of the members of the social system. The insignificance outcome of this study may also explains that the players in the construction industry lacks of the first three adopter categories described by Rogers namely the innovators, early adopters and early majority. They determines how early for innovation to diffuse for adoption decision. In this context, the communication channel established from external networking with project players during project implementation is insufficient for innovation adoption. These reasoning provide the possible explanations on the insignificant influence of external networking with project players on project performance.

CONCLUSIONS

This study sheds additional light on the implications of fostering innovation within the construction industry context. Additionally, this research provides several contributions to the stream of innovation research. The Diffusion of Innovation Theory highlights the importance for communication channels for diffusion of innovation and in the context of this research; such channel is established through external networking. The insignificance of communication channel established through external networking among project players possibly due to the nature such network in the construction industry, that is project based and short term which is insufficient for an innovation-decision process to complete. This finding extends the understanding on the theory which suggests that the communication channel for innovation to diffuse in a social system demands long term relationship. It is indicated that external networking with government bodies and academic institution plays an important role in influencing innovation. This implies the need for the involvement of government in providing the direction of innovation in construction industry in Malaysia. In the context of Malaysia's environment, the Construction Industry Development Board (CIDB) would be able to deliberate the findings of this research in their effort in developing appropriate policies for the development of the industry. For instance, CIDB could consider in introducing more incentives that promote new advanced technology to be available in Malaysia. The vast availability of these technologies would encourage construction organization to utilize them for improving performance. The continuous trends in adopting advanced technologies will create the economies of scale effect in technology supplies which in turns will generate greater benefits to the industry as a whole.

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Sustainable Asset Management on Decision Making Factors of Building Retrofitting

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ABSTRACT

This paper presents the significant factors considered during decision making in retrofitting process of public ownership such as hospital and school buildings. One of the major issues in facility planning is to retrofit the existing facility. In fact, for government assets, they have to be economically managed by knowing the holding cost, so that it is viable to be retained in long run. The objectives of this paper are to list down the entire decision making factors that considered in asset decision making. The aim of this paper is to propose the innovative model that will become a framework or guideline as to improve and as an added value to the existing procedure. This model will also consider some adaptation from the existing model that has been implemented by our countries. The results expected that could be used by organizations especially for the decision makers as a guideline or a tool to make a wise and good decision in building replacement related activities.

Keywords: Sustainable Asset Management, Retrofitting, Decision Making & Public Building

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INTRODUCTION

Sustainable asset management crystallized the concept of *'cradle to the grave'* into existence. It basically puts forth the consideration for maintenance right from the design stage all the way to the operation of the building, as well as making it ready for adaptive re-use. Based on Figure 1, achieving sustainable asset management basically deals with the business process, human resources and information technology system. *(A.I.Che-Ani, Badaruzzaman, 2010).*

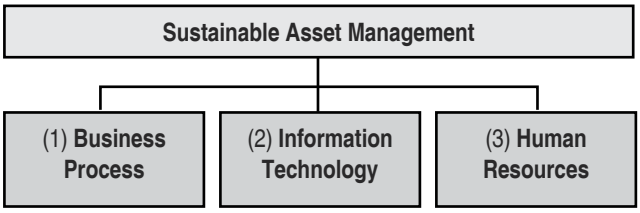

Figure 1: Sustainable Asset Management Factors *(The Ingeniuer, 2010)*

In term of business process, The Prime Minister Department has given an instruction under the *"Pekeliling Am Bil. 1 Tahun 2003, Arahan Penyelengaraan Bangunan Kerajaan di Putrajaya* dated February 11th 2003," building maintenances must be efficiently and properly executed. The Government has also given instructions to all their agencies to carry out maintenances of all their building in the very early stage so that to reduce the cost of maintenance and to avoid risk of higher maintenance cost due to negligent through time. *(N.Mohd Noor, 2011).* Furthermore, The Malaysia industry reference point for asset management has to be the TAM Manual (*Total Aset Management Manual*), part of DPAK (*Dasar Pengurusan Aset Kerajaan*). Launched in April 2009 by former Prime Minister Y.A.B. Dato' Seri Abdullah Hj. Ahmad Badawi, this document provides the key idea and direction for the whole life cycle of our assets. According to the manual, asset refers to moveable assets (*aset alih*), fixed assets (*aset tidak alih*), life asset (*aset hidup*) and intellectual property (*harta intelek*). *(Pekeliling Am Bil. 1 Tahun 2009, Kerajaan Malaysia)*

With the wide coverage of assets, an asset management team is no longer focused on building only. It has to be integrated to achieve the aspiration of TAM Manual. The existing practices of building retrofitting in government are Tatacara Pengurusan Aset Tak Alih Kerajaan 2012: Procedure that has been used by government as a guideline in asset decision making. The details of the procedure are in the 'Bab F: Pemulihan/Ubah Suai/ Naiktaraf Aset' and 'Bab G: Pelupusan Aset'. *(Pekeliling Am Bil. 2 Tahun 2012, Kerajaan Malaysia).*

In terms of information technology, this is reflected to current information system. Information is critical to the management process. Therefore, in order to implement effective property management process and strategies, sufficient and precise information need to be provided. This information can be used to make better decisions related to the implementation of property management activities. *(Shardy Abdullah, 2011).* The determination of the cost for maintenance work in government-own buildings is the federal government or the state government building has always been a headache and conflict between the contractor and client. Worsening the scenario, it is always a problem and it is usually a very hard task to determine the exact cost of maintenance works such as repairs, replacement or internal maintenance works and estimated cost usually go haywire and far from the actual cost. *(N.Mohd Noor, 2011).*

In term of human factor which is more reflected to the owners and the consumers. The owners himself fails to set goals and objectives that are clear and comprehensive and the users fails to understand or fulfil management requirements and regulations set by government agencies who own these public properties. (Shardy Abdullah, 2011) Since decision not only affects the organization in which they are taken but also the society, it is not surprising that decision making process has been heavily researched. One stream of these researches has focused on the decision making process and factor influencing the process. *(Hussien, 2012).* The objective of the study is to identify all the decision making factors in building retrofitting and then create the asset innovative model that will become a framework or a guideline in order to improve and as an added value to the existing procedure.

MATERIALS AND METHODS

The processes involved in this study are summarized in Figure 2. This figure illustrated three distinct levels of data collection, namely the first level (Literature Review) followed by the second level (Interview Experts) and ended up with the third level (Questionnaires Surveys). The first level is based on primary data collected from published books, research papers, seminar papers and journals while second level used objective data from official sources of government experts. The third or final level used questionnaires survey in order to validate the data from both of Level 1 and Level 2 of the methodology of study.

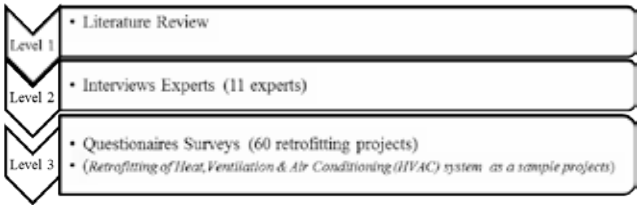

Figure 2: Methodology of Study

In Level 2, validating a factor is a process that starts with the researcher, who then seeks validation among experts. While in Level 3, the interviews conducted with the questionnaire survey consisted of variables thought to have effects on project's replacement cost to obtain detailed investigation information of the building replacement during their life cycle. The study adopted closed and open interviews in order to tap as much as possible information form parties interviewed. Furthermore, the objectives of Level 3 are to investigate about what extent the factors identified in the earlier phases had affected projects selected under the pilot studies and to identify other factors that could contribute to the replacement cost in project selected under the pilot studies.

All the data are analysed using IBM SPSS Software as a tool for statically analysis**.** IBM SPSS Modeller is a data mining and text analytics software application from **IBM**. It is used to build predictive models and conduct other analytic tasks. It has a visual interface which allows users to leverage statistical and data mining algorithms without programming. For this study, the data from 11 experts and 60 retrofitting project of Heat, Ventilation & Air Conditioning (HVAC) system are used. HVAC system is the one of the biggest component in building retrofitting. The analysis of Normality Test, Reliability Test and Descriptive Analysis are presented in the next section.

RESULTS AND DISCUSSION

Normality Test is employed to establish whether the distribution of data is normal or is skewed to one-sided (Kellar&Warrack,2004). Skewness is the extent to which the data points lack symmetry. This test is applicable to interval or ratio type of data where the decision must be made to use either parametric or non-parametric methods. The result shows that the tests of normality and the significant value have a reading of 0.200, which indicates that the scale and data obtained is normal for this study. Furthermore, the Reliability Statics Test is done. It is vital to use a reliable scale in the study. Reliability is the consistency of the measurement or the degree to which an instrument measures the same way each time it is used under similar conditions with the same subjects (Pallant, 2001). In this study, Cronbach's Alpha coefficient showed a reading of 0.761, which indicates that the scale and data obtained is reliable.

The results in Table 1 show almost all the 21 factors listed are important in decision making of retrofitting. Number 5.0 is represented the most important and number 1.0 is represented the less important in decision making. The entire factors are above 3.0 points except an *Individual Profiles, Information Database* and *Business Changes*. The top 5 important factors of building retrofitting decision making are depend on ***Availability Funding, Asset Condition, Skill & Experience of Manager, Asset Age*** and ***Level of Competency***.

Table 1: Item Statics

	Mean	Std. Deviation	N
Level of Competency	4.45	.811	60
Skill & Experience	4.68	.537	60
Individual Profiles	2.65	1.448	60
Self Confidence	4.38	.865	60
Level of Commitment	3.22	1.585	60
Project's Owner (Stakeholders)	4.32	1.157	60
Feedback Reviewed (User)	4.12	1.329	60
Asset Condition (Physically)	4.75	.600	60
Asset Age (Obsolete)	4.53	.965	60
Performance (Utilization)	4.32	1.172	60
Energy Efficiency (Green Technology)	3.70	1.293	60
Security Risk (Breakdown Frequency)	3.93	1.118	60
IT System (Latest Technology)	3.23	1.477	60
Life Cycle Cost (Value of Asset)	3.33	1.481	60
Availability Funding (Annual Budget)	4.70	.743	60
Policy (Asset Management)	3.65	1.313	60
Safety & Health (Risk/Hazard Possibilities)	4.33	1.068	60
History Record (Achievement)	3.35	1.424	60
Informed Decision (Original Equipment Manufacturer Manual)	4.20	1.312	60
Information Database (Organization SOP)	2.75	1.772	60
Business Changes (Organization Function)	1.90	1.469	60

CONCLUSION

For the conclusion, the entire decision making factors that considered in asset decision making are listed down in this paper. The innovative model that will become a framework or guideline as to improve and as an added value to the existing procedure is also proposed. The results successfully expected that could be used by organizations especially for the decision makers as a guideline or a tool to make a wise and good decision in building replacement related activities.

From Figure 3, it shows the three types of asset decision making factors. The *competence, experience, individual, personal, commitment, client* and *user* are categorized as human factor while *condition, age, performance, energy, security, IT system* and *life cycle cost* are categorized as technical factor. Lastly, the organizational

factor is *funding, policy, safety, history, informed, database* and *changes*. For the future work, regression analysis using SPSS software can be done on these factors in order to create the novel decision making model. Finally, Sustainable Asset Management is depending on the three factors which are human factor, technical factor and organizational factor.

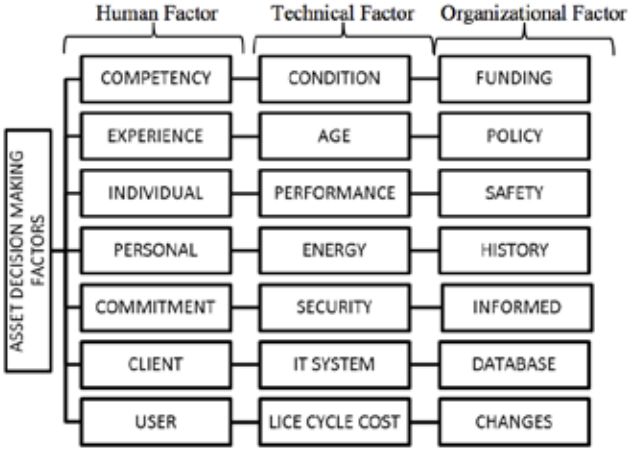

Figure 3: Asset Decision Making Factors

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Modeling Stress-Induced Failure for Deep Tunnel Excavation of Pahang-Selangor Raw Water Transfer Project

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ABSTRACT

The stress-induced failures, such as spalling and rock burst are considered as engineering disasters in deep underground excavations in hard rock. A practical predictive technique or a model to evaluate these stress-induced failures and a spalling strength is a concern in the design of support systems and excavations in underground tunnels. In the present study, tunnel excavations subjected to rock spalling failure is investigated in Pahang-Selangor Raw Water Project and the numerical model is conducted. The rock mass properties and spalling depth were recorded and compared with predictions from numerical modeling. The numerical modeling using the finite element analysis program Phase2 provides a visual representation of the stress and deformation situations and their respective locations in the tunnel. The predicted depth of spalling failure in the model was in good agreement with the observed failures. The model provided a reasonable spalling prediction of the maximum depth of failure in a deep hard rock tunnel.

Keywords*:* Spalling, Deep Tunnel, Stress-Induced, Numerical Model, Site Observation

This paper was presented at the 9th Asian Rock Mechanics Symposium, 18 – 20 October 2016, Bali, Indonesia.

INTRODUCTION

Deep tunnel excavations, which are included in civil, hydropower, and mining infrastructure requirements, have recently increased in number. However, excavations to considerable depths may lead to numerous uncertainties and a high probability of adverse conditions. Owing to the high overburden involved in these excavations, stress magnitudes increase with depth, and instability potential increases. Furthermore, failures around tunnels occur in the form of spalling or rock bursts in overstressed rocks, such as granite, and may therefore cause safety risks in deep rock excavations. For example, high in situ stress conditions caused spalling and rock burst failures in the tunnels of the Jinping II Hydropower Station (Yin et al., 2013) and the Olmos Tunnel (Diederichs et al. 2013). Therefore, understanding rock mass behaviors and stress-induced failure processes is crucial to predict the potential of failures in deep underground excavations.

Rock Spalling occurring on tunnel walls are a special form of failure encountered in tunnel projects, where the failure is one of the critical design problems involved in deep tunneling (Diederichs et al. 2004). Several rock bursts and spalling failures were generated at the side walls of the PSRWT tunnel. In this study, results of comprehensive analysis conducted using the numerical modeling, and field observation to analyze the occurrence and development process of the spalling failure are presented. In addition, the evaluation of spalling depth along the periphery of a tunnel section is attempted, and the predictions from the numerical model are compared with field observations. The results of the analysis presented in this study are expected to advance the existing knowledge of spalling failure forms and may also serve as a reference for the design of resistant measures for other similar project.

BRITTLE FAILURE AND ROCK SPALLING STRENGTH

Stress-induced failures, such as spalling, are unstable phenomena in underground openings surrounded by rocks that are subject to brittle failure (Diederichs et al, 2004; Hajiabdolmajid, 2002; Cai & Kaiser, 2014; Martin, 1997). Martin et al. (1999) have proposed various spalling criteria that simply predict spalling occurrences on the basis of in situ stress and spalling strength. However, the attempts to predict brittle failure using the traditional criteria have achieved limited success (Hajiabdolmajid et al., 2002). Therefore, different methods to model the failures of brittle and hard rock masses have been proposed. Hoek et al. (1995) suggested an elastic–brittle material model with low residual values of cohesion and friction angle to represent brittle failure. Lee et al. (2013) proposed a numerical simulation method that could predict spalling failure occurrences, failure shape, and the depth and extent of failure zones; however, certain skill requirements are necessary for the provision of adequate input parameters and the accurate interpretation of results.

In laboratory tests on intact rocks, crack initiation stress or threshold is defined by the onset of stable crack growth. The in situ strength of a massive rock is approximately 0.4 ± 0.1 UCS, where UCS is the uniaxial compressive strength obtained from laboratory tests on intact rocks (Diederichs et al., 2004; Martin et al., 1999). These findings are supported by the back analyses of case histories that carefully document failures. Therefore, in situ rock spalling strength, that is, the strength of the wall of an excavation site when spalling initiates, can be set to the crack initiation stress determined from laboratory tests. However, according to Cai and Kaiser (2014), when surface irregularities in the excavation boundary resulting from the drill-and-blast method are considered, the “actual” in situ spalling strength of massive rocks is not equal to 0.4 ± 0.1 UCS but can be as high as 0.8 ± 0.05 UCS.

PROJECT BACKGROUND

The Pahang–Selangor Raw Water Transfer (PSRWT) project includes the excavation of a 44.6 km-long tunnel (5.2 m diameter) located in the central zone of Peninsular Malaysia (see Fig. 1.). The tunnel crosses the Titiwangsa Range, the main range of Peninsular Malaysia. The highest peak of this range is 2,183 m, and the tunnel route is approximately 1,350 m above sea level. The tunnel excavation used three TBMs (TBM 1, TBM 2, and TBM 3) for about 35 km of the whole tunnel length with a maximum depth of approximately 1,200 m.

Fig. 1. Tunnel structure of Pahang-Selangor Raw Water Transfer

Fig. 2. shows the general geology along the tunnel. TBM 1 was employed to completely excavate Bukit Tinggi granite, which is porphyritic and coarse grained, mostly fresh to slightly decomposed, and cut by the Krau Fault. TBM 2 was employed for all three granite types, with 75% of the drive being in Genting Sempah micro-granite and passing through two major faults: the Bukit Tinggi Fault and Lepoh Fault. TBM 3 was employed for Kuala Lumpur granite, with small sections of Hawthorndon schist and several faults, such as the Tekali Fault and Kongkoi Fault.

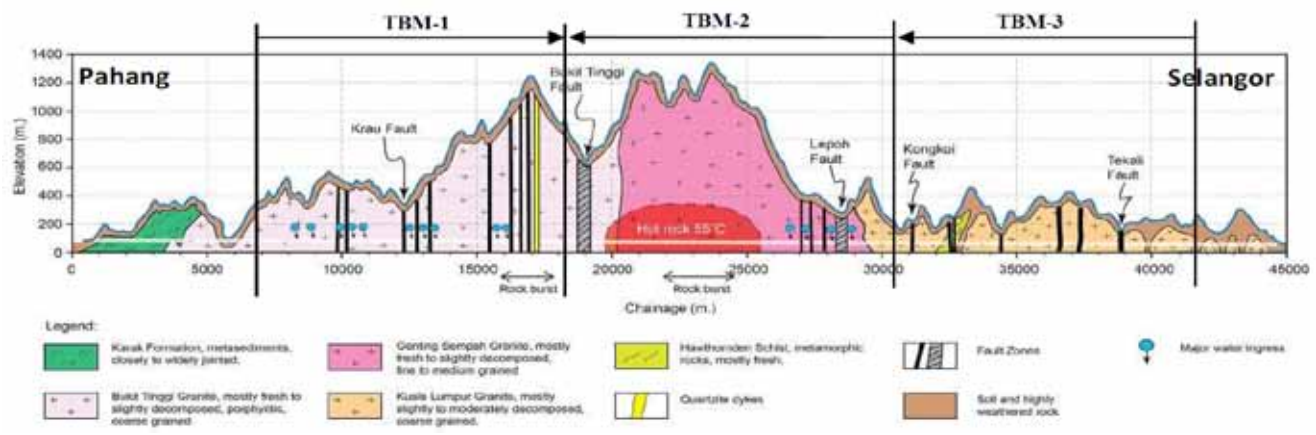


Fig. 2. Geological profiles along tunnel and TBM excavation directions [10]

During the excavation, several rock bursts and spalling failures were generated at the side walls of the tunnel. The failures were not influenced by geological structures (Kawata et al., 2014) and the tunnel crown was mostly unaffected. Fig. 3. shows one of spalling failure occurred in PSRWT. A summary of the observed spalling failures in the Pahang–Selangor Raw Water Tunnel is presented in Table 1.

Fig. 3. Rock spalling in Pahang-Selangor water transfer tunnel

Table 1 Summary of observed spalling failures in Pahang-Selangor tunnel

Chainage (m)	Overburden (m)	Original text taken from Geological Map
16302	1002	Rock spalling up to 50 cm depth after rock burst.
21919	1040	Spalling up to 30 cm depth at side walls.
21929	1037	Spalling up to 30 cm depth at side walls.
21997	1003	Spalling up to 30 cm depth at side walls.
23048	1002	Spalling up to 30 cm depth at side walls.
23732	1241	Spalling occur at face & tunnel walls. Sequence rock burst at tunnel walls damaged the shotcrete and caused over break up to 60 cm depth.
23742	1239	Spallling occur at face & tunnel walls. Sequence rock burst at tunnel walls damaged the shotcrete and caused over break up to 50 cm depth.
23899	1190	Spalling couse large blocks of hard rock forming exfoliated “onion skin-like” blocks of hard rock up to 50 cm in size with sharp, angular edges and rough undulating surface.

METHODOLOGY

Analysis of Spalling

The spalling analysis was performed on the tunnel with the use of the empirical approach to spalling prediction suggested by Diederichs (2007). The rock mass spalling strength was assessed using the results from the in situ stress data and was expressed as a fraction of the derived UCS. Theoretically, stress conditions along a circular tunnel are calculated by the following equations:

$$\sigma_r = \frac{p+q}{2}\left(1-\frac{a^2}{r^2}\right) - \frac{p-q}{2}\left(1+\frac{3a^4}{r^4}-\frac{4a^2}{r^2}\right)\cos 2\theta \quad (1)$$

$$\sigma_\theta = \frac{p+q}{2}\left(1+\frac{a^2}{r^2}\right) + \frac{p-q}{2}\left(1+\frac{3a^4}{r^4}\right)\cos 2\theta \quad (2)$$

$$\tau_{r\theta} = -\frac{p-q}{2}\left(1-\frac{3a^4}{r^4}+\frac{2a^2}{r^2}\right)\sin 2\theta \quad (3)$$

where a and r are the tunnel radius and distance from the center of the tunnel; θ is the counterclockwise angle from the spring line of the right side wall; p and q are σ_v and σ_h, which are the vertical and horizontal stresses, respectively. Along the face of the tunnel wall, r is equal to a, and the stresses for the radius direction σ_r and the shear stress $\tau_r\theta$ along the tunnel wall are both zero. The positions of the maximum stresses along the right and left sides of the wall are 0° and 180°, which are denoted by θ.

As spalling is a stress-induced failure process, the stresses on the boundary of the excavation and the maximum boundary stress should be determined. The maximum tangential stress at the side wall (θ = 0° and 180°) is simplified and calculated by Eq. 4:

$$\sigma_{\theta\max} = 3\sigma_v - \sigma_{hmin} \quad (4)$$

where $\sigma\theta_{max}$ is the maximum tangential stress, σ_v is the vertical stress, and σ_{hmin} is the minimum horizontal stress.

Numerical Modelling

Data from field observations are compared with the predictions from the numerical modeling using the finite element analysis program Phase^2. All the eight cases considered were documented in terms of spalling characteristics and rock mass properties. The analysis was conducted using Phase^2, a two-dimensional (2D) finite element program Rocscience Inc. (Jing, 2003). This finite element method (FEM) is the most widely applied numerical method for rock mechanics problems because of its flexibility in the treatment of material heterogeneity, nonlinear deformation, and in situ stresses and gravity (Rocscience Inc., 2012). Observed spallings were compared with the spallings predicted from the numerical models using the stress analysis program Phase2.

In analyzing cases with a numerical model, the numerical code should be validated, and the model should be verified to avoid any errors caused by poor processes or missing data. Case analyses can be conducted using analytical methods or using software with different procedures. To check the analytical correctness of the results obtained, the 2D FEM model was verified using the Kirsch solutions for elastic stresses around a circular opening. The tangential stress around the tunnel was calculated using Eq. 2. Fig. 4. shows the verification of Phase^2 with the Kirsch solutions for the stresses around a circular tunnel.

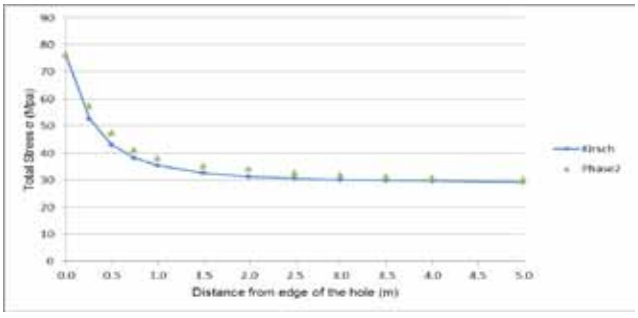


Fig. 5. Verification of Phase^{2d} with Kirsch equation for stresses around a circular tunnel

A very fine mesh with eight-node elements was used to increase the stress analysis accuracy. In the FEM, the domain was discretized into a finite number of elements with a fixed number of nodes. The displacements inside an element were approximated using a shape function that linked the nodal displacement values. The original partial differential equations were replaced by a system of algebraic equations. A global stiffness matrix was formed and stored. The solutions to the system of equations determined the node displacement values, which could in turn be used to obtain the stresses and strains in each element. The constant external boundary

was five tunnel diameters away from the tunnel. To apply the field stress load gradually as the tunnel excavation progressed, the model was completed in 16 stages with the use of the load split technique. The load split technique allows users to split the stress-induced load between any stages of the model instead of applying the entire load to the first stage. Fig. 5 shows the progressive development of a failure profile with respect to the average pressure after each stage.

In plastic analysis, the stress value may reach the yield limit such that plastic deformation occurs. The region of a yielded element shows where yielding and the associated strength reduction occur. Yielded elements failing in shear and/or tension can be evaluated. Moreover, Phase^2 tackles the problem by a series of static equilibrium solutions involving iterative procedures. In this work, an elastic solution was first obtained, and the stress state in each element was checked against the yield criteria.

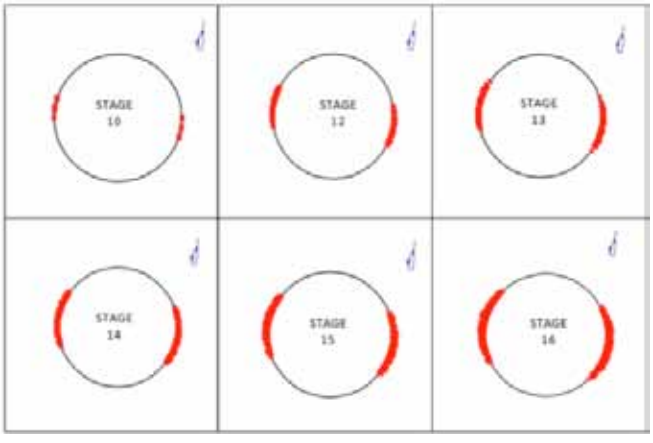


Fig. 6. Simulated progressive development of progressive failure profile with respect to average pressure after each stage.

Estimation of Rock Mass Strength

Reliable estimates of the strength and deformation characteristics of rock masses are required for almost any form of analysis used for the design of underground excavations. The most common way of determining rock mass strength is with the use of a failure criterion. The Mohr–Coulomb failure criterion was used to describe the elastic–perfectly plastic behavior of the models in this study. For the case of deep tunnels, the generalized Hoek–Brown and Mohr–Coulomb criteria were used to generate hundreds of solutions (Sofianos, 2003).

The RocLab program (Rocscience Inc., 2007) was used to estimate the generalized Hoek–Brown and Mohr–Coulomb strength parameters applied to the rock masses. The program provides a simple and intuitive implementation of the Hoek–Brown failure criterion, allowing users to easily obtain reliable estimates of rock mass properties, including the equivalent Mohr–Coulomb parameters (i.e., cohesion, c and friction angle, ϕ). This software program also visualizes the effects of changing rock mass parameters on failure envelopes using the Hoek–Brown parameters, namely, intact UCS (σ_{ci}), geological strength index (GSI), intact rock parameter (m_i), and disturbance factor (D), as inputs. D depends on the degree of disturbance to which the rock mass has been subjected by blast damage and stress relaxation. Therefore, the rock mass in this study was assumed to undergo minimal disturbance during construction; thus, $D = 0$ was adopted.

RESULTS AND DISCUSSION

Evaluation of Spalling Failure

Young's modulus and Poisson's ratio were determined using the conventional uniaxial compression test on the samples from the in situ stress test locations Adit 2 and TBM 2. The results are shown in Table 2. The results of the in situ stress test were based on the vertical, maximum, and minimum horizontal stresses of σ_v = 28.22 MPa, σ_{hmax} = 10.83 MPa, and σ_{hmin} = 5.17 MPa, respectively. The horizontal plane stress was relatively small given the horizontal to a vertical stress ratio (σ_{hmax}/σ_v) or k of 0.38. Fig. 7. presents the predicted maximum tangential stress or spalling strength on a measured stress ratio of k = 0.38 based on maximum, average, and the minimum UCS. The maximum tangential stress is a function of the profile shape and orientation of a tunnel relative to the in situ stress tensor. Therefore, determining the maximum tangential stress is essential for evaluating spalling potential.

Table 2 Result of uniaxial compressive strength in overcoring test

	Adit 2			TBM 2		
	UCS (MPa)	Young's modulus, *E* (MPa)	Poisson's ratio *v*	UCS (MPa)	Young's modulus, *E* (MPa)	Poisson's ratio *v*
Max.	173	63100	0.25	166	61900	0.26
Min.	156	61900	0.18	108	48600	0.13
Ave.	163	62533	0.21	141	54450	0.20

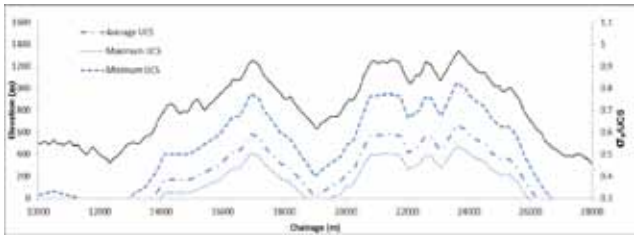


Fig. 7. Predicted spalling strength base on k = 0.38 for PSRWT project

Overstress on the rock at the tunnel side walls occurred in TBM 1 and TBM 2 at around Ch. 15,800–23,700 m with 800–1,200 m overburden. The failures were documented at depths of 0.3–0.6 m from the side walls during the excavation of the tunnel. Each of the observed cases of overstressing was evaluated by plotting the maximum boundary stresses based on the measured stress ratio along the tunnel alignment in relation to the UCS. As shown in Fig. 8, the failure initiated when the concentrated tangential stress reached approximately 0.4–0.6 UCS. This value was found slightly higher than the crack initiation measured in the laboratory samples presented by Cai et al. [5]. The recommended crack initiation stress in laboratory specimens starts at 0.3–0.5 UCS, which represents the lower-bound strength at the onset of damage or crack initiation [3]. Our result suggested that the existing approximations of in situ strengths of massive rocks of 0.3–0.5 UCS are not applicable for this condition.

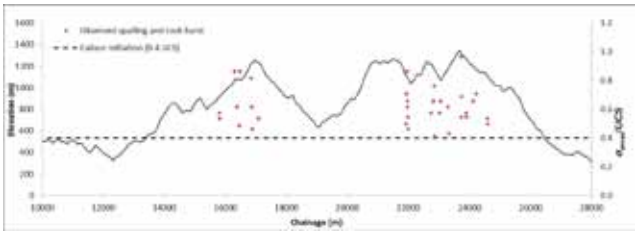


Fig. 8. Observed rock spalling failure at PSRWT project

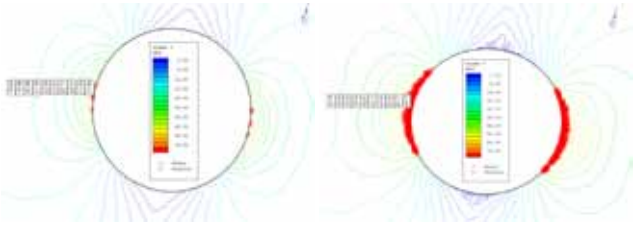
Numerical Modeling

The in situ stress measurements obtained in the nearby area in TBM 2 at 1,230 m are as follows: σ_1 = 28.76 MPa, σ_2 = 10.29 MPa, and σ_3 = 5.17 MPa, where σ1 is inclined at an angle of 80° with respect to the horizontal stress. The maximum wall tangential stress according to the Kirsch solution was $\sigma\theta$max = $3\sigma_1 - \sigma_3$ = 81 MPa. The average UCS of the rock was approximately 141 MPa (> $\sigma\theta_{max}$); thus, no failure should be expected at the tunnel site. However, the site observations revealed that spalling failures occurred at the side wall, thus indicating that the wall rock strength was much lower than 81 MPa.

Table 3 shows the inputs of rock mass properties and estimated strength parameters for the finite element analyses. The yielded elements failing in shear and intersecting shear bands were found to be good indicators of stress-induced failures. Fig. 9. shows the distributions of the yielded elements at the side wall, along with the maximum principal stress (σ_1). The first element yield occurred at Stage 10 near the excavation boundary. As the tunnel further advanced and additional load was applied, the spalling failure gradually propagated and eventually formed a notch. At this stage, the results of the numerical assessment corresponded to the observations of actual overstressing and appeared to be valid for the prediction of overstressing.

Table 3 Strength parameters of rock masses used in the numerical model

Cases	UCS (MPa)	RQD	$Jcon_{89}$	GSI	Hoek-Brown Criterion		
					m_b	s	a
1	94	70	20	65	2.865	0.021	0.502
2	141	68	23	69	3.305	0.032	0.501
3	114	70	23	70	3.245	0.035	0.501
4	124	61	19	59	4.137	0.011	0.503
5	124	65	16	57	2.153	0.008	0.504
6	94	58	16	53	1.866	0.005	0.505
7	118	60	16	54	1.934	0.006	0.504
8	149	75	16	62	2.574	0.015	0.502



(a) Stage 10 (b) Stage 16

Fig. 9. Distributions of the maximum principal stress from elastic stress analysis:

a) Stage 10 stress initiation failure and b) Stage 16

For an element located at the tunnel boundary, where σ_3 is zero, a localized yielding occurs when σ_1 is greater than 141 MPa, which is the UCS of the wall. The yielded elements that failed in shear and the maximum principal stresses for each case are presented in Fig. 10. These indicators were used to predict the stress-induced failure in which the yield condition at a point was reached when the state of stress reached the yield surface. Spalling failure gradually propagated when the maximum principal stresses near the excavation boundary exceeded 81 MPa. The results obtained from the three different methods of analyses were compared with the observed fallout, as shown in Table 4. Fig. 11. shows the good relation between the numerical model simulations and the field observations of spalling depth at the side wall. Such result demonstrates the need for an accurate representation of actual failures.

Table 4 Comparison of spalling depth failure from various analyses with observed spalling

Chainage (m)	Overburden (m)	Modeling depth (cm)	Observed depth (cm)
16302	1002	46	50
21919	1040	29	30
21929	1037	40	30
21997	1003	28	30
23048	1002	37	30
23732	1241	50	60
23742	1239	39	50
23899	1190	38	31

Fig. 10. Spalling depth predicted from numerical model for various cases a) case 1 to f) case 6

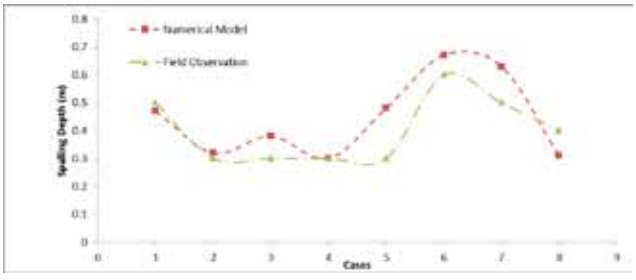


Fig. 11. Comparison of spalling depth for various analyses with observed spalling cases

CONCLUSIONS

In order to assess the stress-induced failure, it is necessary to compare the concentrated rock stress around the excavations with the rock spalling strength. The in situ rock stress and its occurrence at the site were described, together with the method of estimating the concentrated stress around circular excavations. According to the results obtained from the in-situ stress measurements, there were some stability problems for this tunnel project. The rock uniaxial compressive strength values at the site were then presented and the associated spalling strength explained. The value of spalling strength was taken as 0.4 of the uniaxial compressive strength.

The comparison of the results from the analyses with the observed spalling depths shows that the numerical modeling developed in this study can provide visual representations of the stress and deformation situations and their respective locations in the tunnel. Thus, such modeling is considerably useful in recognizing the critical locations in a tunnel section. In addition, the numerical model provides deep insights into rock mass behavior, rock stress distribution, and required rock support installation.

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Natural Ventilation Potential in Kuala Lumpur: Assumptions, Realities and Future

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ABSTRACT

Malaysia accounts for 11% of Southeast Asia's carbon emissions in recent years, is the third highest emissions contributor in the region. It has been estimated that 25% of these carbon emissions are generated from the buildings, especially from the electrical and mechanical equipment that are present in residential buildings. Malaysia's capital, Kuala Lumpur, has 81.5% of the high-rise buildings in the country and half of the buildings are residential. They have supposedly been designed as predominantly naturally ventilated, but the occupants had to add inefficient mechanical ventilation to achieve the required cooling. It is due to the lack of acknowledgement of the hot-humid climate of Malaysia by the current building regulations and the fact that the requirements for energy use are not customised for residential buildings. Recent developments concerning the use of green rating tools are helping to improve the sustainable design of buildings. This paper reviews these existing regulations and green rating tools and explores the full potential for natural ventilation in Kuala Lumpur, to substantially reduce carbon emissions while considering both the health and comfort of the occupants. It concludes that the building regulations should be revised to deal with current and future climatic conditions and to achieve the critical conditions that allow for natural ventilation in Kuala Lumpur.

Keywords*:* Natural ventilation, indoor comfort, indoor air quality, building regulations, Kuala Lumpur

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INTRODUCTION

The implications of climate change, including heat stress and air pollution, contribute to a wide range of impacts on human's health and comfort in urban areas (IPCC, 2014). More than half of the carbon emissions in the world, that are causing the climate change, will be produced by Asian cities in the next 20 years and it is estimated that 1.2 billion Asians will migrate to the cities over the next 35 years (ADB, 2015).

The carbon emission in the Southeast Asia (SEA) region has increased rapidly from 1990 to 2010 (ADB, 2015). Five countries that are Indonesia, Malaysia, Philippines, Thailand and Vietnam, have collectively contributed 90% of the carbon emissions in the SEA region (Raitzer et al., 2015). Malaysia accounts for the 11% of these emissions in recent years, ranking as the third highest emission contributor in 2014 (ADB, 2015). In order to address this problem, the government of the country has recently signed the Paris Agreement, committing to reduce 45% of carbon emissions by 2030 in accordance to the 2005 baseline (UNFCCC, 2017).

The building sector is one of the largest carbon emissions contributors in the world (IPCC, 2014). In the case of Malaysia, the carbon emissions from this particular sector have been doubled from the 1970s, representing now the 25% of the total country's emissions (Lucon et al., 2014). The residential buildings, construction of which has been quintupled during the last four decades (Lucon et al., 2014), and in particular their mechanical and electrical cooling equipment are the greatest contributors to the emissions. Thereafter, the appropriate ventilation design in these residential buildings, in particular high-risers, is a key element to find solutions to reduce carbon emissions and to overcome the damaging effects of climate change in the future. For example, the buildings in the urban areas such as Malaysia's capital, Kuala Lumpur. There are many challenges concerning the provision of natural ventilation in dense urban areas such as Kuala Lumpur, including the problems associated with the urban heat island effect and air pollution. The current practices in building design have failed to achieve the required environmental conditions for health and comfort and the occupants had to afterwards increase the amount of mechanical ventilation to achieve cooling.

The current building regulations in Malaysia (UBBL) were implemented in 1984 and these are based on the recommendations provided by the United Kingdom's Building Research Station (BRS), which is currently known as Building Research Establishment (BRE); these recommendations were previously applied in Kuala Lumpur and Singapore, both British colonies until 1957 (Said, 2011). The UBBL 1984 does not take Malaysia's hot-humid climate and the issues concerning carbon emissions in full account (Mohd Sahabuddin and Gonzalez-Longo, 2015). The regulations establish that the minimum size of openings for natural ventilation purposes in residential buildings should not be less than 10% of the total clear area of the room (UBBL, 2013), a requirement which remained unchanged for 33 years. There have been recent developments concerning the use of green rating tools in Malaysia, which are helping to improve the sustainable design of buildings and the health of their occupants. This paper reviews these existing regulations and green rating tools and explores the full potential for natural ventilation in Kuala Lumpur, in order to substantially reduce carbon emissions while ensuring a healthy and comfortable internal environment for the occupants of high-rise residential buildings.

IDENTIFYING THE CRITICAL ISSUES FOR NATURAL VENTILATION IN CONSOLIDATED URBAN AREAS

Kuala Lumpur accommodates 81.5% of the total number of high-rise buildings in Malaysia, and half of these buildings are residential buildings (CTBUH, 2016). Although most of these buildings were initially designed as naturally ventilated, the majority of their occupants have included inefficient mechanical ventilation to achieve indoor cooling (Aflaki et al., 2016). Other capital cities in the SEA region, such as Singapore and Bangkok, have also experienced the same problem (Aldossary et al., 2016, Oswald and Riewe, 2013).

The three common factors associated with indoor discomfort and unhealthy environment in high-rise residential buildings in SEA cities are high air temperature, high air pollution and low air movement. The high ambient air temperature resulted from urban heat island effects, is the result of the combination of direct solar radiation, diffused radiation from the sky dome and reflected radiation from both adjacent buildings and hard surfaces in urban areas. It has increased heat penetrates into indoor spaces through convection, conduction and radiation mechanisms (Chenvidyakarn, 2013, Nave, 2012).

The high levels of carbon emissions are directly linked to increments in temperature (Lucon et al., 2014). The scientific report of Climate Change Scenarios for Malaysia 2001-2099 produced by the Malaysian Meteorological Department (MMD) in 2009, has projected a temperature increment of 1.1°C to 3.6°C by 2095 in Peninsular Malaysia. It has also been recorded that the average dry-bulb temperature in Kuala Lumpur in 2015, was 27°C and that by 2050 this figure is expected to increase by 1.2°C (ESRI, 2015, MMD, 2010 - 2016).

As in many other cities, air pollution causes unhealthy environment in Kuala Lumpur's urban areas, as it contains airborne particulate matter and toxic gases from fuel vehicles, (Leh et al., 2012). Moreover, during the dry months of February to March and June to August in the past few decades, haze has become a regular event in Kuala Lumpur (Payus et al., 2013, Elsayed, 2012).

Both temperature and pollution issues are worsened by the insufficient wind movement in Kuala Lumpur, potentially reducing the possibilities of natural ventilation (Payus et al., 2013, Tahir et al., 2010). The city's average monthly wind speed was 1.1 m/s in 2015 (MMD, 2010 - 2016); this low figure together with the high air temperature, the presence of airborne particulate matter and urban roughness produce a series of challenges in order to implement natural ventilation strategies in buildings within the city. These factors have been so far considered in isolation and it is necessary to analyse them in an integrated way to inform the design which allows achieving a healthier and more comfortable indoor environment in high-rise residential buildings in an urban area in hot-humid climate such as Kuala Lumpur while reducing carbon emissions (Fig. 1).

CURRENT BUILDING REGULATIONS, STANDARDS AND GREEN RATINGS

The mandatory building regulations in Malaysia are called the 'Uniform Building By-Laws' (UBBL) 1984 and are contained within the 'Street, Drainage and Building Act' (SDBA) 1974. The requirements for natural ventilation in residential buildings are established in the 3rd part of the regulations: 'Space, Light and Ventilation' under clauses 39(1), 39(4), 40(1) and 40(2). However, they are only concerned about the proportion of windows and size of light-wells and there are not more specific regulations on achieving healthy indoor air quality.

Clause 39(1) states that '*every room designed, adapted or used for residential purposes, shall be provided with natural ventilation by means of one or more windows having a total area of not less than 10% of the clear floor area of such room and shall have openings capable of allowing a free uninterrupted passage of air of not less than 5% of such floor area'* (UBBL, 2013). Clause 39(4) determines that '*every water-closet, latrine, urinal and bathroom should be provided with natural ventilation by means of one or more openings having a total area of not less than 0.2 sqm*' from the room's total area (UBBL, 2013).

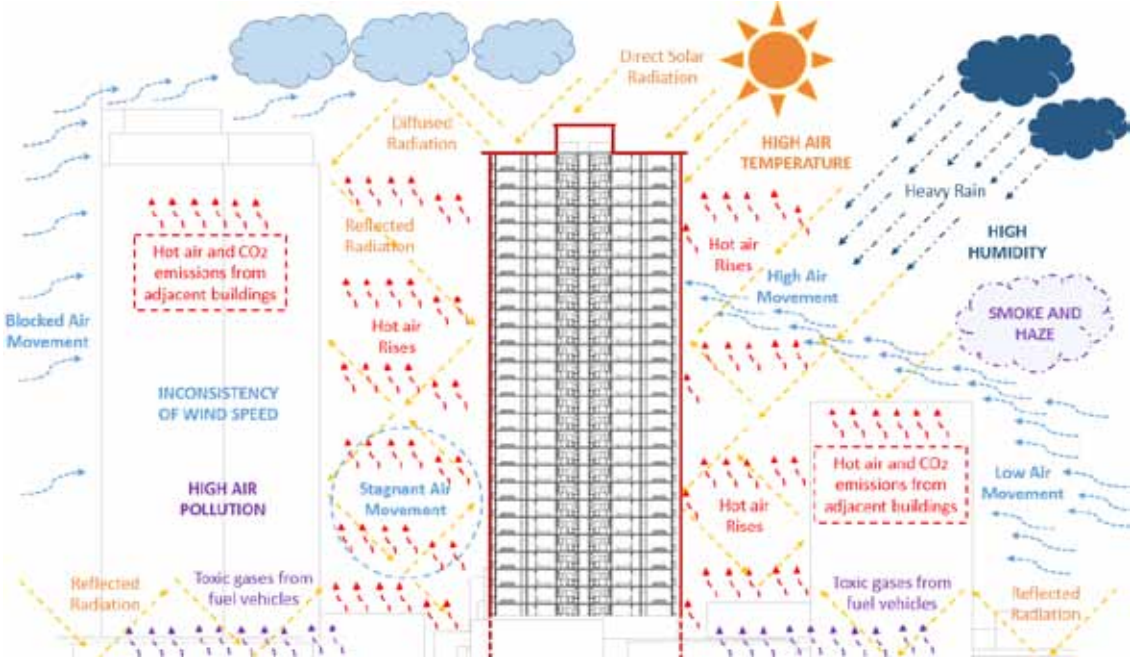

Figure 1: Factors affecting natural ventilation in a typical high-rise building within an urban area in hot-humid climate

For buildings that are more than 8 storied high, clause 40(1), establishes that the minimum size of light-wells should be not less than 15 sqm, being the minimum width 2.5 meters and clause 40(2) requires the minimum size of each light-well for lavatories, water closets and bathrooms shall be 5.5 sqm and 2.0 meters minimum width (UBBL, 2013). These could not provide an acceptable ventilation by natural means in high-rise residential buildings where weaker stack effect due to lower temperature differences and heat build-up at the top of the light-wells might happen at certain levels (Prajongsan, 2014, Kotani et al., 2003).

Concerning energy use, UBBL 1984 only refers to the Malaysian Standard 1525:2014 - 'Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings', which proposes several passive design strategies for natural ventilation such as cross ventilation and stack ventilation. However, the standard only suggests using CO_2 sensors to control indoor air pollution. For indoor comfort cooling in air-conditioned spaces, this standard recommends the maximum air movement of 0.7 m/s and air temperature of 24ºC to 26ºC.

Malaysia, like many other countries, has recently developed several green rating tools. Three most popular green rating tools used by both private and public sectors, are the Green Building Index (GBI), the Green Real Estate (GreenRE) and Malaysian Carbon Reduction & Environmental Sustainability Tool (MyCREST). However, only GBI and GreenRE have been used for residential buildings so far (MGBC, 2014, REHDA, 2015).

The first green rating tool used in Malaysia was the GBI, initiated in 2009 by a private organisation, the Malaysian Green Building Corporation (MGBC, 2014). Until October 2015, approximately 327 buildings have been rated by GBI and 41% of them are residential (MGBC, 2017). Although the tool refers to UBBL 1984 for minimum percentage of openings, in its latest version for 'Residential New Construction' published in 2014, some natural ventilation strategies have been proposed. These include the provision of light-wells to promote the stack effect (as we have seen already considered by UBBL), open plan layouts to promote cross ventilation, shading devices or overhangs to protect windows from sun radiation and naturally ventilated public spaces. This rating tool also encourages the use of low Volatile Organic Compounds (VOC) materials and finishes to reduce the indoor air pollutants, but there is no minimum air movement and indoor air temperature recommendation.

Another private organisation, the Real Estate Housing Development Association, created GreenRE in 2013 (REHDA, 2015). This tool proposes several strategies to enhance natural ventilation in residential buildings. In addition to the strategies previously proposed by GBI such as the use of open plan layouts to promote cross ventilation and the provision of public spaces naturally ventilated, GreenRE encourages a more appropriate orientation of buildings, so that they face prevailing winds. The latest version of the tool, 'Design Reference Guide for Residential Building and Landed Home' published in 2015, recommends a provision of no less than 0.6 m/s average air movement in indoor spaces (REHDA, 2015) and avoiding VOC materials to achieve good indoor air quality. As in the case of GBI there are no recommendations for the minimum percentage of openings or indoor air temperature set.

MyCREST was created by a collaborative effort of several government agencies such as the Ministry of Works, Public Works Department of Malaysia (PWD) and the Construction Industry Development Board Malaysia (CIDB) in 2016 (CIDB, 2016). This document is at the moment available only for non-residential buildings. In order to maintain good quality in the indoor air, this tool requires that all naturally ventilated spaces should be '*permanently open to and within 7.6 meters of operable wall or roof openings and that operable area is at least 4% of the net occupiable area'* (CIDB, 2016). This figure is much lower than the 10% required by Clause 39 in UBBL 1984 and researchers have considered that the minimum opening percentage in high-rise residential buildings should be not considered equally and should have a variety of sizes depending on the location and height (Mohd Sahabuddin and Gonzalez-Longo, 2015). MyCREST proposes that the minimum average of air movement for naturally ventilated spaces should be no less than 0.6 m/s. Similar to the other two green rating tools, MyCREST considers that the sources of air pollution are mainly from materials that contain VOC only (CIDB, 2016).

Table 1: Comparison of natural ventilation strategies in the laws, standards, and green rating tools in Malaysia

	PARAMETERS (Established) / (Latest Version)	UBBL (1984) (2013)	MS:1525 (2001) (2014)	GBI (2009) (2014)	GreenRE (2013) (2015)	MyCREST (2016) (2016)
EXTERNAL	Suggest minimum percentage (%) of openings of the clear floor area	10%	-	-	-	4%
	Suggest minimum percentage (%) of uninterrupted openings	5%	-	-	-	-
	Suggest recesses, shading devices, or overhangs	-	√	√	-	√
	Suggest louvres and wing walls	-	√	-	-	√
	Use vented skylights	-	-	-	-	√
INTERNAL	Suggest to promote ventilation through adjoining rooms	-	-	-	-	√
	Suggest internal air speed	-	*0.7 m/s	-	>0.6 m/s	0.6 m/s
	Use cross Ventilation	-	√	√	√	√
	Implement open plan arrangement	-	√	√	√	√
	Suggest roof space be ventilated	-	-	-	-	√
	Suggest to use mechanical equipment	-	√	-	-	√
	Provide light-well or wind chimney to promote stack effect	15m2 (> 8 stories)	√	√	-	-
	Suggest internal air temperature	-	*24-26°C	-	-	-
ETC	Suggest all public spaces should be naturally ventilated	√	√	√	√	√
	Provide wind direction table	-	-	-	-	√
	Suggest buildings should face prevailing winds	-	√	-	√	√
*	For residential buildings	√	-	√	√	-
	Suggest passive method to reduce airborne particulate matter from incoming air intake	-	-	-	-	-

*For air-conditioned spaces

This entire situation in the current scenario is concerned about the regulations and green rating tools, needs some clarification concerning the parameters they consider. Table 1 shows the comparison of natural ventilation strategies in the regulations, standards and the green rating tools used in Malaysia, as discussed above. Although there are significant improvements, in particular, the development of the recent MyCREST tool, Malaysia needs to address the need for a revision of its building regulations so that residential buildings are designed to minimise their carbon emissions and to improve the health and comfort of the occupants.

LEARNING FROM THE VERNACULAR ARCHITECTURE

In the residential buildings at tropical regions cooling is more important than heating. According to the chapter of 'Buildings: Mitigation of Climate Change' in the 5th Climate Change Assessment Report produced by the Intergovernmental Panel on Climate Change (IPCC) in 2014, residential buildings in tropical regions could lower the carbon emissions by introducing a design that could maintain indoor comfort temperatures without using any mechanical equipment. The clear precedent is vernacular houses, which design have succeeded in achieving cooling and comfort (Lucon et al., 2014). Although, obviously, they were not built in a dense urban context such as Kuala Lumpur.

In the case of traditional houses in Malaysia, it took hundreds of years to refine a well-adapted design to the local climate. The key factors for achieving healthy indoor comfort in Malaysia's rural areas are the integration of building form, the use of lightweight materials and green surroundings. Large overhangs, for example, prevent direct solar radiation and rain from entering the houses and timber-gap-floor on stilts promote fresh air intake from beneath the floor. High pitched roofs with ventilation at the top exhaust warm air by the stack effect. Lightweight materials immediately release solar heat (Lim, 1987), and large openings on the facades, which effectively balance the external and internal air temperatures (Kubota and Toe, 2015). An integrated natural ventilation strategy informed by these vernacular precedents has a great potential to reduce carbon emissions directly and at the same time ensuring the health and increased comfort of the occupants.

A study on the possible adaptation of these vernacular strategies to a modern social housing building has proved that an appropriate envelope and layout configuration could achieve the acceptable operative temperature of 25.2°C to 27.2°C, increase the indoor air movement up to 80% and reduce 67% of the carbon emission as well as energy consumption (Mohd Sahabuddin and Gonzalez-Longo, 2015). This study, which has introduced the concept of an 'Airhouse' standard for hot-humid climates, established that the percentage of openings in the building façade should be between 15% to 45% depending on the height of the residential units, increasing or decreasing the area depending on the height of the residential unit. A full-height opening configuration was proposed with three elements and these are - main windows, fixed louvres and adjustable louvres. Fixed louvres are introduced at the upper level of the internal walls to allow air to circulate throughout the units at every time. The proposed standard has also suggested that the depth of rooms should be decreased to enhance cross ventilation and the overhangs should be provided to protect all windows from solar radiation at any angles. Further studies are being carried out to refine and validate the standard.

CONCLUSION AND RECOMMENDATIONS

Although current building regulations, standards and green rating tools have proposed many natural ventilation strategies in Malaysia, they have not been able to acknowledge the current and future climatic conditions of Kuala Lumpur. At the same time, they are not able to address the required improvements in occupant's health and comfort as well as the reduction of the carbon emissions. The UBBL, especially the clauses 39(1) and 40(1) that regulate sizes of openings and light well requirements, were informed by British building standards and have not been reviewed and further researched in accordance with local climate conditions. These clauses, which have been used for 33 years without revision, should be revised and improved in order to reduce carbon emissions while ensuring occupant's health and comfort. Likewise, the standards (MS1525:2014) and green rating tools (GBI, GreenRE and MyCREST) have failed to devise strategies that could reduce airborne particulate matter and toxic gases as well as to prevent convective, conductive and radiative heat from entering and permeating high-rise residential units in Kuala Lumpur.

As per the clause 39(1), the minimum size of openings for ventilation purposes in a residential building in Malaysia should not less than 10% of the total clear area of the room. However, this sole figure seems to be inappropriate to provide ventilation and filter airborne particulate matter from entering indoor spaces in high-rise residential buildings due to different heights factor. Clause 40(1) of UBBL sets the requirement for a light-well of 15 sqm in buildings higher than 8 stories, which could not provide an acceptable ventilation by natural means in high-rise buildings due to weak stack effect and the absence of wind-force ventilation. Further studies should be carried out to test the appropriateness of these requirements to achieve suitable ventilation while ensuring the health of the building occupants and increase comfort levels in indoor spaces.

Building regulations in Malaysia, which are concerned about the natural ventilation, should be revised in order to reduce energy consumption and carbon emissions as well as to deal with the challenges of heat stress and air pollution which affect the comfort and health of the building's occupants. This revision should take into consideration the critical conditions, which allow for natural ventilation to enhance air movement, reduce the airborne particulate matter and maintain the acceptable operative temperature. By improving the regulations and maximising the potential of natural ventilation, high-rise residential buildings in Kuala Lumpur would become healthy and comfortable places to live in and great contributors to the mitigation of climate change.

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Induction Motor Bearing Fault Diagnostic Using I-Kaz™ And Decision Tree Classification

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ABSTRACT

In this paper, I-kaz™ method is proposed for the detection of induction motor bearing faults using vibration signal, which is not presented so far. The purpose of the study is to compare this new technique with the classical kurtosis method in the time domain and to validate the performance of the proposed I-kaz coefficient using decision tree classification. Three bearing conditions are investigated; i.e. normal, ball fault and inner race fault; with a very small fault size (0.1778 mm). All faulty bearings are artificially damaged using electro-discharge machining and placed in the motor drive end side. The experimental test rig is consisted of a 2 HP induction motor, a torque transducer, a dynamometer and control electronics. Vibration data is obtained using an accelerometer and analyzed with MATLAB software for the time domain analysis which include the I-kaz graphical and coefficient comparison with time waveform and kurtosis value for all bearing conditions. Then, both features are used to train a conditional inference tree (CTree) fault classifier, separately. The proposed I-kaz coefficient provides higher percentage differences between all faulty and normal bearings compared to kurtosis. However, the I-kaz graphic present similar identification as time waveform where only inner race fault is distinguished from the normal bearing. The training classification results also revealed that the I-kaz coefficient is significantly better with accuracy of 99.64% and Kappa value of 0.9946 compared with kurtosis are only 63.57% and 0.4536. Furthermore, all test data are classified accordingly with I-kaz coefficient whereas for kurtosis, only 65% is correctly classified with 0.475 Kappa value. It is proved that the I-kaz™ method is suitable for induction bearing fault detection and recommended as a classification feature especially for diagnostic of ball fault which is the most difficult to diagnose.

Keywords*:* Condition monitoring, decision tree classification, bearing fault diagnosis, vibration signal, I-kaz™.

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INTRODUCTION

Bearings are among the most common components in rotating machinery such as an electrical motor, gearbox, pump, fan, etc. As a consequence, bearing fault is also one of the primary causes of failure in rotating equipment [1]. Therefore, bearing fault detection is important in order to prevent an abnormal event which can lead to productivity loss, emergency breakdown, and catastrophic damage. Condition monitoring of bearing can be done using many techniques. Toliyat et. al. [2] specified sources of signal-based electric motor fault diagnosis can be from vibration, shock pulse, temperature, acoustic noise, electromagnetic field, output power variation, gas, oil, radio-frequency, motor current, etc. Vibration signal is a popular tool in fault diagnosis and has been applied successfully by many researchers [3-6].

Bearing failure can be categorized as 'distributed' or 'localized' [7]. Distributed defects can happened during manufacturing process, improper installation or abrasive wear. This type of defects include surface roughness, waviness, misaligned races, and off size ball. Whereas, localized defects are include cracks, pits, and spalls on the rolling surfaces which might be caused by the fatigue failure due to overloading or shock loading to the bearings during operation and installation. Jin et al. [8] listed common causes of bearing failures which include overloading, contamination, improper lubrication and misalignment.

Time domain analysis is the easiest technique performed directly on the signal time waveform itself. Traditionally, time domain analysis calculates characteristic feature as descriptive statistic such as mean, peak, peak-to-peak interval, standard deviation, crest factor, high-order statistics: RMS, skewness, kurtosis, etc. [9]. Kurtosis is one of an earliest method for bearing fault detection, first introduced by Dyer & Stewart [10]. Kurtosis, *Kur* for *N* number of data $(y_1,y_2,\ldots,y_n)$, can be calculated as:

$$Kur = \frac{\frac{1}{N}\sum_{n=1}^{N}(y_n-\mu)^4}{s^4}, \quad (1)$$

where μ is the mean and s is the standard deviation of data. For a good bearing condition, kurtosis value is close to 3 complied with Gaussian distribution whereas for faulty bearings, kurtosis is relatively higher than 3. However, in some cases when the fault is well advanced, the kurtosis value was reported to go down, close to 3. Kurtosis also approaching 3 for a small ball fault as disclosed by Smith and Randall [11] which are between 3.04 to 3.15, compared to normal bearing which are from 2.76 to 2.96.

The present paper emphasizes the detection of bearing faults using the new kurtosis based method called I-kaz™ compared with the kurtosis technique in the time-domain analysis. Both features are also used to train the decision tree model separately and are evaluated with the same test data set using accuracy and Kappa coefficient comparison. As well, it is aimed to compare the performance of I-kaz and kurtosis in bearing fault diagnosis especially for detection of ball fault which is certainly the most difficult to diagnose [11].

INTEGRATED KURTOSIS-BASED ALGORITHM FOR Z-FILTER (I-kaz™) METHOD

The I-kaz™ method was developed by Nuawi et al. [12] based on the concept of data distribution about its center points. This method applied both descriptive and inferential statistics. The descriptive part is a numerical value called I-kaz coefficient, Z^{κ} and inferential part is a three-dimensional graphic summarizing of data distribution with low, high, and very high-frequency range represented in the x-axis, y-axis, and z-axis respectively. Detail of signal decomposition process is shown in Figure 1, as follows:

- Low-frequency range (LF): 0 to 0.25 $f_{max,}$
- High-frequency range (HF): 0.25 to 0.5 $f_{max,}$
- Very high-frequency range (VF): 0.5 f_{max} to $f_{max,}$

where f_{max} is half value of the data sampling rate.

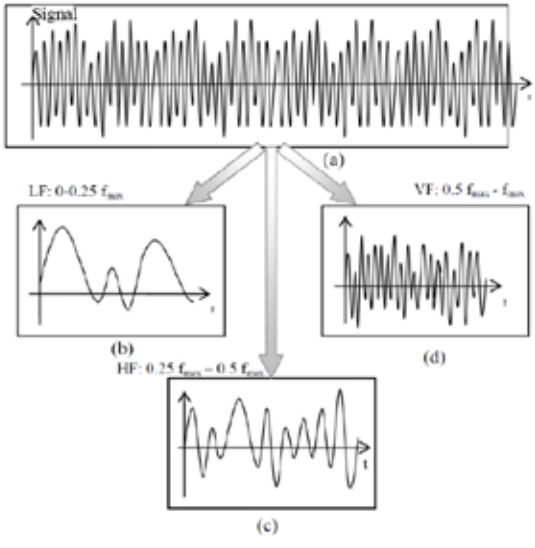

Figure 1. Detail of I-kaz signal decomposition process [12].

Previously, the I-kaz™ method has been successfully applied for the analysis of car engine bearing [13], engine block [14], suspension system [15], machine cutting tool [16], etc. To the author's best knowledge, this method has never been applied in the field of induction motor bearing diagnostics.

FAULT DIAGNOSIS USING DECISION TREE

Bearing fault diagnosis using decision tree has proven good performance in the classification [17, 18]. The decision tree is a tree-like model that predicts the value of a target variable by learning simple decision rules inferred from the data features. There are several algorithms for decision tree classification such as ID3 [19], C4.5 [20], CART [21], CHAID [22] and CTree [23]. A typical decision tree is consists of the root node, internal nodes and leaf nodes [24] as shown in Figure 2.

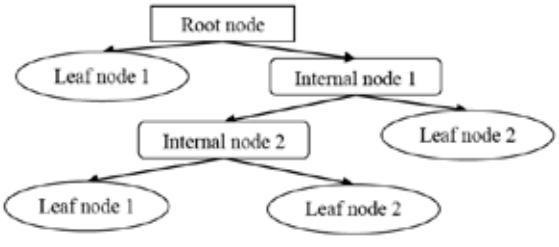

Figure 2. Typical decision tree structure.

The arcs from one node to another node denote the conditions on the features. The leaf node represents the target variable. Train data are used to build the tree model. Then, the tree model is pruned to check for overfitting and noise. Finally, the optimized tree is used to classify the unlabeled test data.

METHODOLOGY

The process flow chart for this research is shown in Figure 3. The vibration signals data are obtained from the Bearing Data Center supported by Case Western Reserve University [25]. This database is widely used by researchers [5, 26-28] especially for testing new diagnostic algorithms with a recognised benchmark study [11].

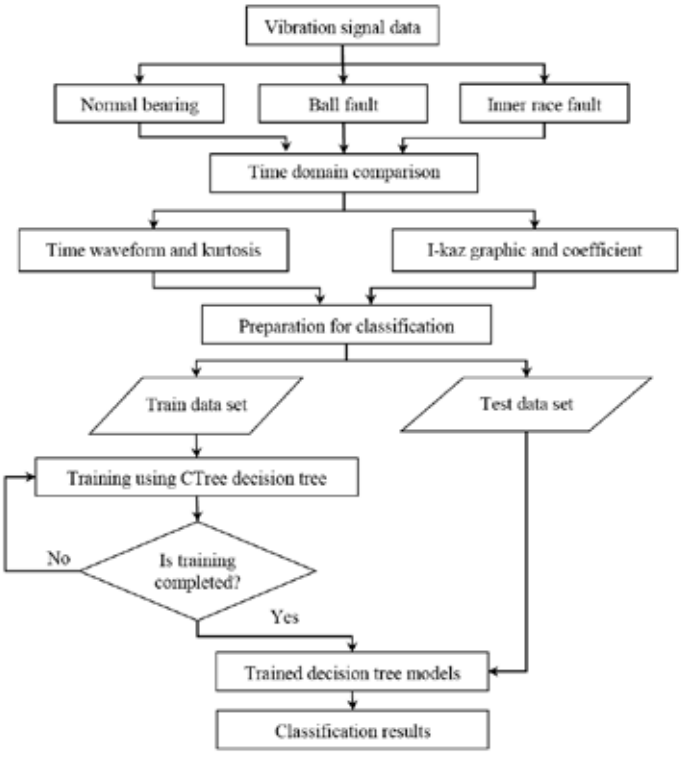

Figure 3. Proposed research process flowchart.

EXPERIMENTAL SETUP

As shown in Figure 4, the test rig for this experiment consists of a 2 HP Reliance induction motor coupled with a torque transducer to measure the torque value which have been applied by a dynamometer via an electronic control system. The test bearings used are the 6205-2RS JEM SKF deep groove ball bearings with the dimension displayed in Table 1. All faulty bearings are artificially damaged using electrodischarge machining (EDM).

Table 1. Test bearing dimension.

Inside Diameter	Outside Diameter	Pitch Diameter	Thickness	Ball Diameter
25 mm	52 mm	39 mm	15 mm	7.94 mm

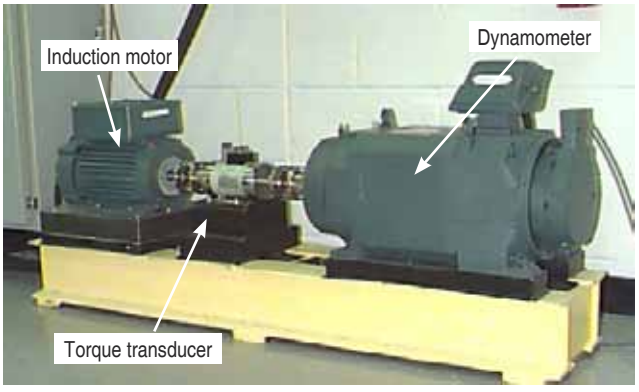

Figure 4. Experimental test rig setup.

Vibration data are collected using accelerometers with a bandwidth up to 5000 Hz and a 1 V/g accuracy, which are attached with magnetic bases at the 12 o'clock position at the drive end of the motor housing, as Figure 5 shows. A 16 channel DAT recorder is used to record the data. The data are post-processed in the computer using MATLAB software. The experiment has been carried out with a very small fault diameter of 0.1778 mm at 48 kHz sampling rate and various torques (0, 1, 2 and 3 HP). Basically, small fault size is indicated an early fault stage. Data acquired from the maximum torque (3 HP) are selected for the time-domain analysis. Raw vibration signals data are segregated by 0.5 second segment and features are extracted from each segment with the total of 5 seconds data length.

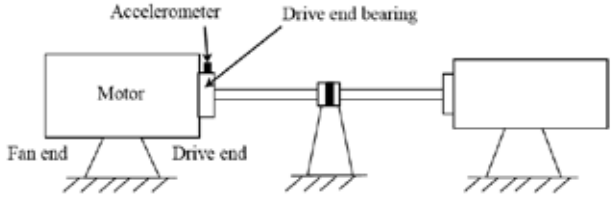

Figure 5. Schematic diagram of experimental setup.

Time waveform together with classical statistical parameters from the first segment are compared between all bearing conditions. The process is repeated with the use of I-kaz graphic and coefficient. Then, the average values of all features are calculated and the percentage differences between faulty and normal bearings are compared. The I-kaz coefficient is derived from the kurtosis and standard deviation from three frequency ranges, as stated in equation (2).

$$Z^{\infty} = \frac{1}{N}\sqrt{Kur_{LF} \cdot s_{LF}{}^{4} + Kur_{HF} \cdot s_{HF}{}^{4} + Kur_{VF} \cdot s_{VF}{}^{4}}, \quad (2)$$

where N is sample size; Kur_{E} , Kur_{H} and Kur_{F} are kurtosis; and s_{E} , s_{H} and s_{F} are standard deviation for low, high and very high-frequency range, respectively. All frequency ranges are filtered using Butterworth notch filter which the low-frequency range (LF) is derived from the lowpass of 6 kHz cutoff frequency, the high-frequency range (HF) is from the bandpass of 6 kHz to 12 kHz and the very high-frequency range (VF) is from the highpass of 12 kHz and above.

Decision Tree Classification

The proposed bearing fault diagnosis using decision tree classification is started with features extraction, i.e: kurtosis and I-kaz coefficient from all torque values, divided at 0.05 seconds segment intervals. The total of 1200 data are segregated for training and testing set at 70:30 proportion. The decision tree classification is processed using R software [29] with 'caret' package [30]. Training data set of both features is classified with CTree algorithm [23] in a separate model using the same control settings as showed in Table 2. Then, all trained models are validated with the testing data set and their accuracies and Kappa values are compared. Accuracy and Kappa are obtained using equation (3) and (4) respectively.

Table 2. Decision tree training control settings.

Description	Value
Method	Cross validation
Fold Number	10
Tune Length	10
Class Probabilities	True

$$Accuracy = \frac{T}{N} \times 100\% \quad (3)$$

where T is is the number of sample cases correctly classified and N is the total number of sample cases.

$$Kappa = \frac{p_o - p_e}{1 - p_e} \quad (4)$$

where p_o is the predicted value and p_o is the actual value of classified sample cases.

RESULTS AND DISCUSSION

Time-Domain Comparison

Time waveform with kurtosis value for normal and faulty bearings are shown in Figure 6. Clear differences between the shapes of the waveform for inner race fault compared to normal bearing are observed in the figure. The time waveform of inner race faulty bearings showed a unique repetitive signal pattern, repeated at a constant interval with high amplitude values, matched with typical pattern reported by Randall & Antoni [31]. However, ball fault time waveform was similar to normal bearing made this fault type difficult to be detected. The kurtosis for the normal bearing is closed to 3, complied with the Gaussian distribution. Kurtosis value for the inner race faulty bearing is slightly higher than 3 but the ball faulty bearing is remained closed to 3. Therefore, time waveform and kurtosis method are not suitable for the detection of ball fault.

The results for I-kaz analysis is displayed in Figure 7. I-kaz graphic for the inner race fault is clear enough to be distinguished from the normal bearing compared to the ball fault. The scatter plot for the inner race fault is bigger than the normal and ball fault because the data were distributed far off from the mean value. A higher value of I-kaz coefficient for this fault type corroborated the bigger scatteration of its plots. The inner race fault data for the low-frequency range have highest amplitude among two other ranges. Therefore, big scatteration is observed and I-kaz coefficient also higher.

Comparison of the percentage difference between fault and normal bearing are tabulated in Table 3 with the kurtosis and I-kaz coefficient average value of 10 samples of 0.5 second segments. The comparison showed that I-kaz coefficient was significantly higher than kurtosis for both fault types with 515% and 19693% difference for ball fault and inner race fault respectively compared to kurtosis which only 4% and 25% difference. Higher percentage differences for I-kaz coefficient caused by high value of kurtosis and standard deviation especially in the low frequency range for inner race fault.

Table 3. Comparison of percentage differences of between faulty and normal bearings.

Features	Normal bearing (baseline value)	Ball fault		Inner race fault	
		Value	% diff.	Value	% diff.
I-kaz coeff. (×10-7)	2.342	14.402	515%	463.643	19693%
Kurtosis	2.942	3.055	4%	3.666	25%

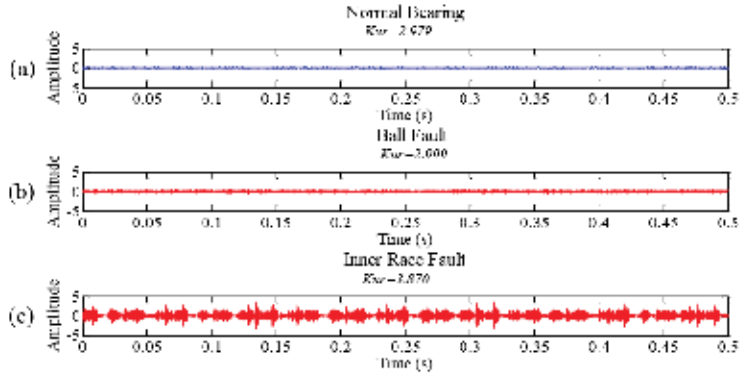

Figure 6. Time waveform with features for the (a) normal and (b),(c) faulty bearings.

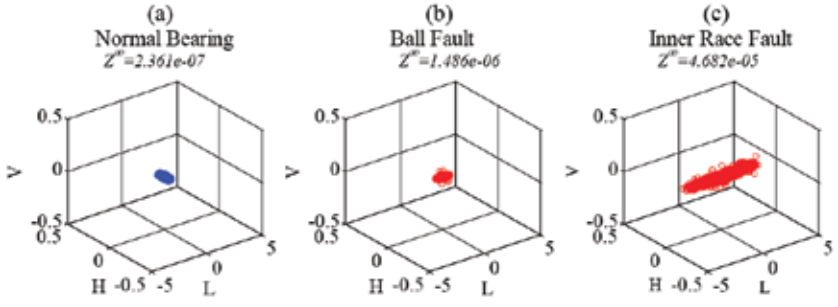

Figure 7. I-kaz graphic and coefficient, Z^* for the (a) normal and (b),(c) faulty bearings.

Decision Tree Classification

The trained decision tree model for I-kaz coefficient and kurtosis are shown in Figure 8 and the detail of classification result is tabulated in Table 4. The I-kaz coefficient trained model is perfectly distributed from the root node to Node 2 and then branched to an internal node before split to leaf nodes 4 and 5. Node 2, 4 and 5 are classified as normal bearing, ball fault and inner race fault respectively. The training accuracy for this model is 99.64% and the Kappa coefficient is 0.9946.

The trained decision tree model for kurtosis generated 9 nodes which contained three internal nodes before split to five leaf nodes that contained a combination of all bearing conditions. Leaf nodes 4, 5, 6, 8 and 9 contained a total number of 141, 309, 168, 108 and 114 classified targets respectively. The first three leaf nodes is a mixture of all bearing conditions whereas the others are represented only faulty bearings. The training accuracy for this decision tree model is significantly lower than I-kaz coefficient which is 63.57% and the Kappa coefficient is only 0.536.

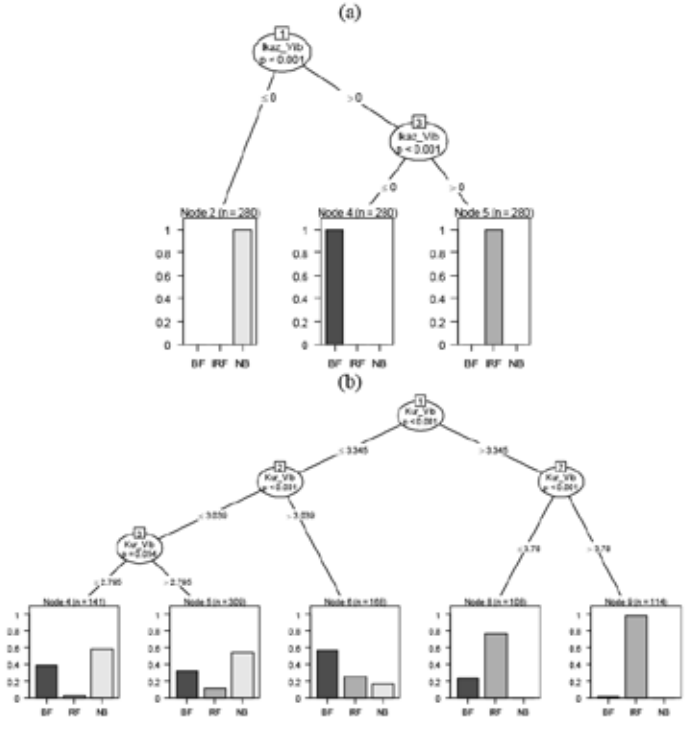

Figure 8. (a) I-kaz coefficient and (b) kurtosis trained decision tree model.

Table 4. Comparison of decision tree classification training and testing results using I-kaz coefficient and kurtosis.

Feature	Node size	Training		Testing	
		Accuracy	Kappa	Accuracy	Kappa
I-kaz coeff.	5	99.64%	0.9946	100%	1
Kurtosis	9	63.57%	0.4536	65%	0.475

Significant results are observed in I-kaz coefficient testing classification which the accuracy is 100% and the Kappa coefficient is 1 whereas kurtosis accuracy is only 65% and the Kappa coefficient is 0.475. High increment in testing accuracy is possibly caused by the usage of same data for training and testing set [28]. The decision tree classification using I-kaz coefficient was able to detect the ball faults which are not diagnosable with any of the applied methods by the benchmark study [11].

CONCLUSIONS

In this paper, we demonstrate the usage of kurtosis and I-kaz™ method for quick detection of bearing faults using raw vibration signal data. In time-domain, both time waveform and I-kaz graphic displayed clear identification to distinguish the inner race faulty bearing from normal bearing, and also the I-kaz and kurtosis value with high percentage differences from normal bearing. However, the ball faulty bearing cannot be detected in both plots by visual comparison. Although I-kaz graphic is inadequate to separate between ball fault and normal bearing, the I-kaz coefficient provided a significant percentage difference of 515% compared to kurtosis, which is only 4%. The results for decision tree classification show that I-kaz coefficient is significantly better with higher training accuracy and Kappa coefficient, which are 99.64% and 0.9946 respectively compared to kurtosis which are only 63.57% and 0.4536. Furthermore, all test data are classified accordingly when using I-kaz coefficient with 100% accuracy and 1 Kappa value whereas only 65% is correctly classified with 0.475 Kappa value for the kurtosis test data. It has been proven that I-kaz analysis is suitable for the diagnostic of bearing faults when using vibration time signals and also can be applied as classification feature. This method also performed better than the benchmark study which cannot detect the ball fault using any of the applied methods.

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NOMENCLATURE

caret	Classification and regression training
CART	Classification and regression tree
CHAID	Chi-squared automatic interaction detector
Coeff.	Coefficient
CTree	Conditional inference tree
DAT	Digital audio tape
Diff.	Difference
EDM	Electro-discharge machining HF High-frequency range
HP	Horsepower
ID3	Iterative dichotomized tree
I-kaz	Integrated kurtosis-based algorithm for Z filter
Kur	Kurtosis
LF	Low-frequency range
RMS	Root mean square

VF Very high-frequency range

SYMBOLS

f_{max}	Half value of the data sampling rate
N	Data size
μ	Mean
s	Standard deviation
$Z^{¥}$	I-kaz coefficient

Comparison of Debris Flow Simulation Model with Field Event in Kuala Kubu Baru, Malaysia

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ABSTRACT

Debris flow is one of the most disastrous types of natural disaster in Malaysia. The two basic conditions for the initiation of debris flows are the presence of abundance loose debris and the high intensity of rainfall. The adversity due to debris flow is its capability of wiping out houses and roads and resulted in fatalities and intense damage to infrastructure. The accurate prediction of the factors related to the occurrence of debris flow such as run out distances, velocities and thickness of the alluvial deposits can substantially reduce damages, minimize or even prevent the consequences of the event. The application of numerical simulation models that describe the deposition of debris flow will become a useful tool in predicting the behavior of future debris flow and to provide parameters for the design of protective measures. Comprehensive studies of available records of past debris flow events including from the investigation/forensic reports, aerial photographs, geological maps, topographical surveys, newspaper cutting and other relevant sources have been carried out in order to describe the fundamental characteristics of debris flow event. Site visits were made to observe the particular debris flow sites in order to earmark route map which is mapping the debris flow terrain in the existing contour map. Site investigations was conducted by utilising mackintosh probe in order to determine the ground profile and hand auger was used to collect soil samples to be tested in order to analyse the coarse grain distribution. Kuala Kubu Baru debris flow event, which occurred on the 10th November 2003, had caused damage to the main road linking two districts and the road was closed for 15 days. Kuala Kubu Baru well-documented event was simulate using the simulation model software that is Kanako 2D (Ver.2.02). The results obtained from the numerical model were compared with the real event in order to evaluate their predictive capabilities. The results showed an accuracy of approximately 93% was obtained from the simulation model as compared to the real in-situ measurements. A successful simulation results would become a useful tool for predicting the behavior of future debris flow hazard of the same nature and characteristics.

Keywords*:* Debris flow, Numerical simulation model, coarse grain distribution.

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INTRODUCTION

Debris flows, which are common phenomena in mountainous regions, are capable of washing down houses, roads, and railways with sudden and fast moving mixtures of water, sediment and large boulders. The occurrences of such event could cause heavy economic losses and human casualties. The two basic conditions for the initiation of debris flows are the presence of abundance loose debris and the high intensity of rainfall (Yu, 2011). The incident is a life-threatening landslide disaster that could kill many lives compared to other landslide types. Subsequently, a number of calamitous debris flows have been reported in Malaysia.

In Malaysia scenario, debris flow incidents are only investigated and reported when human lives and/or infrastructures are impacted. According to (Komoo et al., 2012), there were at least 15 cases of killer debris flow tragedies since the year 1994 until at present and at least 137 people were killed. Currently, research on debris flows in Malaysia is still very limited to post-disaster investigation within the areas of debris flow where disasters occurred. The catastrophes eventually cause heavy economic loses and human casualties. The estimation of run out distances, velocities, flow depths and volumes of the alluvial deposits on fans plays a major role in assessing debris-flow hazards and subsequently be able to reduce damages, minimize or even prevent the consequences of the event. Velocities and flow depths are the factors that need to be evaluated for designing structural countermeasures. The travel distance, which is controlled by the gradient, and the volume of the debris are amongst the critical factors that determine the extent of damages (D'Agostino' et al., 2000). The assessment of the travelled distance of debris flow from the initiation of the deposits until their lowest point on an alluvial fan is of utmost importance for delineating the areas at risk due to debris flows (Armento et al., 2007).

Several mathematical one- and two-dimensional numerical models have been developed to describe deposition of debris flows. The application of these models requires detail field data, as each model has to be calibrated before it is being applied for predictive purposes and hazard map delineation. The application of numerical simulation models that describe the deposition of debris flow will become a useful tool in predicting the behavior of future debris flow (Rickenmann et al., 2005). However, most of the existing models have not been thoroughly tested with actual field cases. Lack of testing being carried out is because of the lack of input parameters such as topographical and hydrological (Bertolo and Bottino 2007). Accurate delineating of the channel and fan topography is important to achieve a good replication of the observed deposition pattern. The objective of the simulation model is to compare the calculated volumes of debris that were generated, transported and deposited with those estimated by the field investigations or with the records made at the time of the event. The results of the numerical simulations of debris flows carried out with the different models were compared to evaluate their predictive capabilities.

METHOD AND STUDY AREA

Debris flow occurred on 10th Nov 2003 during the Northeast Monsoon season. The disaster had caused damage to the main road linking two districts and the road was closed for 15 days. The stream along which the debris flow occurred has an average gradient of about 33° and flows within a narrow valley ranging from 1to 6m wide while the hill slope on both banks of the stream generally has gradients between 44° to 46°. The debris flow elevation, ranging from 670 to 550m, covers the length of approximately 200m. With catchment area of 0.2km^2, the total volume of the transported material has been estimated to be about 3,990m^3 comprising boulders in various sizes, mud and tree trunks. These materials were deposited on the road and had caused the road shoulder to collapse. The average size of boulder is 0.1m.

The weathering grade in the initiation area is V and VI. There were no exposed boulders in this area. The soil types found in this site are of Sandy Silt, Silty Sand and Sandy Silt. An average thickness of soil layers with the potential of failure is between 3.0 to 3.3 m, as determined by the Mackintosh Probe test with 100 blows. The maximum elevation is 667m a.s.l and total run out distant was measured to be as much as 195m from the point of initiation to the toe of deposits.

Based on the Peninsular Malaysia Map of Geology and Selangor Geological Map, this area is located within the Main Range Granite, i.e. part of the granite body which is grouped in the Mesozoic late Orogenic granite. The site is mainly underlain by granite of various weathering grades. Some parts of the area at the valley are covered mainly by colluviums and talus. The area has gone through an active period of faulting.

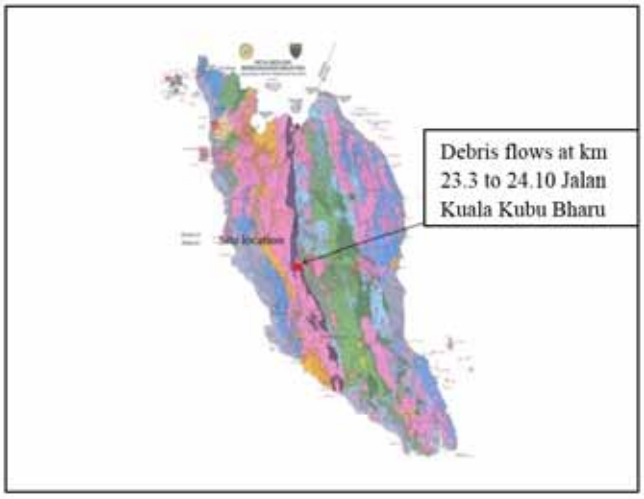

Figure 1: Debris flows at km 23.3 to 24.10 Jalan Kuala Kubu Bharu to Gap (FT 159)

Figure 2: View of the debris location at section 23.3, Jalan Kuala Kubu Bharu - Gap

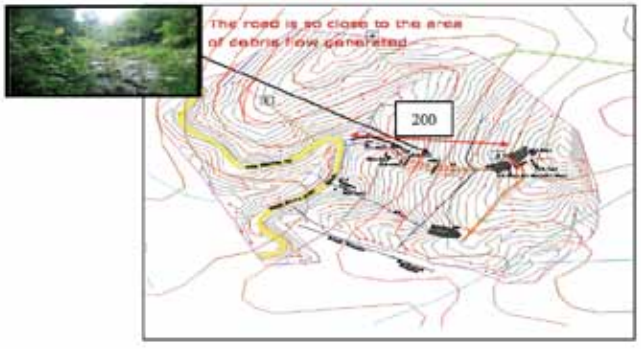

Figure 3: Site of debris flow at Kuala Kubu Baru

NUMERICAL SIMULATION MODEL

Kanako is the debris flow simulation system equipped with a graphical user interface (GUI) to make debris flow numerical simulation easier and more user-friendly when simulation is being carried out (Nakatani *et al*,2007, 2008). In order to simulate the Kuala Kubu Baru debris flow event, KANAKO 1D and KANAKO 2D have been used. KANAKO 1D is a one dimension model which considers only the direction of upstream and downstream of the river model, and reproduce flow and piling up process of the debris while KANAKO 2D is used for the alluvial fan area. In general, to perform simulation of debris flow occurrence, fundamental and preliminary investigations data are needed to prepare the input data. Simulations usually performed in two stages: (1) perform reproduction simulation to calibrate the input data such as hydrograph; (2) perform predictive simulation to assess the risk in case of rainfall with specific return period of interest. In some cases, a third step is required to check the effectiveness of counter measures such as sabo dams.

The basic 2-D debris flow equations are shown below. The same equations are applied in 1-D debris flow simulations without *y*-axis direction terms. Momentum equations, continuation equations, riverbed deformation equations, erosion/deposition equations, and riverbed shearing stress are based on [*Takahashi and Nakagawa,* 1991], and the staggered scheme and arrangement of variables are based on [*Takahashi and Kuang,* 1987].

The continuation equation for the total volume of debris flow is:

$$\frac{\partial h}{\partial t}+\frac{\partial \boldsymbol{h}}{\partial x}+\frac{\partial \boldsymbol{h}}{\partial y}=\dot{\boldsymbol{\varepsilon}} \quad (1)$$

Here, the average grain-size of all the sediment material including both larger and smaller grain-size groups. The phenomenon of *x*-axis direction (flow-direction) flow uses a momentum equation, as follows:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial H}{\partial x}-\frac{\tau_x}{\rho h} \quad (2)$$

Where $H = h + z$

The phenomenon of *y*-axis direction (cross-direction) flow uses a momentum equation, as follows:

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial H}{\partial x}-\frac{\tau_y}{\rho h} \quad (3)$$

The equation for determining change in bed surface elevation is as follows:

$$\frac{\partial z}{\partial t}+i=0 \quad (4)$$

For Eq.(1) through Eq.(4), h is flow depth, u is x-axis direction flow velocity, v is y-axis direction flow velocity, z is bed elevation, t is time, i is erosion/deposition velocity, g is gravity acceleration, ρ is interstitial fluid density, C. is sediment concentration by volume in movable bed layer, and τ_x and τ_y are the riverbed shearing stresses in the x-axis and y-axis directions.

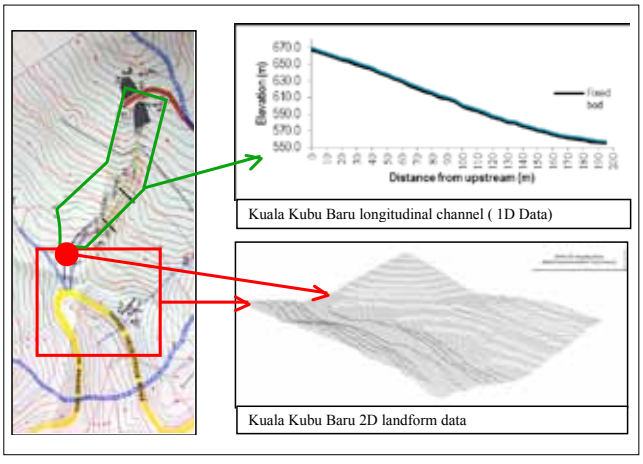

Figure 4: KANAKO 1D and KANAKO 2D input data

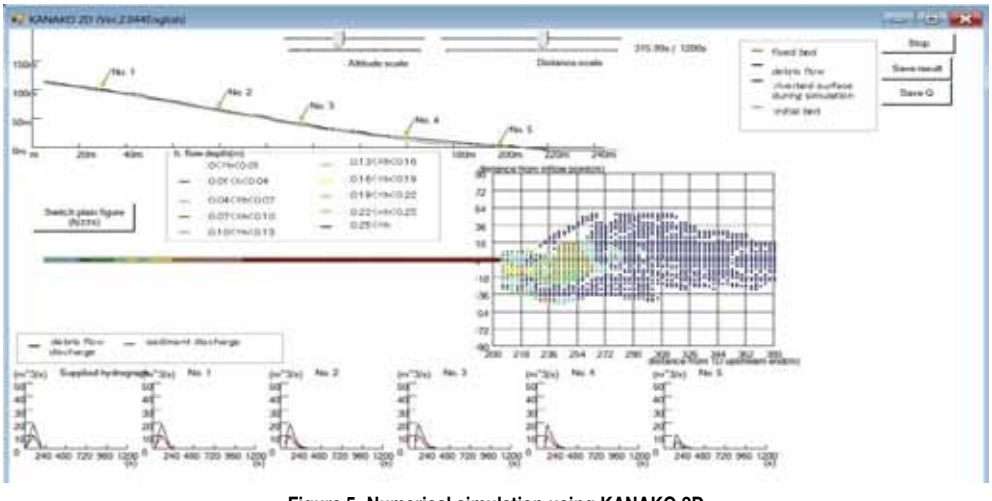

Figure 5: Numerical simulation using KANAKO 2D

DISCHARGE DATA

Sediment concentration is calculated by applying the Takahashi equation (T., Nakagawa, H., Satofuka, Y., Kawaike, K. 2001) as in Eq. (5) for the equilibrium concentration of debris flow.

$$C_d = \rho \tan\theta / (\sigma - \rho)(\tan\Phi - \tan\theta) \quad (5)$$

σ : Mass density of bed material (=2750 kg/m^3) , ρ : Mass density of fluid phase [water and mud, silt] (=1100 kg/m^3) , φ : Internal friction angle (=35^o) , θ : average gradient (=33^o), *Cd* : Concentration of debris flow (* 0.3 $\leq$ *Cd* $\leq$ 0.9*C*), * *C* : Concentration of moveable bed （=0.6）

From Eq. (1), then, the peak debris flow discharge was calculated from equation written in the manual of Sabo master plan for debris flow as in Eq. (6) and Eq. (7):

$$Q_{sp} = 0.01 \times \Sigma Q \quad (6)$$

$$\Sigma Q = C_* \times V_{dqp} / C_d \quad (7)$$

Q: Peak debris flow discharge (m^3/s), ΣQ: Total debris flow discharge (m^3), *Vdqp* :
Sediment volume (m^3)

The total calculated debris flow discharge was 1889 m^3 and the peak debris flow discharge was 18.89m^3/s. The total discharge volume of sediment resulting from the failure was 4270 m^3.

Table 1: Input Variables for KANAKO 1D and 2D

Parameters/ Variables	Value	Unit
Simulation continuance time	1200	sec
Time interval of calculation	0.01	sec
Number of grain sizes (KANAKO 1D)	2	
Number of grain sizes (KANAKO 2D)	1	
Average diameter	0.1	m
Mass density of bed material	2750	kg/m^3
Mass density of fluid phase	1100	kg/m^3
Concentration of moveable bed	0.6	
Internal friction angle	35	deg
Volumetric ratio of coarse particles in the bed	1.0	
Volumetric ratio of fine particles in the bed	0	
Gravity acceleration	9.8	m/s^2
Coefficient of erosion rate	0.0007	
Coefficient of deposition rate	0.05	
Minimum depth at the front of debris flow	0.05	m
Minimum flow depth	0.01	m
Manning's roughness coefficient	0.045	
Parameters used in 1D		
Number of calculation points in 1D	40	
Interval of calculation points in 1D	5	m
Parameters used in 2D		
Inflow center axis in 2D area[jc]	27	
Interval of 2D-x calculation points	3	m
Interval of 2D-y calculation points	3	m
Minimum depth at the front of debris flow in 2D	0.01	m
Number of calculation points in 2D-x direction	60	
Number of calculation points in 2D-y direction	60	

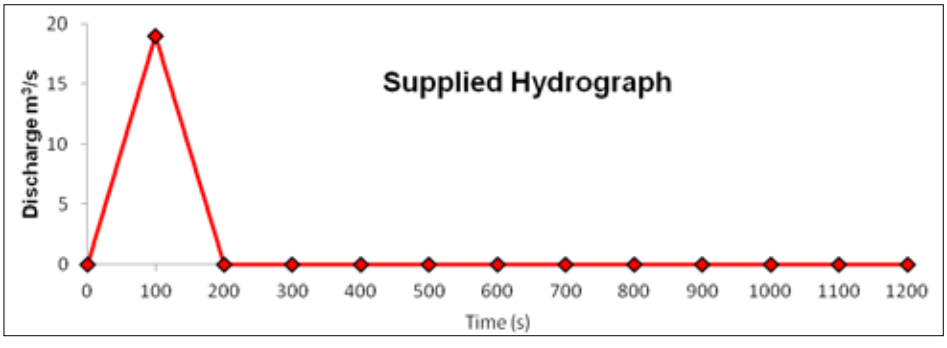

Figure 6: Supplied hydrograph for simulation

RESULT AND DISCUSSION

Simulations were performed with the hydrograph of debris discharge and input parameters shown in Table 1 in order to reproduce the amount of mobilized debris, the deposits at the channel, and the amount that flowed passed to alluvial fan area. Debris flow volume flowing through 1D channel into 2D region can be calculated as follows:

$$Q_{out} = Q_{in} + V_{bed} - D_{bed} \quad (8)$$

Where: Q_{out}: the total debris flow volume into the 2D region (m^3);

Q_{in}: supplied debris flow volume (m^3);

V_{bed}: debris flow volume of moveable bed (m^3);

D_{bed}: debris flow deposition volume in 1D area (m^3).

After putting the above parameters into formula (8), we can get:
Q_{out}:= 1,700 + 2,850 – 279.71 = **4,270.29m³**.

The result obtained from the simulation shows a reasonable value when the volumes estimated by the field investigation are compared to those obtained from the simulation. About 4,270m³ of total sediment discharge volume passed through the alluvial fan as obtained from the simulation while field data was estimated to be approximately 3,990m³. The accuracy of the result obtained from the simulation model is about 93% as compared to the real in-situ measurements. Conversely, there are slight differences in the volumes obtained. The differences may be due to the estimated geometry values that are being used during simulation.

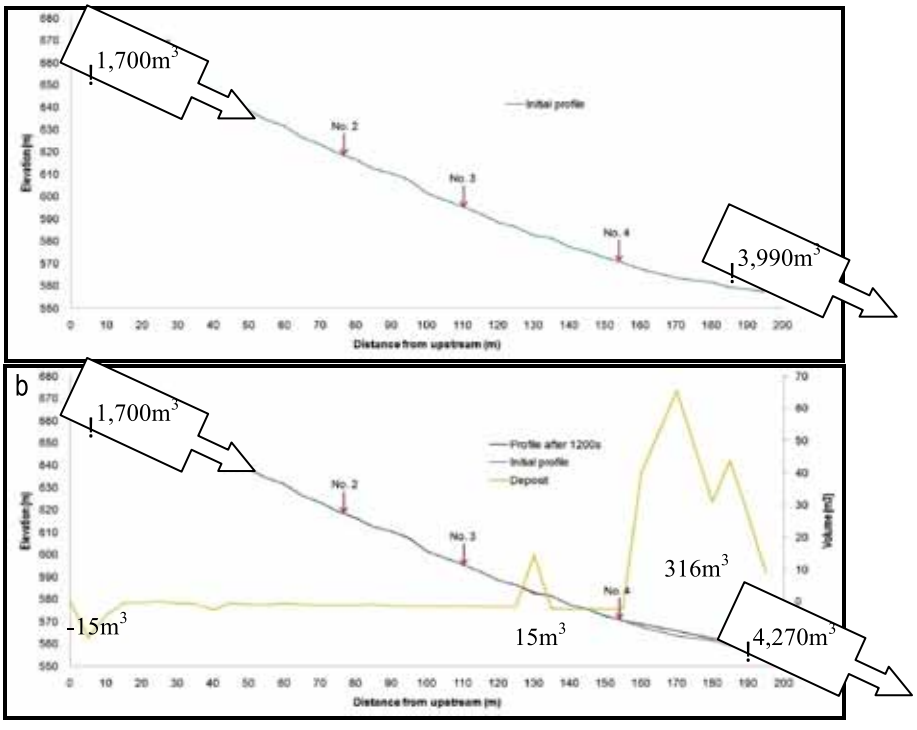

Figure 7: Inflow sediment volume and volume that passed to alluvial fan KANAKO) a. Volume from field data, b. Volume from simulation and condition of river bed after debris flow

From the simulation, the deposited tend to occurs when the gradient of profile moves from steep to gentle area. Volume of sediment at each calculation point can be obtained from the simulation which shows whether a deposition or erosion takes place in the channel during debris flow event. There are two points of major deposition when the slope gradient decreases which is at 582m accumulating about 15m^3 of sediment and 567-558m gathering about 316m^3 of sediment.

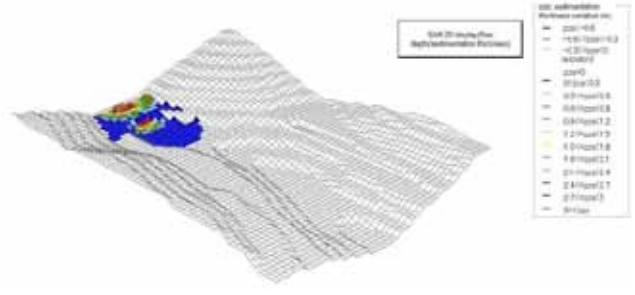

Figure 8: Variation of sediment thickness at alluvial fan area

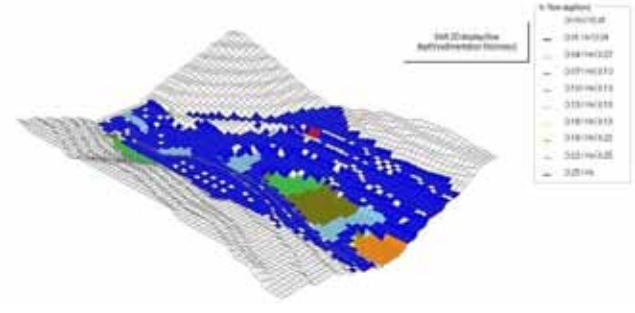

Figure 9: Flow depth at alluvial fan area

From the simulation, it shows that the debris floods occur in the whole area of the alluvial fan after running out from the channel outlet. The alluvial fan area is a narrow road and based on the simulation, at least a 0.04m flow depth and maximum flow depth of 0.25m after it passes the road. The maximum sediment thickness is more than 3m located at the entrance of alluvial fan. This indicate that during debris flow incident, road certainly impassable because have been filled with 3m thick of sediment.

CONCLUSION

KANAKO is a user friendly numerical simulation package with easy to understand manual and simple portrayal of Graphical User Interface (GUI). The software is developed based on theoretical principles of debris flow and supported by laboratory experiment and field data. It is suitable in analyzing the mechanism and potential behaviors having controlled by important factors such as channel gradient and hydrograph. In this study, simulation by KANAKO has been successful in showing the amount of sediment volumes and processes of deposition and erosion along the channel. KANAKO has also successfully showed the flow depth and sediment thickness in alluvial fan area.

Results obtained from the reproduction simulations have demonstrated a reasonable performance of the simulation model and provide a useful mechanism and outputs that will help in the assessment of the risks as well as in the planning and to provide preventive measures whether in the form of structural or non-structural measures. By comparing between the developed and present numerical models with real events, a reliable decision can be made in evaluating the most suitable and accurate model to determine the total discharge volume, run-out distance, flow depth and thickness of alluvial deposited.

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The Impact of BIM Training in Facilitating BIM Adoption in Malaysian Construction Industry

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ABSTRACT

The utilisation of Building Information Modeling (BIM) in Malaysia nowadays is gaining popularity throughout both public and private construction sector. The level of BIM awareness among Malaysian construction players has gradually increased by seminars, workshops and training organised by various agencies and organisations. The awareness of BIM benefits among construction players is important in helping them to improve the implementation of construction projects. Training is one of the factors that could expedite the adoption of BIM. BIM training is a significant aspect in BIM implementation and an essential topic to be explored as BIM awareness is rapidly expanding in construction industry. Training is essential for new and experienced professionals to improve their skills in using BIM technology. The aim of this paper is to examine the influence of BIM training on construction players in the Malaysian construction industry in order to support BIM adoption and future development of BIM. A survey (n=204) has been carried out to analyse the influence of BIM training on Malaysian construction players. Analysis of the responses of ninety professionals who had attended BIM training suggests that quality of training as measured by training reactions contributed positively to promoting BIM adoption. However, extent of training was not related to beliefs that should positively affect BIM adoption.

Keywords*:* Building Information Modelling (BIM), Malaysian Construction Industry, Training, Adoption, Technology Acceptance.

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INTRODUCTION

The Malaysian construction industry today faces great challenges to increase the productivity and to enhance the level of quality and environmental sustainability. Delay, cost overrun and low quality of product are the most common problems currently occur in the project implementation in Malaysia in line with the use of outdated technology (CIDB, 2009). The old technology of information system used for information exchange and sharing has given a major setback to project team due to ineffective management of documents which results in adverse consequences such as misunderstanding and miscommunication. Since information is an essential material in construction project, these effects could obstruct the productivity of projects (Zakaria et. al., 2013).

The resilience of construction sector to address these problems has encouraged the construction players to adopt information system innovation in project implementation. Indeed, the construction players has tended to accept the revolution of technology by investing and employing highly sophisticated information technology system in their organisation. Therefore, Building Information Modelling (BIM) is widely chosen and used as an electronic collaboration tool among design team and contractor for planning, designing, constructing and operating project facilities.

The HM Government (2012) has defined BIM as follows, "A collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets. BIM embeds key product and asset data and a 3-dimensional computer model that can be used for effective management of information throughout a project lifecycle – from earliest concept through to operation". Technically, as a technology, BIM constitutes the utilisation of computer-generated n-dimensional models to facilitate the construction processes of a facility (Lan et al., 2015). The facility models are presented in three- dimensional (3D) visualisation (Wang et al., 2015).

Fundamentally, BIM is an intelligent and parametric representation of project facilities that contains a lot of valuable data which is more advance than conventional method (Lan et al., 2015). It is implemented in order to increase the level of collaboration and improve communication among construction players in managing construction project life-cycle (Latiffi et al., 2015).

This paper seeks to examine the relationship between BIM training and BIM adoption in Malaysian construction industry and investigate the level of influence in BIM training on BIM adoption. An extended Technology Acceptance Model (TAM) for technology development training developed by Marler et al. (2006) is used to attain the aim of this study. The impacts of perceived ease of use, usefulness and employee resources to the wider adoption of BIM are analysed in order to eventually contribute to the improvement of BIM implementation in Malaysian construction industry.

BUILDING INFORMATION MODELLING (BIM) ADOPTION IN MALAYSIA

The BIM awareness in Malaysian construction industry has growth rapidly and the Malaysian construction players have started to utilising BIM in their project management especially the high profile construction projects. However, the utilisation of BIM technology by the construction players is not widely used and still at the early phase. In 2007, the initiative of BIM implementation in Malaysia was triggered by the Director of Public Works Department (PWD) (Latiffi et al., 2013). This idea was a consequence of the government's awareness of the BIM benefits to handle the construction project issues in design and construction phase and to control the project cost. The government took a step forward by forming a committee that was responsible to select the best BIM platform to be used. Furthermore, the roles of the committee also include identifying suitable projects as BIM's pilot projects and preparing BIM standard manual for the use of construction players as a guideline.

The pilot project of BIM implementation in Malaysia is the construction of Multipurpose Hall of Universiti Tun Hussein Onn Malaysia (UTHM). Another BIM's pilot project is the construction of National Cancer Institute of Malaysia and this project has just completed in 2015.

The Malaysia Government has introduced the Construction Industry Transformation Plan (CITP) in 2015 as a continuous plan of Construction Industry Master Plan (CIMP) to boost the physical infrastructure development towards a vibrant and robust construction industry. One of the four strategic thrusts highlighted in the CITP is productivity. BIM has been identified as a key feature in enhancing the construction's productivity and setting the new strategic direction of the construction industry. Particularly, BIM could be used as the most suitable tool to extol the benefit of IT for the purpose of attaining the aim. With the consistent action enhancement plans taken by the Malaysia government, it shows that the Malaysia government taking seriously in promoting BIM and stimulates the construction players to utilising BIM in their construction projects.

Although Malaysia government has initiated the use of BIM in construction projects, generally Malaysia is still struggling to adapt BIM process in project management that require 2D working environment converted to 3D working environment (Latiffi et al., 2013 and Zakaria et al., 2013). According to Hadzaman et al. (2015), the BIM maturity stage in Malaysia is still at the beginning stage as papers

and drawings are still treated as a key data exchange mechanism. However, the Malaysian construction players have made a positive progress where they have started to migrate from Level 0 to Level 1 in the BIM maturity stages.

THE IMPORTANCE OF TRAINING IN BIM

An appraisal of current and future human resources and technical needs is an essential element for an organisation during the BIM implementation in order to acknowledge the divergent organisation needs within the individual and group levels (Pena, 2011). Pena added the success of project implementation, indeed, heavily rely on the appraisal of available resources compared with other factors.

Basically, BIM training can be organised either in-house training or external training (Pena, 2011). Organisations with more BIM experience incline to organise in-house BIM training due to the organisations capability to provide BIM trainer or BIM manager who will conduct the training sessions. Green (2007) advocated that the organisations which have their own trainer and organise in-house training could give benefit to the organisation through assisting training customisation and reducing cost of training. Meanwhile, for companies that are new to BIM technology, they will allow their employees to participate in BIM training organised by external agencies, whether government or private agencies. In this situation, the organisations have to provide large budget in providing BIM training to their employees. Even so, the investment of providing training is worthwhile, since the training can help the employees to sharpen their skills in the use of BIM, as well as benefit the organisation in the project implementation.

It is held view that training could provide a number of advantages to individuals and organisations in enhancing the competence and performance. Arnold et al. (2010) advocated employee training is becoming a crucial aspect and need a special attention in an organisation at a strategic level. This also agreed by Palo and Padhi (2003) where training is an essential element in the practice of human resources that can help improve the ability of employees to work more effectively by increasing the employee's knowledge and skills. Training plays an important role in organisation's effectiveness (Goldstein and Ford, 2002) and is an extensive technique to improve the performance of employees, thus increasing productivity of company (Gupta et al., 2010). The implementation of training by an organisation could be a cost- effective investment if it parallel and match the needs and objectives of the business (Denby, 2010). In industrial and commercial view, Denby also advocated that training can aid develop the extent of available skills within the employees and simultaneously improve the existing skills, all with the aim of enhancing the effectiveness and efficiency of business. The importance of training and its influence on job performance also has been discussed by Cheng and Ho (2001). Cheng and Ho have stated employees are increasingly concerned about their own productivity and are aware of the lacking of knowledge and skills in their working environment due to the top management has made job performance as one of the vital measures. The effective training could align employees to grow their career and, hence, potentially boost their personal motivation in improving job performance.

In BIM perspective, Miodonski (2012) stated based on his interview with William J. Lynch, incoming president of Mechanical Contractors Association of America, each project team requires skill to use BIM. He added that if there are one or two team members who are not proficient in the use of BIM will give an adverse effect on the overall performance of the team. In another Miodonski's interview with Bill Gerke Jr., Senior Principal of GHT Limited, he mentioned that his company has taken huge undertaking on BIM training by applying three-week immersive-style training to his engineers. The engineer will instantly using BIM into real projects after the training is over.

THEORETICAL FRAMEWORK

Technology Acceptance Model (TAM) was initiated by Davis (1989) which originated from the reasoned action theory (Fishbein *et al.* 1975) and has been widely used as a predictive model to measure and assess the user behaviour in the technology acceptance, adoption and use (Davis *et al.*, 1989). TAM has been used to evaluate the user adoption of new technology in the construction industry (e.g. Son *et al.*, 2015). In BIM technology, many researchers interested to use TAM to predict the user acceptance and adoption of this technology. In this study, extended TAM for technology implementation training created by Marler *et al.* (2006) was utilised as a means for measuring the influence of training on behavioural intentions to use BIM. Marler *et al.* used this extended TAM for their research on technology implementation training to investigate the influence of training in facilitating employee technology acceptance in mandated organisation-wide information technology implementations. Originally, Mathieson *et al.* (2001) have proposed to add one more belief that is called perceived resources as an additional to ease of use and usefulness. The perceived of resources was defined by Mathieson and colleagues as the extent to which a person believes that he or she has the required personal and organisational resources in order to utilise a technology or an information system. Thus, the extended TAM related to technology training is particularly focus on the specified external variables of extent of training and training reaction that affect the intention of use the technology with influence of internal belief of ease of use, usefulness, employee resources (Marler *et al*, 2006) as shown in Figure 1:

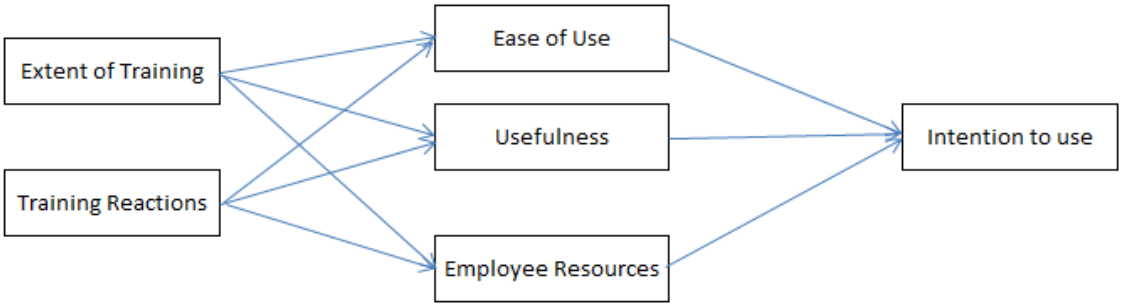

Figure 1: Technology acceptance model (Marler et al., 2006)

AIM AND OBJECTIVES

The overall aim of this research is to examine the influence of BIM training in Malaysian construction industry in order to support the BIM adoption. To achieve this aim, we have identified the type of BIM training organised by government agencies and explored the level of training participation among the Malaysian construction players. Our research objectives are:

1. To explore suitable and reliable measurement scales for individual beliefs about the participation of BIM training.
2. To evaluate the type, extent and satisfaction of employees who participate in BIM training.
3. To analyse the relationship between the BIM training and BIM adoption in Malaysian construction industry by using extended TAM.

The analysis in the current paper focuses on the 3rd objective.

METHODS

The research objectives were achieved using a questionnaire survey of Malaysian construction players. Seven hundred technical government agency employees were selected as the primary survey population consisting seven different professionals comprises project manager, architect, civil & structural engineer, mechanical engineer, electrical engineer, quantity surveyor and building surveyor. The questionnaire was produced and organised online via commercial survey website. The pilot test of the questionnaire was done on ten selected employees in different professions in construction sector to assessing the feasibility of a survey and testing adequacy of research instruments. The result from the pilot test showed that no major issues were detected.

The closed-ended question has been adopted and the structure of questionnaire was divided into three main parts consist of the awareness of BIM and the participation of BIM training – Part 1, the training and BIM adoption – Part 2 and personal information – Part 3. The first part of the questionnaire aimed to identify the level of BIM awareness and the participation in BIM training among the participants. The basis of BIM training participation is introduction and technical course organised by government agencies. The second part of the survey focused on respondents' reaction on the BIM training and attitudes towards BIM adoption. A 5-point likert-scale (1 means strongly disagree and 5 means strongly agree) was applied to investigate their level of agreement with 16 measurement items. These 16 items were categorised in five main groups (training reaction, ease of use, usefulness, employer resources and intention to use). In the latter part of the questionnaire, respondents were asked for demographic information such as professional background, current job title and work experience.

In total, 204 responses were received. Of these, 90 respondents had completed some combination of introductory or technical BIM training and were included in the analysis in this paper. Measurement scales for the variables in Figure 1 were constructed by totalling individual scale items. Extent of training was operationalised as number of days training consistent with the approach of Marler *et al.* (2006).

RESULTS

The analysis reported in this paper was undertaken by calculating correlations between scale scores. These are shown in Table 1 as follows:

- EOT: Extent Of Training
- TR: Training Reaction
- EOU: Ease Of Use
- U: Usefulness
- ER: Employee Resources
- ITU: Intention To Use

Statistically significant relationships are shown in bold text.

Table 1: Relationships between BIM training and BIM adoption variables

	EOT	TR	EOU	U	ER
EOT					
TR	.184				
EOU	.166	.681**			
U	.144	.576**	.663**		
ER	.293**	.490**	.493**	.595**	
ITU	.221*	.429**	.389**	.535**	**.474****

***. Correlation is significant at the 0.01 level (2-tailed).*

**. Correlation is significant at the 0.05 level (2-tailed).*

The variables in Table 1 are generally, but not completely, inter-correlated as would be predicted from the theoretical model in Figure 1. There are moderate to strong significant relationships between the TAM variables and moderate to weak relationships between TAM variables and Intention to Use. There is a clear difference in the pattern of the relationships between Training variables and TAM variables: Training Reaction shows moderate to strong correlations with TAM variables while Extent of Training shows only weak significant relationships or none.

DISCUSSION

Within the context of the model proposed in Figure 1, Extent of Training (EOT) does not predict perceptions of either Ease of Use or Usefulness. Further data and analysis would be necessary to inform the reasons for failing to find positive relationships.

For Usefulness, IS research has found that training can positively influence salient beliefs (Agarwal & Prasad, 1999) and is recommended to promote BIM adoption (Zakaria, et al. 2104). However, this was not found here. We might speculate that for this sample, the general benefits of BIM were already high and that EOT therefore had little opportunity to influence this perception. Alternatively, the benefits of BIM could have been covered early in any combination of courses and subsequent additional days did not contribute further. (Analysis of the relative Usefulness scores for those who have not attended training might shed some light on this interpretation). The lack of a relationship between perceived Ease of Use and EOT is also puzzling as one might expect that more training would increase the trainee's confidence in using BIM. For this sample, those with high scores (in days) for EOT had attended technical training courses which might have exposed trainees to the complexity and difficulty of BIM software of which those who had only attended introductory course remained unaware (Further categorical analysis could test this possibility).

In contrast to EOT, Training Reactions showed moderate to strong relationships with TAM variables. This implies that it is the positive response to training, rather than the skills acquired, that is beneficial for promoting BIM adoption. However, it is important to remember that TR and TAM variables were measured at the same time making these correlations prone to inflation due to common-method variance. Note that the relationships with the differently and 'objectively' measured EOT were much lower.

Although the model in Figure 1 suggests that the relationship between training variables and Intention to Use (ITU) are via the TAM variables this is reflected on significant relationships between ITU and TR (moderate) and EOT (weak). This pattern of correlations is similar to that between the training and TAM variables and the interpretations above are also applicable. It is worth reflecting on fundamental alternative interpretations of these relationships due to the cross-sectional nature of the research. While the significant relationships are consistent with the causal assumptions in Figure 1 it is not possible to rule out alternative causal paths. For example, a strong ITU might prompt someone to seek out and attend BIM training. Equally, relationships seen may be due to the measured variables both being related to an unmeasured third variable, e.g. an employee who has been assigned to a BIM project might score highly on both EOT and ITU without the training having had any actual effect on intention.

CONCLUSIONS

Although the ability to infer strong causal conclusions is limited in our data the differences in the pattern of relationships with TAM variables between extent and perceived quality of training is clear and merits further research.

Subject to the reservations expressed, it appears that increasing the amount of training may not in itself contribute to the intention to adopt beyond that provided by minimal training. Although it should be remembered that quality of training is important and that training serves other important business needs such as the acquisition of skills.

Although not possible to test with the available data the findings may point to a deficiency in the training courses that meant that beliefs about Ease of Use and Usefulness were no enhanced by the training sessions. If BIM training is to fulfil a role on BIM adoption, beyond its role as a knowledge delivery and learning mechanism, then attention would need to be paid to designing learning experiences to improve attitudes to BIM in both the content and the learning experiences.

Another contextual issue that the results point to is the complexity of the implementation context; specifically the degree of the process and business change work that has been done in advance of BIM training. Gaspar & Manzione (2015) found that BIM training effectiveness was affected by how well the training was aligned with updated and well integrated BIM design processes and argued that training in tool use has limited application. BIM implementation is theoretically and practically complex so it is maybe not surprising that so is the role and impact of training within it.

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Model BIM (Pandangan Perspektif 3D) - Dewan Serbaguna Piawai

Research on Skid Resistance Value, Texture Depth And Skid Number For Federal Roads In Malaysia

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ABSTRACT

The loss of skid resistance and decrease of texture depth are factors that reduced surface friction and hence causing slippery pavement surfaces. At present, references from the studies conducted by Transport and Road Research Laboratory (TRRL) and Permanent International Association of Road Congresses (PIARC) are being used as guides on the appropriate values for the above parameters. However, the suitability of these values for Malaysian roads are questionable. Hence the objective of this study is to conduct a statistical analysis on Skid Resistance Value (SRV) and Mean Texture Depth (MTD) obtained through Evidence-Based Research data collected by Road Safety Forensic Unit on Federal roads over the years since 2008. This study also attempted to determine the appropriate limiting values for SRV (microtexture), MTD (macrotexture) and SN (Skid Number) for the Federal roads. From the analysis, the results showed that the average value of SRV at locations where wet-surface accident occured is **46.65 ± 4.94 (41.71, 51.59).** While for MTD, the accident risk is higher when MTD value is below the average of **0.45 ± 0.03 (0.42, 0.48)**. For SN value, it can be concluded that accident risk increases significantly when the value is below the average value of **24.41 ± 3.99 (20.41, 28.40)**. This study recommended that the minimum SRV value for Malaysian Federal roads to be **47 SRV** and minimum value of SN to be **SN24.5.** To understand the relationship of SRV and MTD, Road Safety Forensic Unit has developed a graph known as "UF Skid-Texture Graph" that can assist in determining the level of accident risk due to skidding.

This paper was presented at the 14th Road Engineering Association of Asia & Australasia (REAAA) Conference 2013, 26 - 28 Mac 2013, Kuala Lumpur, Malaysia.

INTRODUCTION

Road accidents can be attributed by many factors. Generally, these factors are mainly human, vehicle and road environment factors. In almost every research done on these factors, it has been shown that over 90% of these accidents are due to human factor. However, accidents are seldom caused by a single factor alone but usually by two or more of these factors and this interaction is known as the Human - Environment – Vehicle System (Road Safety Manual, PIARC 2003).

On the aspect of road environment factor, there are many elements that can cause accidents or influence the outcome of the accident. Deficiencies on elements such as substandard curves, limited sight distances, intersections at curves, and poor intersection design are some of the issues normally found in road accident investigations. However, one of the common elements that raised the concern of the road authority is the level of pavement-tyre friction. Friction can be described as the resistance to motion between two surfaces in contact (Road Safety Manual, PIARC 2003). Poor skid resistance and decreasing texture depth reduce the level of friction and are generally causes of wet-surface accidents. Commonly, accident rate increases when the level of surface friction on the road decreases.

OBJECTIVE

The main objective of this study is to undertake statistical analysis on Skid Resistance Value (SRV) and Mean Texture Depth (MTD) data that have been collected since 2008 for the Federal roads. In addition, the study also aims to analyse the influence of SRV and MTD on the Skid Number (SN) which is being practiced by the Road Safety Forensic Unit, Malaysian Public Works Department (PWD). The current use of SRV 45 (TRRL 1969) and SN 25 (Page and Butas, 1986) as the basis for the limiting values in relation to the surface friction are also being evaluated for the Federal roads.

METHODOLOGY

Since 2008, the Road Safety Forensic Unit (RSFU) has conducted plentiful number of road accident investigations including a significant number that relates to wet-surface accidents. This study focuses specifically on wet-surface accidents given that the threshold value for the minimum surface friction occurs on wet pavement surfaces. This methodology, usually known as evidence-based research, analyses data collected for this specific accident type.

However, this evidence-based research conducted on the wet-surface accidents are limited to the use of static manual-based instrumentation. The instruments used are as follows:

- Sand Patch Test Method
- British Pendulum Tester (Portable Skid Resistance Tester)

Photos 1 and 2 show the tests carried out by the RSFU during road accident investigation.

Photo 1: Sand Patch Test to determine the Mean Texture Depth (MTD)

Photo 2: Portable Skid Resistance Tester to determine the Skid Resistance Value (SRV)

Statistical analysis is performed on the SRV and MTD data to determined the mean and standard deviation values respectively. Since vehicle speed has some influence over the level of surface friction, tests should be conducted for a range of speed. However, it is not possible to conduct friction test at various speed and, hence, the friction – speed relationship can be approximated based on the

properties of the microtexture and macrotexture of the pavement surfaces. Using indirect approach, the Skid Number (SN) method is used that takes into account the relationship between speed and friction (Leu and Henry, 1978).

Further analysis was conducted to improve the understanding of SRV, MTD and SN by developing relationship between these parameters using graphical approach. A graph known as "UF Skid – Texture Graph" is created for this purpose.

RESULT AND ANALYSIS

Data collection is an important process in this study. The data collected will be useful for future references on the study of pavement surface condition over time. **Table 1** shows the statistical analysis of data collected through the investigation on 24 locations of wet surface accidents.

Table 1: Summary of the statistical analysis on wet surface accident data

	Skid Resistance Value	Mean Texture Depth	Skid Number SN
Arithmetic mean	46.65	0.45	24.41
Variant	24.45	0.0008	15.95
Standard Deviation	4.94	0.03	3.99

Based on the analysis, it can be concluded that the mean value of SRV and MTD are **46.65 ± 4.94 (41.71, 51.59) and 0.45 ± 0.03 (0.42, 0.48)** respectively**.** By inserting these values in the Skid Number equation (Leu and Henry, 1978), the mean value for SN is equal to **24.41 ± 3.99 (20.41, 28.40).**

$$SN = SN_o \exp\left[-\frac{(PNG)\,V}{100}\right] \quad (1)$$

SN = Skid Number
SNo = Skid Number at the zero speed
= -31 + 1.38SRV
(SRV is the result of a British Pendulum Test)
PNG = Percent Normalized Gradient of the SN versus V curve
= 0.45 $(MTD)^{-0.47}$
(MTD is the mean texture depth measured during a sand patch test)
V = Slip Speed

Determination of the minimum threshold value for the SRV

In the absence of locally collected data, the minimum limiting value for SRV practiced by the RSFU is based on research conducted by TRRL on skid resistance in the United Kingdom (UK). A limiting value of 45 SRV (Based on Category C, TRRL 1969) is being adopted as a guide for the minimum skid resistance value for all roads.

Based on the results of the statistical analysis, the mean value of SRV is **46.65 ± 4.94 (41.71, 51.59).** It turns out that this finding is acceptable and consistent with the study conducted by Giles et al. (1962) on the relationship between accident and skid resistance at 120 locations. They found that the risk of accident increases drastically when the skid resistance is lower than 50 SRV. Hence, it is proposed that the minimum value of SRV for safe riding condition on Malaysian roads is **47 SRV.**

Determination Of The Minimum Threshold Value For The Sn

Page and Butas (1986) claimed that the accident rate is high when the skid number less than **25.** The SN value computed from this analysis is also consistent with the above statement where the mean value of SN is **24.41 ± 3.99 (20.41, 28.40).** Thus, it is proposed that the SN value of **24.5** to be used as a minimum threshold value**.**

UF Skid - Texture for wet surface accidents

To understand the relationship of SRV and MTD on the level of accident risk due to skidding, a graph known as "UF Skid-Texture Graph" is developed based on the analysis above. The purpose of this graph is to assist accident investigator in predicting the risk of wet surface accident on pavement surfaces.

The graph consisted of three curves that signifies the array of parametric values for the accident risk ranging from "Good Friction Against Skidding" up to "High Accident Risk Due to Skidding".

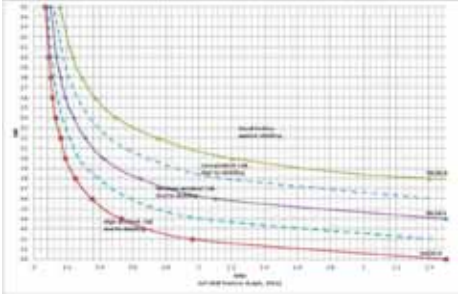

Figure 1: UF Skid – Texture Graph for the assessment of the risk of accidents wet surface (after the Road Safety Forensic Unit, 2011)

From this study comparison can be made on the standard design parameters and the limiting threshold values in relation to the pavement surface. Comparison between the minimum radius used by *Arahan Teknik Jalan* (ATJ) Guidelines and that calculated based on the threshold values showed that the design values used by ATJ are more conservative (see figure 4).

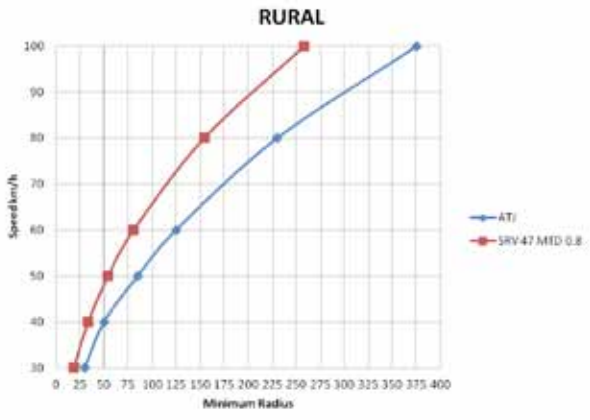

Figure 2: Comparison of ATJ minimum radius with a minimum radius of friction coefficient should be modified to use the SRV47 and MTD 0.8 (μ = 0.245)

CONCLUSION

The results of this analysis on the entire data relating to wet surface accident are as follows:

a) Minimum threshold value of SRV is **46.82 ± 4.94 (41.88, 51.77).**
b) Minimum threshold value of MTD is **0.45 ± 0.03 (0.42, 0.48).**
c) Risk of accidents is higher when the SN value less than **24.41 ± 3.99 (20.41, 28.40).**

This study recommended that the minimum SRV value for Malaysian Federal roads to be **47 SRV,** minimum value of MTD to be **0.50mm** and minimum value of SN to be **SN24.5.** Relationship of SRV and MTD on risk of accident due to skidding is graphically plotted as "UF Skid-Texture Graph". This graph can be used in predicting the risk of wet surface accident on pavement surfaces.

The findings of this study also showed that design values used by ATJ are more conservative compared to the values calculated based on minimum threshold parameters.

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Fireproof Concrete in Tunnel Lining Structure

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ABSTRACT

Tunnels, especially road tunnels are the most expensive investment parts of highways. During fire, the temperature in tunnels rises extremely rapid in a short time which results in explosive concrete spalling of the tunnel lining. The structure could be damaged seriously and become unstable. One passive system that needs to be incorporated into the design to ensure optimum life safety system is fire-proof concrete. Fireproof concrete can avoid explosive concrete spalling of the tunnel lining during a fire. In this paper, details on previous researches conducted on the fire performance of concrete tunnel lining structure are reviewed. Recent developments in sustainable fireproof concrete as tunnel lining structure and the challenges are highlighted.

Keywords*:* Fire test; fireproof concrete; tunnel linings

This paper was presented at the 9th Asia Pacific Structural Engineering and Construction Conference and 8th ASEAN Civil Engineering Conference (APSEC-ACEC 2015), 3 – 5 November 2015, Kuala Lumpur, Malaysia.

INTRODUCTION

Following major tunnel fires worldwide, the need for effective protection for tunnel lining structure has become a matter of priority for both new and existing tunnels. Structural fire protection aims to retain load-carrying capacity and serviceability during and subsequent to a fire. For this purpose, it is of particular importance to prevent extensive concrete spalling and protect the main reinforcement from being exposed to high temperatures that would result in irreversible strain. In the event of fire, the temperature in a tunnel rises extremely rapid within a short amount of time. Large scale fire test have shown that maximum temperatures of 1200°C or even more could occur [1], [2]. The predominant material in segmental linings is concrete that uses Ordinary Portland Cement (OPC) as a binder, and is reinforced either with steel or steel fibres. Currently, the materials used in actual tunnel construction are reinforced concrete (RC), fibre reinforced concrete (FRC) [3], macro synthetic fibres concrete (MSFRC) [4], polypropylene (PP) fibre concrete [4] (see Fig. 1); and steel fibre reinforced concrete (SFRC) [4], [5] (see Fig. 2) while the new technology of material under development including fibre reinforced geopolymer concrete (FRGC) [6] and high-volume fly ash nano silica concrete [7]. This paper is divided into three sections: (i) previous research of fireproof concrete; (ii) recent developments; and (iii) challenges.

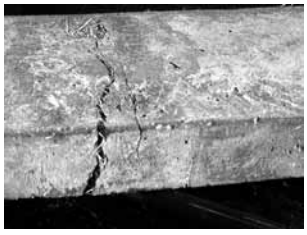

Fig. 1. PP fibre concrete [4]

Fig. 2. SFRC [4], [5]

Previous research of fireproof concrete

The previous research of fireproof concrete can be categorized into two types: (i) fire test on actual specimens; and (ii) fire test on laboratory specimens as exhibit in Table 1.

Table 1: Previous research on fireproof concrete

Type of tests	Material components	Samples	Temperature	Results	Researchers
i) Fire resistance test on actual specimen	FRC without reinforcement and ordinary concrete	Segmental lining used at Brenner Base Tunnel, between Italy and Austria	Not mentioned	Fibre reinforcement increases the fire protection performance of the material by limiting the spalling effect to the concrete	Moccichino et al. [3]
	SFRC and PP microfiber.	Segmental linings used at Channel Tunnel Rail link between Paris and London.	Not mentioned	Metallic fibres improve over reinforced concrete causes rapid bursting of the exposed concrete. Splintering is limited compared to reinforced concrete. PP microfibers reduces the risk of splintering.	Rivaz [8]
	SFRC and PP fibre	Tunnel lining structure used at Lee Tunnel and Heathrow Tunnel in UK	Not mentioned	PP fibre proved to mitigate against spalling in case of fire	Foley [5]
	Fly ash (FA) and ground granulated blast furnace slag (GGBS)	Segments lining used at Shanghai Metro, China	1100°C, standard cellulosic fire curve	Severe concrete explosive spalling and property deterioration at high temperatures	Yan et al. [9]
	Thinner steel-concrete composite segment linings	Segments lining used at Fushimi Tunnel, Japan	1200°C, RABT ZTV fire curve	Spalling of concrete reaches up to 60 mm. Compressive strength drops to one half of the unheated value and Young's modulus to one quarter by the heating.	Yasuda [10]

Type of tests	Material components	Samples	Temperature	Results	Researchers
ii) Fire resistance test on laboratory specimen	Synthetic fibres and special aggregates	Small scale and large scale specimens	1200°C, RABT ZTV fire curve	No spalling occurred on the side that was exposed to fire. Even the surface of the concrete structure revealed a very good level of consistency.	Dorgarten et al. [11]
	SFRC and PP fibres	Small scale specimens	1300°C, Hydrocarbon modified fire curve	Irreversible loss of stiffness which is referred to as thermal damage (or softening) and thermal decohesion. Exposive spalling of concrete.	Maraveas et al. [12]
	RC, SFRC and low calcium ash	Small scale specimens	1100°C, Hydrocarbon fire curve	Significant non-uniform thermal expansion and material property degradation	Yan et al. [13]
	RC, SFRC, and PP fibre concrete	Small scale specimens	1100°C, Hydrocarbon fire curve	Mechanical properties deteriorate significantly, decrease of load-bearing capacity and significant increase of displacement of segments and joints	Yan and Zhu [14]
	Microfibre reinforced and PP monofilament microfibres	Small scale specimens based on EFNARC guideline	1100°C, Hydrocarbon fire curve	PP monofilament microfibers counteract explosive spalling in cast concrete and in shotcrete.	Ken Smith and Trevor Atkinson [15]

In a fire resistance test to actual tunnel specimen used in construction, Moccichino et al. [3] conducted a test on full scale specimens of FRC used in the tunnel segment of Brenner Base Tunnel, between Italy and Austria and conclude that the fibre reinforcement is increases the fire protection performance of the material by limiting the spalling effect to the concrete. In a journal article by Foley [5], SFRC incorporate with PP fibres used for the construction of Lee Tunnel and Heathrow Terminal 5 Tunnel in UK has been proved to mitigate against spalling in case of fire.

Yan et al. [9] conducted a full-scale experimental test results of actual segments lining used at Shanghai Metro, China that are exposed to a standard ISO834 curve heating durations. These member segments are 1200 mm in width, 350mmin thickness, and their outer and inner diameters are 6200 mm and 5500 mm, respectively. The material used for the concrete is the combination of OPC, FA, and GGBS as shown in Fig. 3. The purpose of this work is to investigate fire damage to the actual RC metro shield TBM tunnel linings and to develop a feasible method to improve the fire safety of existing metro shield TBM tunnel linings. The experimental test results indicate that severe concrete explosive spalling as well as property deterioration occurs under high temperatures. The maximum explosive spalling depth and spalling area vary within a range of 26–51 mm and 13.1–55.7%, respectively, depending on the heating duration, water content of the concrete and load state.

A research by Yasuda [10] involving a fire test based on RABT ZTV fire curve on thinner steel-concrete composite segment with various fire protection measures. These segments are identical to the segment to be used for the Fushimi Tunnel in Japan. Each segment is 2.5 m long, 1.5 m wide and 0.25 m thick. Through the fire test, spalling of concrete occurs and it reaches up to 60 mm if there is no fire protection on the surface. Compressive strength of the concrete drops to one half of the unheated value and Young's modulus to one quarter by the heating. Carbonation of concrete occurs by portlandite resolution at the place where the temperature becomes over 500°C.

In a fire resistance test to laboratory specimen used in tunnel construction, Dorgarten et al. [11] conducted the fire resistant test based on RABT ZTV fire curve on fireproof concrete using synthetic fibres and special aggregates for tunnel constructions in underground works and in tunnelling (see Fig. 4). An evaluation of the test results obtained revealed that the synthetic fibre content has a significant impact on spalling behaviour. Maraveas et al. [12] study the effect of steel fibre incorporating with PP fibre concrete tunnel lining based on hydrocarbon modified fire curve. The PP fibres melt at about 160°C and thus create channels and micro-cracks in which the water can be transported without developing high pore pressures. Steel fibres, in combination with PP fibres, can limit the risk of propagating spalling by increasing the fracture energy of concrete whereas its residual mechanical properties show significant improvement.

Yan et al. [13] presents comprehensive experimental test results on the behaviour of the RC and SFRC shield tunnel lining segments and the lining rings exposed to a Hydrocarbon fire curve as exhibit in Fig. 5. The lining segments used are 300 mm in width and 120 mm in thickness with average radius is 990 mm. The material used for the concrete is the combination of OPC and low calcium ash. The experimental results indicate that the nonlinear non-uniform temperature distribution within the concrete linings causes significant

non-uniform thermal expansion and material property degradation. Minor spalling are found on the heating surface of the lining segments attributed to lower moisture, smaller size of the lining segments with low risk of explosive thermal spalling. Steel fibre of the SFRC lining segments still remains intact after exposure to high temperature, along with colour changes from a metallic colour to a darker colour.

Yan and Zhu [14] evaluate the fire safety of tunnel lining under and after fire scenarios based on Hydrocarbon fire curve. Three types of concretes that are RC, SFRC, and PP fibre concrete are employed in the experiments. The results indicate that mechanical properties of lining materials especially uniaxial compressive strength, elastic modulus and permeability deteriorate significantly after high temperature. Comparing with normal temperature condition, high temperature result in significant decrease of load-bearing capacity and significant increase of displacement of segments and joints. Because of material deterioration, thermal damage and thermal stress due to high temperature, the load-bearing capacity and reliability of tunnel lining system decrease heavily. Moreover, large displacement of lining system may affect the safety of surrounding substructure and surficial buildings. Smith and Atkinson [15] provide a comprehensive review of the factors to be considered in designing a fibre reinforced shotcrete and in-situ concrete for fire resistance to explosive spalling. The dosage of PP fibre used is between 1.0kg/m3 and 1.5k/m3. The key findings is similar to Dorgarten et al. [11] which the addition of suitable PP monofilament microfibres will counteract explosive spalling in cast concrete and in shotcrete (see Fig. 8).

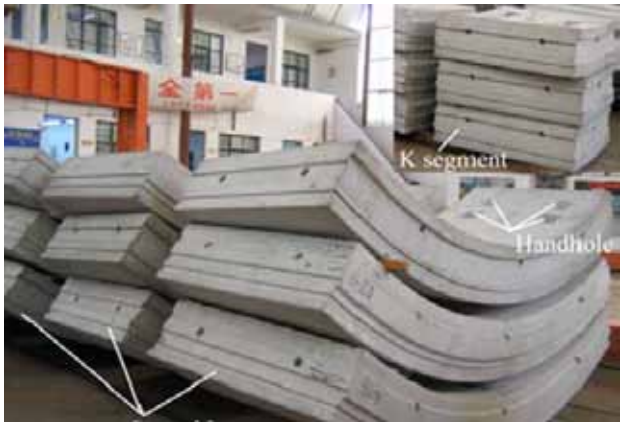

Fig. 3. Actual RC TBM segment [9]

Fig. 4. Test specimen [11]

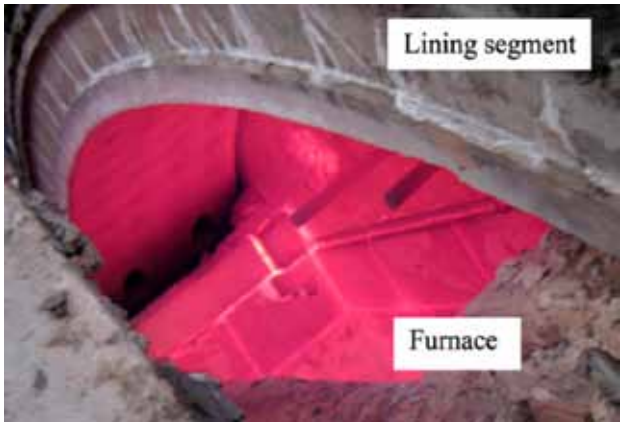

Fig. 5. The fire test of lining segment [13]

Fig. 8. PC and PP concrete after fire test [15]

RECENT DEVELOPMENTS

Currently, there are many research contribute to the use of HSC and HPC in order to contribute to the development of fireproof concrete that can be used as tunnel lining structure. Wimpenny and Chappell [6] have presented research into the use of fibre reinforced geopolymer concrete for tunnel segments that demonstrates that geopolymer can achieve equivalent or better structural, durability and fire performance than traditional OPC. In research by Rahel et al. [7], fireproof high-strength concrete can be produced by using high-volume FA with nano-silica. The result proved this material has a good fire resistance and indicated higher compressive strength after exposure to high temperatures. High-volume fly ash nano-silica concrete could control the carbon dioxide emission from the earth which is shown by using FA concrete products instead of all-cement concrete. The use of Supplementary Cementitious Material (SCMs) such as FA, GGBS, and silica fume as a partial replacement for OPC in tunnel structure can reduce the energy and CO_2 impacts of concrete.

CHALLENGES

In order to minimize the effect of explosive spalling during fire, many preventive measures being taken to make sure the tunnel structure is safe. The preventive measures are by installing the thermal barrier or panel, addition of the PP fibre to the concrete, proper choice of aggregate, controlling the moisture content, controlling the compressive strength, using the air entrain agent, using the suitable reinforcement, addition of steel fibre, and by choice of shape. In such cases, a cost and benefit analysis, informed by a quantitative risk assessment, may demonstrate a strong case for additional fire protection measures, including passive fire protection and/or fire suppression systems.

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Model BIM (Perspektif 3D) - Hospital Parit Buntar, Perak

The Performance of Slopes in Hilly Terrain with Respect to Drainage

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ABSTRACT

This paper presents the analysis of slope failures along the roads on hilly terrain. The analysis includes a review of the detailed investigation report of Slope Failure at Federal Road FT185 from Lojing to Gua Musang, Malaysia on May 2011 and a few of design reports of road projects. The investigation report found that one of the probable causes of the failure is broken pre-cast roadside drain. Basically, the pre-cast and in-situ concrete material to be used are as roadside drains and berm drains. Consequently, this could be easily caused splashing of water to the sides of the drain when heavy downpour. The analysis of the slope stability of hilly terrain with respect to drainage was computerized by Slope/W programs to investigate its geometry and commonly used the slices method. The slope geometries have been analysed in order to make the comparisons between safety factors (FOS) for many cases of different slope conditions. The FOS of analysed slope was identified by back analysing comprises four cases namely engineered slope at rest, with concrete drain on the top, with presence of water pressure through the cracked concrete drain and with remedial work of retaining wall. Such slope behaviour with respect to drainage system was illustrated clearly with effects of geometry diagram. Furthermore, the analysis in probability of hilly terrain instability phenomena are frequently responsible for considerable losses of both money and lives could be an advantage in order to recognize the root causes.

Keywords*:* Performance, hilly terrain, drainage, slope failure, geometry, safety factor

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INTRODUCTION

Natural slopes of hilly terrain are likely to degrade very slowly over time but may be triggered into more dramatic failure by a variety of natural and man-made processes. Man-made or engineered slopes including cut slope and slope formed by filled material with adequate compaction, usually provided with surface drainage or supported by retaining wall structures. Long-term engineered slope stability is also dependent on seepage forces and therefore, on the ultimate groundwater level in the slope. After excavation, the free-water surface will usually drop slowly to a stable zone at a variable depth below the new cut or fill surface. This drawdown usually occurs rapidly in slopes made in sand but is usually much slower in clay slopes.

Landslides pose chronic problems causing damages to hill roads and loss of precious human lives and property. Landslides are frequent and annually recurring phenomenon in the hills. The load of road causing the soil movement that consists re-grading or changing the geometry of the slope can be reduced by reducing the height of the slope, compacting slopes to a flatter angle, creating stepping slope and putting an additional load such as drain at the berm. This method has an immediate effect on improving stability of slope. The combination of the retaining wall at the toe to half part of slope and the guniting work on another half till the top of the slope are used to prevent the behaviour of slope movement.

The stability of slopes is generally assessed using limit equilibrium method where factor of safety is estimated as the ratio of the soil strength and driving stress acting along the potential failure surface. Safety factor (FOS) 1.25 to 1.4 is considered appropriate for natural slope and routine cut and fills, but for the design purpose also require higher safety factor such 1.5 to 2.0. The stability of a slope affected the changing in slope geometry by slope height and slope angle due to the facilities that installed on the ground and development at the crest. The steeper slope made in living area need to be concerned about the safety factor.

The presence of water also increases the weight of the soil and changes the angle of repose, thus lead to slope instability. Those modifications of a slope either by human or by natural causes can result in changing the slope angle so that it is no longer stable. Efforts to stabilize slopes basically by improving slope drainage system and supporting the base of the slope with retaining walls.

RESEARCH REVIEW

Surface drainage and protection is necessary to maintain the stability of the designed slopes through reduction of filtration and erosion caused by heavy rain especially during the rainy season. Runoff from both the slopes and the catchment area upslope should be cutoff, collect and lead to convenient points of discharge away from the slopes. When designing surface drainage on steep slopes, it is important to make sure the drains have sufficient capacity to carry the runoff. [1]

Drainage of a hilly urban area needs to be planned for future giving due emphasis to its expansion pattern. Toe cutting made in the process of unplanned expansion adversely affects the slope stability and the retaining wall constructed as remedial measures may in turn adversely affect the subsurface drainage if sufficient weep holes are not provided or if the permeability aspect of the retaining wall is not addressed properly. This increases the slope instability during rainy season. Similarly the exposition of land surface because of vertical and horizontal cutting aggravates the surface erosion process by many folds. Deposition of such eroded sediment inflicts serious problem in the drainage system in the area located downstream of it. [2]

Planning and achieving sustainable development in hilly areas is particularly important in regard to drainage, flash flood, erosion and sediment and slope stability management. Proper drainage is recognized as the most important element that reduces soil moisture content and the destabilizing hydrostatic and seepage forces on a slope, as well as the risk of surface erosion and piping. Poor site planning and design in a hillside development area causes large quantities of rainwater collected in the drainage system and from direct rainfall, to infiltrate into the ground. Design and construction of drainage system in hilly terrains are to be established with proper caution, failure of which may cause slope instability. [3]

SAFETY CONCERN

Most of the landslides occur due to exhaustive deforestation being undertaken for urbanization and plantation. In these areas, rainwater directly penetrates into the soil and causes landslides.

During the process of expanding towards the prime valley line many a time people encroach into the secondary transverse valley line blocking the natural waterways. Obstruction to natural drainage may affect the slope stability adversely with varying severity depending on the geology of the formation. Care should be taken to keep these natural secondary valley lines clear so that natural drainage is not obstructed. Irrespective of the expansion pattern, because of urbanization in the hilly area, imperviousness of the surface increases and thus leads to high runoff generation. Safe drainage of such high runoff to the ultimate outlet (river or water bodies in the form of lake) always remains a challenging task. Design discharge need to be calculated taking in to consideration the future possible development in the area. Discharge may increase with time primarily due to three factors:

i) increase in building density and paved area,
ii) increase in rainfall intensity because of impact climate change, and
iii) increase of per capita water utilization because of improved life style and better water supply.

Considering these factors, it is advisable to go for an appropriate design of the drainage system, so that system remains sufficient to meet the increasing future demand at least for the next 50 years. [2]

METHODOLOGY

Desk study includes reviewing of the detailed investigation report of Slope Failure at Federal Road FT185 from Lojing to Gua Musang, Malaysia on May 2011 and a few of design reports of road projects. Two locations have been studied about the slope geometry characteristics due to drainage system. The safety factor to be analysed using Slope/W program with method of Morgenstern-Price which led to mathematically more rigorous formulations include all interslice forces and satisfy all equations of statics. This method will give a lower factor of safety than other methods. The cases of study are divided into four different conditions comprises of A, B, C and D as described in Figure 1.

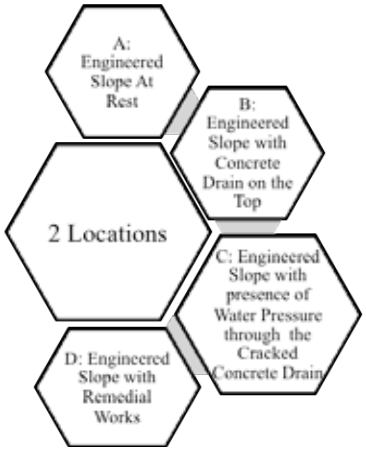

Figure 1: The cases of the slopes to be analysed.

Case Study of Slope Landslide with Respect to Drainage

For the analysis of the slopes due to drainage structure system, detailed information on the ground conditions to be used is presented in Table 1. [4]

Table 1: Detailed Information on the Ground Conditions

Location (Federal Road FT185 from Lojing to Gua Musang)	Kilometer (KM)	Chainage (Ch.)	Existing ground parameters	Backfill material parameters	Concrete Materials
1	84.6	25950	Model : Mohr-Coulomb γ : 18 kN/m³ c : 10 kPa φ : 32°	Model : Mohr-Coulomb γ : 18 kN/m³ c : 5 kPa φ : 32°	Model : Mohr-Coulomb γ : 24 kN/m³ c : 365 kPa φ : 35°
2	134	18825	Model : Mohr-Coulomb γ : 18 kN/m³ c : 10 kPa φ : 32°	Model : Mohr-Coulomb γ : 18 kN/m³ c : 5 kPa φ : 32°	Model : Mohr-Coulomb γ : 24 kN/m³ c : 365 kPa φ : 35°

PROGRAM ANALYSIS

Analysis of conditions for different slope geometry easily to be carried out using Slope/W program. Computer simulation of Slope/W model is used in slope stability analysis in order to obtain the comparisons between the changes on slope diagram with safety factor in each case. Slope/W program provide a means for detailed analysis of slope stability. Morgenstern-Price method has been chosen in software analysis which it allowed for various user-specified interslice force functions. Two locations of study are described in Figure 2 and Figure 3 respectively and to be analysed in the program analysis in four cases each location. The results of the safety factor of each case are presented in Table 2.

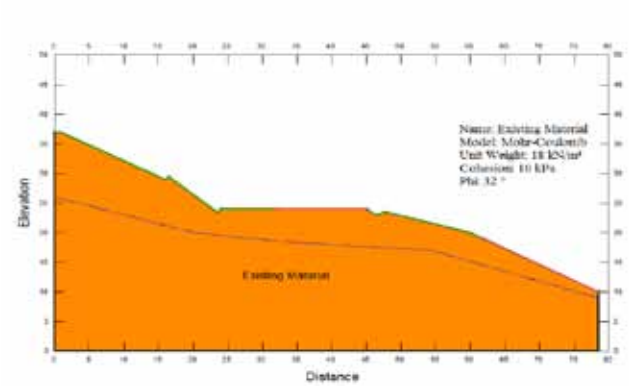

Figure 2: Geometry of slope for location 1 at KM 84.6 (Ch. 25950).

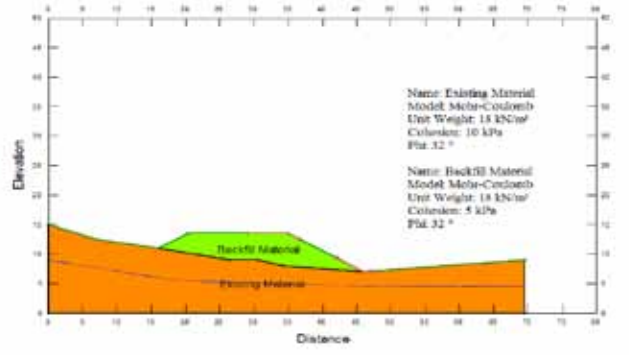

Figure 3: Geometry of slope for location 2 at KM 134 (Ch. 18825).

Table 2: Result of safety factor of the case analyses.

Slope Analysis With Respect to Drainage	Location 1 KM 84.6 Ch. 25950	Case A : 1.725
		Case B : 1.701
		Case C : 1.701
		Case D : 1.838
	Location 2 KM 134 Ch.18825	Case A : 1.756
		Case B : 1.750
		Case C : 1.646
		Case D : 2.031

DISCUSSIONS

Based on the results of the analyses as tabulated in Table 2, the safety factors perform the different values of each case except case B and case C for Location 2. The comparison of safety factor between the slope conditions is described in Table 3.

Table 3 : Comparison of safety factor for different slope conditions.

Case	Descriptions	FOS (Location 1)	FOS (Location 2)
Case A	The value of safety factor is enough satisfied however the performance of this slope is most required to be checked.	1.756	1.725
Case B	The value of safety factor is lower than Case A since the top of slope was subjected to surcharge or point loads that shall contribute a lot of deformation of soil movement. However it will be satisfied if there are no additional interruptions like cracks or voids subjected to the surface.	1.750	1.701
Case C	The surface with presence of water through the cracked concrete drain tend to an increase in deformation of soil movements and the value of safety factor is need to be concerned and controlled.	1.646	1.701

Case	Descriptions	FOS (Location 1)	FOS (Location 2)
Case D	Engineered Slope with Remedial Work of Retaining Wall for Location 1 and the cut slope 1 to 2 ratio. The values respectively show that the engineered slopes with remedial works are satisfied and more secure than the slope without any protection work implemented.	2.031	1.838

The results show the satisfied safety factor where all is above requirement 1.5, however the behaviour of the soil movement comes from many factors that can contribute to the slope failures. There is recommended that engineered slope protection in such cases should be designed in-line with the standard requirements so that the soil movements could be controlled and maintain the slope safety. The damage of drainage structures either in flat or in hilly terrain are caused by the same factors and subjected to any load. In term of damage due to the presence of water includes the case where the soil layers lose shear strength due to increase in moisture content or saturation, resulting in an increase deformation when subjected to surcharge or point loads consequent cracking on the structure installed on the soil surface. Water infiltrating the surface layers through voids or cracks and causing the slope instability. The soil movements in hilly terrain probably caused by drainage structure failures that produce the cracking but not the drainage structure itself if it well provided and managed. On the other hand, the probability of contribution of drainage loads on the slope movement or instability is low. Furthermore, if the slope itself is not well protected, slope failures may occur.

RECOMMENDATIONS

The drainage system shall be installed properly depends on the terrain conditions. The hydraulic behaviour of a steep drain section shall be further investigated to ensure proper functionality. Splashing water can be contained by sufficient free board. A deep sump pit shall be provided when the flow from different drain sections converge before discharging to the outlet drain downslope. Sump pits and cascading drains may also be introduced at certain intervals to break the flow energy and reduce the speed of flow to prevent water splashing.

The amount of the surface runoff to the certain area is insignificant as the catchment area covered by dense grass or trees. Whereas in the raining day and same time the drain produced the gap, water infiltration is concentrated at the crack or gaps. Even though the amount of surface runoff is not excessive, nonetheless continuous water infiltration can induce the built up of pore water pressures within the body of the embankment of slope. Thus, the proper maintenance shall be carried out in order to monitor and protect the drainage structures from the major defects.

CONCLUSION

Four (4) cases of slope performances at two (2) locations were studied in this paper and lead to the conclusion. The value of safety factor is enough satisfied however the behaviour of this slope are most required to be checked in term of soil layer parameters and pore water pressure line. In the case where the top of slope was subjected to surcharge or point loads that shall contribute a lot of deformation of soil movement and the surface with presence of water through the cracked concrete drain also tend to an increase in deformation of soil movements, the value of safety factor is need to be concerned and controlled during the design stages. Generally, the safety factor will be satisfied if there are no additional interruptions like cracks or voids subjected to the soil surface. However, the overall elements of engineered slope shall be designed in compliance to the standards. The main item need to be considered is the slope protection. Slope protections come from many methods that maintain the safety factor of the slope especially for the hilly area developments.

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Model BIM (Pandangan Hadapan 3D) - Dewan Serbaguna Piawai

Earthquake Resistance School Building Using Peninsular Malaysia Bedrock Response Spectrum

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ABSTRACT

Response spectrum is a very useful tool in earthquake engineering for estimating the performance of structures. In this research, attenuation equation will be used to find the response spectrum of bedrock to predict reliable and more accurate ground motions as far 700 km from potential earthquake sources. According to historical records, the earthquakes that influenced Peninsular Malaysia are originated from two earthquake faults: the Sumatra subduction zone and Sumatra great fault zone. The worst earthquake ever occurred in Sumatra subduction zone is identified as M^w = 9.11 and M^w = 7.81 for Sumatra fault zone. These data were then used to predict the response spectrum of bedrock in Malaysia using Probabilistic Seismic Hazard Analysis (PSHA). The maximum response spectrum of bedrock from Sumatra subduction zone for megathrust is 67 gals, benioff is 60 gals and fault zone is 90 gals for site location in Kuala Lumpur while for Pulau Pinang the values of response spectrum from Sumatra subduction zone for megathrust is 57.5 gals, benioff is 47.78 gals and fault zone is 58.33 gals. Performance of building shows that the values of moment for combination load 2 increases about 15.07 percents for column 1 and approximately 4.70 percents for beam 2..

Keywords*:* Attenuation equation, Peak Ground Acceleration (PGA), response spectrum, Sumatra subduction zone (megathrust), Sumatra subduction zone (Benioff), Sumatra great fault zone, axial load, shear force, moment

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INTRODUCTION

Despite being located on the stable part of the Eurasian Plate, buildings on the surface of Peninsular Malaysia were occasionally subjected to tremors due to far-field effects from earthquake in Sumatra (Balendra et al. 1990). For the past few years, several tremors were felt by tall buildings residents in Kuala Lumpur due to large earthquake in Sumatra. The mechanism for such tremors is illustrated in Figure 1.

The seismic waves, generated from an earthquake in Sumatra, travelled long distance before they reach the bedrock of Malaysia. The high frequency earthquake waves were damped out rapidly in the propagation process while the low frequency waves were able to travel long distance as these long period waves are more robust to energy dissipation.

Thus the seismic waves at bedrock of Malaysia Peninsula are rich in long period waves. Additionally, these waves would be significantly amplified due to resonance effects when they propagate upward through the soft soil sites with a period close to the predominant period of the seismic waves. The amplified waves cause resonance in buildings with a natural period close to the period of the site, and the resulting motions of buildings are large enough to be felt by the residence (Balendra 2008).

Malaysia is located in the stable Sunda Shelf with low to moderate seismic activity level, surrounded by Indonesia and the Philippines, which are close to active seismic faults. The fact that Malaysia has not experienced any major earthquake disasters should not be used as an argument to dismiss the need for taking any pro-active steps to look into the earthquake threat. The main objective of this research are as follow;- (1) to identify suitable attenuation equation; (2) to find response spectrum of bedrock, and; (3) to find performance of building with different response spectrum.

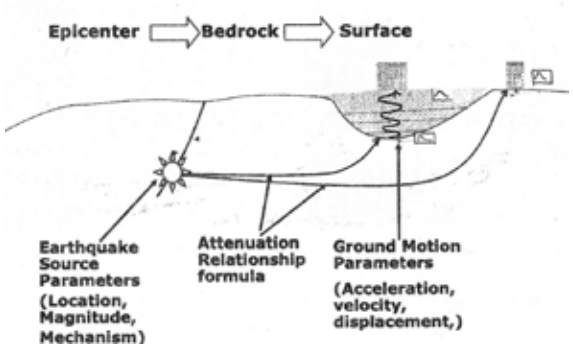

Figure 1. Schematic illustration of wave propagation through engineering bedrock and soil surface (Hendriyawan 2007)

METHODOLOGY

This research consisted of four main steps. The first step was collecting data and design specification for reinforced concrete building. This included finding the detailing drawing for standard schools built in Malaysia. The collection of related information on potential seismic risks in the region as well as related research works done by others researchers were emphasized in this stage.

The next stages were collecting and reviewing of appropriate attenuation equation. This formula, also known as ground motion relation, is a simple mathematical model that relates a ground motion parameter (i.e. spectral acceleration, velocity and displacement) to earthquake source parameter (i.e. magnitude, source to site distance, mechanism) and local site condition (Campbell, 2003). It is considered one of the critical factors in seismic hazard analysis. There has been a number of attenuation relations derived in the last two decades since the record of ground motions are becoming more available. In general, they are categorized according to tectonic environment (i.e. subduction zone and shallow crustal earthquakes) and site condition as shown in Table 1.

After finding out the suitable attenuation equation, the probabilistic seismic hazard analysis (PSHA) method was carried out to predict ground motion in Malaysia from Sumatra earthquake sources. The method has allowed uncertainties in the size, location and rate of recurrence of earthquakes and in the variation of ground motion characteristics with earthquake size and location to be explicitly considered in the evaluation of seismic hazards (Steven 1996). The results from this method will be the response spectrum of the bedrock in Malaysia.

The Finite Element Modelling (FEM) was used in this research to investigate the seismic performance of building structure. Commercial FEM computer software SAP2000 was used to carry out both static and dynamic linear analysis respectively. The input loading for seismic analysis will be the response spectrum of bedrock with different mechanism's and locations. Table 2 shows the combination loads used in the structural analysis. Combination load 1 only consisted of dead load and live load acting on the superstructure, while combination load 2 would be the same as load 1 but with addition of bedrock response spectrum for dynamic analysis. The results of shear force, axial force and moment were compared to investigate the performance of the building.

Table 1. Table of several worldwide attenuation functions

Model	Calculated	Site Condition	Range	
			R (km)	Mw
Western North America				
Abraham and Silva (1997)	PHA, PVA, Sah, Sav	Rock, Deep Soil	0 – 100	4.0 – 8.0
Boore et al. (1997)	PHA, Sah	Vs in upper 30m	0 – 80	5.5 – 7.5
Campbell (1997)	PHA, PVA, PHV, PVV, Sah, Sav	Hard Rock, Soft Rock, Soil	0 – 100	4.0 – 9.5
Sadigh et al. (1997)	PHA, Sah,	Rock, Deep Soil	0 – 100	4.0 – 8.0
Sadigh and Egan (1998)	PHA, PHV, PHD	Rock, Soil	0 – 100	4.0 – 8.0
Central and Eastern North America				
Atkinson and Boore (1997)	PHA, Sah	Rock	10 – 300	4.0 – 9.5
Toro et al. (1997)	PHA, Sah	Rock	1 – 100	5.0 – 8.0
Campbell (2003)	PHA, Sah	Rock	1 – 1000	5.0 – 8.0
Subduction Zones				
Youngs et al. (1997)	PHA, Sah	Rock, Soil	0 – 100	4.0 – 9.5
Petersen (2004)	PHA	Rock	>200	4.0 – 9.5
Azlan et al. (2005)	PHA	Rock	2 – 1000	5.0 – 8.5

Source : InternationalSeismologycal Center, Online Bulliten, http://www.isc.ac.uk/Bull,

International Seismology Center, Thatcham, United Kingdom

Table 2. Combination loads

Combination Load	Dead Load	Live Load	Response Spectrum
1	√	√	
2	√	√	√

RESULT AND ANALYSIS

The data sources of earthquake for this research were taken from Off the West Coast of Northern Sumatra and Southern Sumatra with magnitude 9.11 for subduction zone and 7.81 for fault zone. The distances between source of subduction zone to Kuala Lumpur and Pulau Pinang are approximately 620km and 550km respectively, while the distance between sources of fault zone to Kuala Lumpur is around 340km and 620km to Pulau Pinang. Response spectrums in these locations were defined by PSHA method with the mentioned distances. Most of the attenuation equations are suitable for distance from source to location below 200 km. hence, the suitable attenuation equation from Campbell (2003) and Peterson (2004) because the closest location from Sumatra to Malaysia is approximately 340km.

Table 3 shows the maximum PGA with different location and mechanism as well as the maximum values for fault zone with 90 gals for Kuala Lumpur and 58.33 gals for Pulau Pinang. In the present study, macrozonation maps for Peninsular Malaysia shows that the peak ground acceleration (PGA) for Kuala Lumpur ranges from 60 gals to 100 gals. Meanwhile, the PGA for Pulau Pinang falls between 40 gals to 60 gals. The results obtained were compared with previous research in figure 4, and it was found that the response spectrums calculated are within the range for 500-year return period events. The figure 2 and figure 3 will be used as input data to analyze four-storey school building by using SAP2000.

Table 3. Maximum value for response spectrum

Type of Mechanism	Location	Response spectrum (gals)
Subduction Zone (Megathrust)	Kuala Lumpur Pulau Pinang	67 57.5
Subduction Zone (Benioff)	Kuala Lumpur Pulau Pinang	60 47.78
Fault Zone	Kuala Lumpur Pulau Pinang	90 58.33

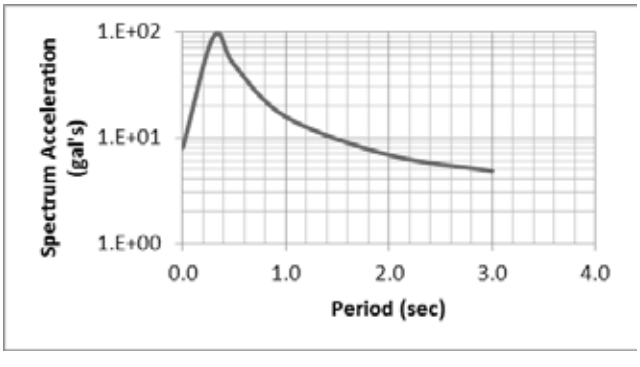

Figure 2. Response Spectrum for fault zone Location in Kuala Lumpur

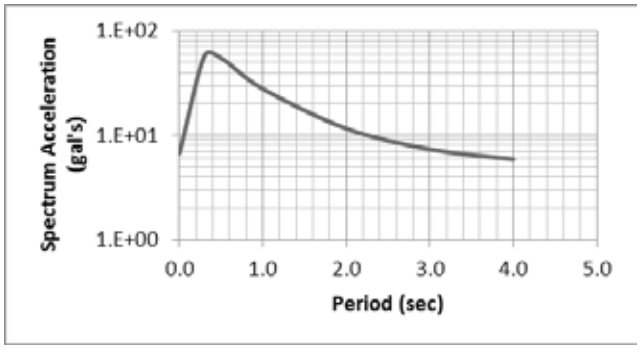

Figure 3. Response Spectrum for fault zone location in Pulau Pinang

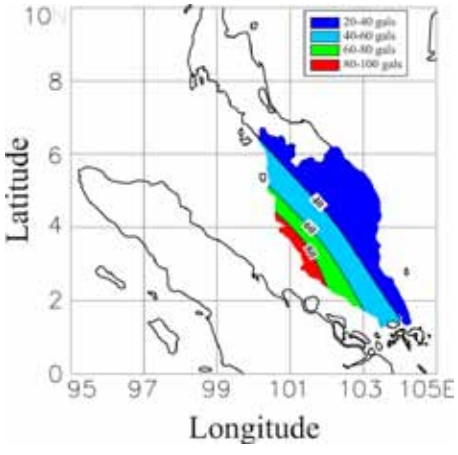

Figure 4. Macrozonation map for the Peninsular Malaysia (T_R=500year).

Table 4. Results for Shear Force and Moment with different mechanisms, locations, loadings and capacity.

TYPE	Combination Load 1		Combination Load 2		Capacity	
	Shear Force/ Axial Force (kN)	Moment (kNm)	Shear Force (kN)	Moment (kNm)	Shear Force (kN)	Moment (kNm)
Subduction (Megathrust) location in Kuala Lumpur						
Column 1	935.70	33.45	942.52	38.32	1761	129
Column 2	637.89	48.41	641.97	53.55	1761	129
Column 3	339.21	46.69	341.00	50.05	1407	110
Column 4	41.02	30.32	41.43	31.71	1153	61
Beam 1	161.95	178.87	164.68	188.89	324	296
Beam 2	162.81	189.18	165.09	197.77	324	296
Beam 3	162.33	177.28	163.70	182.40	324	296
Beam 4	7.65	14.24	8.05	15.76	156	135.68
Subduction (Megathrust) location in Pulau Pinang						
Column 1	935.70	33.45	941.45	26.83	1761	129
Column 2	637.89	48.41	641.33	52.74	1761	129
Column 3	339.21	46.69	340.73	49.53	1407	110
Column 4	41.02	30.32	41.36	31.50	1153	61
Beam 1	161.95	178.87	164.25	187.32	324	296
Beam 2	162.81	189.18	164.74	196.43	324	296
Beam 3	162.33	177.28	163.49	181.60	324	296
Beam 4	7.65	14.24	7.99	15.52	156	135.68
Subduction (Benioff) location in Kuala Lumpur						
Column 1	935.70	33.45	941.72	37.75	1761	129
Column 2	637.89	48.41	641.50	52.95	1761	129
Column 3	339.21	46.69	340.80	49.66	1407	110
Column 4	41.02	30.32	41.38	31.55	1153	61
Beam 1	161.95	178.87	164.36	187.72	324	296
Beam 2	162.81	189.18	164.83	196.77	324	296
Beam 3	162.33	177.28	163.54	181.80	324	296
Beam 4	7.65	14.24	8.00	15.58	156	135.68
Subduction (Benioff) location in Pulau Pinang						
Column 1	935.70	33.45	940.60	36.95	1761	129
Column 2	637.89	48.41	640.82	52.10	1761	129
Column 3	339.21	46.69	340.50	52.63	1407	110
Column 4	41.02	30.32	41.31	31.32	1153	61
Beam 1	161.95	178.87	163.91	186.06	324	296
Beam 2	162.81	189.18	164.45	195.35	324	296
Beam 3	162.33	177.28	163.31	180.96	324	296
Beam 4	7.65	14.24	7.94	15.33	156	135.68
Fault Zone location in Kuala Lumpur						
Column 1	935.70	33.45	942.75	38.49	1761	129
Column 2	637.89	48.41	642.11	53.72	1761	129
Column 3	339.21	46.69	341.07	53.81	1407	110

TYPE	Combination Load 1		Combination Load 2		Capacity	
	Shear Force/ Axial Force (kN)	Moment (kNm)	Shear Force (kN)	Moment (kNm)	Shear Force (kN)	Moment (kNm)
Column 4	41.02	30.32	41.44	31.77	1153	61
Beam 1	161.95	178.87	164.77	189.22	324	296
Beam 2	162.81	189.18	165.17	198.06	324	296
Beam 3	162.33	177.28	163.75	182.59	324	296
Beam 4	7.65	14.24	8.07	15.82	156	135.68
Fault Zone location in Pulau Pinang						
Column 1	935.70	33.45	941.82	37.82	1761	129
Column 2	637.89	48.41	641.55	53.02	1761	129
Column 3	339.21	46.69	340.82	53.30	1407	110
Column 4	41.02	30.32	41.38	31.56	1153	61
Beam 1	161.95	178.87	164.40	187.86	324	296
Beam 2	162.81	189.18	164.86	196.88	324	296
Beam 3	162.33	177.28	163.56	181.87	324	296
Beam 4	7.65	14.24	8.01	15.59	156	135.68

The school building was modeled as plan two-dimensional structure. The base support and connection between beam and column were modeled as rigid. The main materials of the structures were concrete and steel bar reinforcement. The loading for the structure will be calculated referring to BS8110 bases on materials, dimension of the structures and type of usage of the structures.

Six different seismic loading in different locations and mechanisms has been imposed on the structure to analyze the behavior of the structure. The analysis has been done to:

(i) Find the shear force, axial load and moment of the beams and columns for each floor.
(ii) Compare the shear force, axial load, moment with the capacity of the building.

Table 3 shows the results for axial load, shear force and moment with different mechanisms, locations, loadings and capacity of the school building with each floor. The maximum values for the axial load and shear force of the structures shows that the column 1 and beam 2 are higher values for all mechanism's and locations. Kuala Lumpur with fault zone shows that the column 1 for combination load 1 is 935.70kN, and combination load 2 is 942.75kN and capacity is 1761kN. The values beam 2 for combination load 1 is 162.81kN, combination load 2 is 165.17kN and capacity is 324kN. These values show that the structural responses for both combination 1 and combination 2 are within the capacity level (figure 5) of the corresponding structural elements.

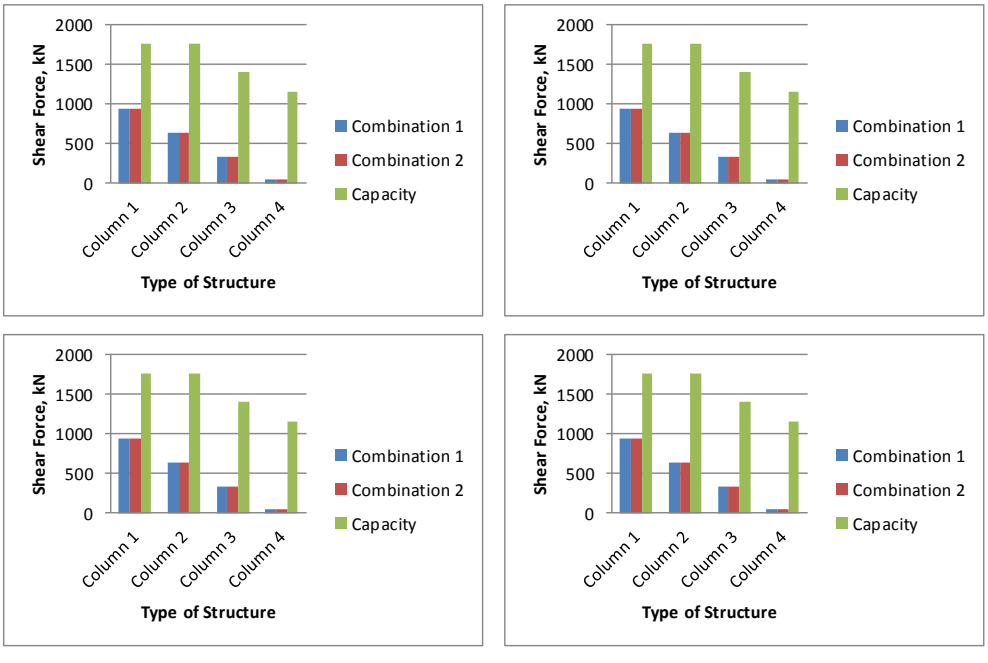

Figure 5. Shear Force and Moment at columns and beams for fault zone in Kuala Lumpur

CONCLUSION

From the research, the suitable attenuation for distance more than 200km from sources Sumatra Subduction zone and Sumatra Fault zone to location Kuala Lumpur and Pulau Pinang are Campbell (2003) and Petersen (2004). The result of PGA on bedrock for each mechanisms and site locations are acceptable if compare with the previous researcher. The maximum value is 90 gals for mechanism fault zone and the site location Kuala Lumpur while Pulau Pinang 58.33 gals. The source location is Bengkulu, Southern Sumatra to Malaysia are very close compare to others mechanism.

The performance of building with different combination loads and response spectrum on bedrock would affect the shear force, axial force and moment values of the structural elements. The axial force of structure for column 1 in Kuala Lumpur with fault zone mechanism, increases about 0.75 percents while shear force for beam 2, it increases by 1.4 percents. The moment reaction of column 1 increases about 15.07 percents while the moment for beam 2 increases approximately by 4.70 percents. However, the results for both combination loads are still within the capacity level of the structure.

The possible factors that affect the result for this research are (1) the ground motion should consider the soils layers and (2) for more accurate analysis, the structure should be analyzed in non linear analysis.

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