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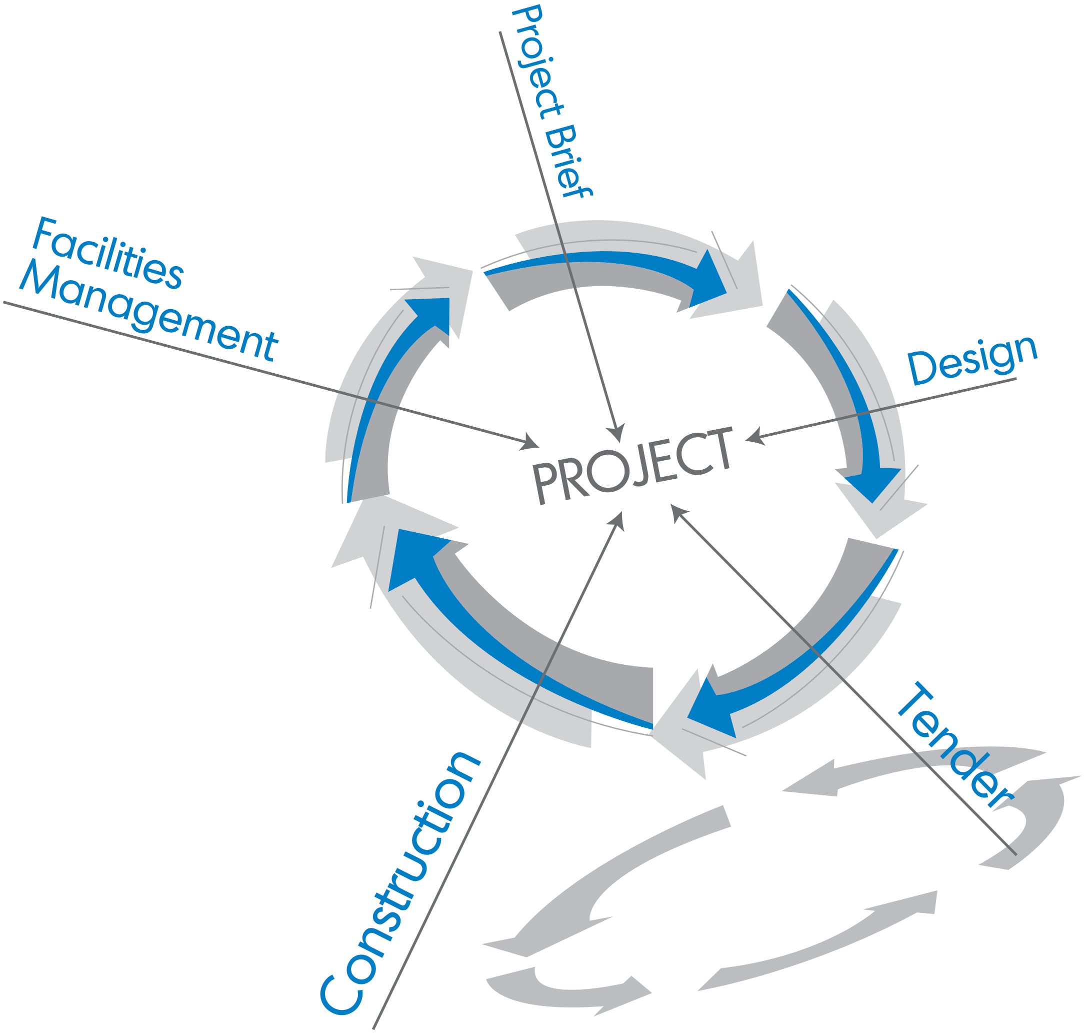

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Editorial Advisory Board

Editorial

Welcome from the Editors

Welcome to the twenty-first (21st) issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include six papers that cover wide range of research area in construction industry. The editorial team would like to express our sincere gratitude to all contributing authors and reviewers for their contributions, continuous support and comments.

In this issue:

Using the partial least square (PLS) of the structural equation modelling (SEM), **Lee Yee Lin, *et. al.*,** develop an innovation model that considers the effect of capabilities, such as entrepreneurship and networking, in achieving superior performance in construction SMEs. The findings reveal that entrepreneurship and networking play a significant role in spurring the contracting SMEs to innovate successfully and to develop superior firm performance. The new model is expected to offer insight for both practitioners and government policymakers on how to trigger a higher rate of innovation activities to ensure continuous growth among construction firms of SME size.

Mohd Fairullazi Ayob, *et. al.,* present the outcomes of the comparative study of life cycle cost and pavement performance between two exclusive alternatives of road rehabilitation for flexible pavement, i.e. cold-in-place recycling (CIPR) and reconstruction. The life cycle cost and performance of the flexible pavement, which has been rehabilitated using the CIPR and reconstruction methods, were evaluated to identify the correlation between the costs incurred against the performance gained. The results have established that the total cost of the reconstruction method is cheaper than the CIPR. However, looking at the performance of the flexible pavement, the CIPR method is superior to the reconstruction method for both the functional and structural strength performance.

Foo Chee Hung and **Nabila Syazwanie Kamaludin** attempted to establish a list of percentage wastage level for commonly used building materials in the Malaysian construction industry, in response to the Construction Industry Development Board's (CIDB) effort in developing the Standard Code of Practice for Construction Solid Waste Management. Such list will act as a reference to facilitate industry stakeholders in construction waste estimation. The study successfully determined the level of material wastage through median test, and further revealed that off-cuts from cutting materials to length and packaging are the major contributor of waste generation.

Adedeji Afolabi and **Opeyemi Oyeyipo** assess the building profession in the eyes of future decision makers in Nigeria through questionnaire survey conducted among two hundred and thirty-six (236) final year students of selected private and public universities in Lagos and Ogun state, Nigeria, termed as future decision makers. The results indicated that future decision makers in the selected institutions in Nigeria had very little awareness of major and evolving roles of the professional builder. Two (2) major areas can influence the popularity of the profession, which are the Student/Professional builders' participation and the Professional Associations. The study also developed a framework to ensure the sustainability of the profession by influencing the awareness level of future decision makers.

Faisal Sheikh Khalid, *et. al.*, investigate the RPET fibre in term of pull-out strength of RPET fibre from matrix concrete by pull-out test. Three sizes of fibres were used in the experiment which was 5, 7.5 and 10 mm width of RPET namely as RPET-5, RPET-7.5, and RPET-10 respectively. The study concluded that the RPET-10 fibre exhibited the highest pull-out load of 103.6% and 33.6% compared with RPET-5 and RPET-7.5 fibres, respectively, at 15 mm embedded length. This finding shows a similar pattern for 20 mm and 25 mm embedded lengths RPET-10 fibre obtained 77.2% to 91.7% and 13.7% to 29.2% increases in pull-out strength compared with RPET-5 and RPET-7.5 fibres, respectively, at 20 to 25 mm embedded lengths.

Norul Ernida Zainal Abidin, *et. al.*, present an experimental study on the behaviour of slender, concrete filled steel tube (CFST) columns filled with self-compacting concrete (SCC) incorporating coal bottom ash (CBA), which were tested in compression to failure. Six specimens were tested to investigate the effect of SCC incorporating CBA as an infill. Depth-to-wall thickness ratios of between 28 to 32 were investigated. The ultimate strength results were compared to the current specimens governing the design of CFST columns. The experimental results suggested that the CFST column filled with SCC incorporating CBA gave good performance in terms of strength. The local buckling of the steel tube was delayed by the restraint of the concrete and the strength of the concrete was provided by the confinement effect of the steel tube.

Editorial Committee

AN EXPLORATORY STUDY OF THE EFFECT OF ENTREPRENEURSHIP AND NETWORKING TO THE INNOVATIVE PERFORMANCE OF CONSTRUCTION SMES

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Abstract
Innovation has been known as one of the driving factors for continual growth of all firms. However, there is a dearth of scholarly effort addressing the relevance of innovation in the construction industry within a small-and-medium-enterprises (SMEs) setting. For this reason, the study aims to develop an innovation model that considers the effect of capabilities, such as entrepreneurship and networking, in achieving superior performance in construction SMEs. In particular, 'innovation activities' is defined as firms' adoption of two different types of new activities – technological and organizational innovations. Research strategy hinges on a quantitative approach, to which a sample of 750 general and/or specialized contracting SMEs located in Kuala Lumpur is drawn to participate in a questionnaire survey. Build on the collected data, a new innovation model is developed using partial least square (PLS) of structural equation modelling (SEM) tool. The findings reveal that entrepreneurship and networking play a significant role in spurring the contracting SMEs to innovate successfully and to develop superior firm performance. The new model is expected to offer insight for both practitioners and government policymakers on how to trigger a higher rate of innovation activities to ensure continuous growth among construction firms of SME size.

Keywords: *Construction SMEs, Innovation, Entrepreneurship, Networking, Performance*

INTRODUCTION

In respond to challenging external environment, the Malaysia economy has strived to grow and expand as a whole. In this regard, the small and medium businesses, which have constituted the bulk structure of the economy, have been reported to play significant role in the nation. In terms of contribution of GDP, SMEs have performed exceptionally well in all economies sectors in the period of 2010 to 2014 (SME Corporation Malaysia, 2015). Particularly, SMEs in construction sector have recorded a higher GDP contribution superseding those in agriculture, manufacturing and other service sectors. Despite their smallness, these firms present conflicting evidence in that they are capable to pursue long run competitive advantage. However, to stand out among intense rivals and to cohere well together with established big players, being innovative is known to be the top priority in the agenda of most construction SMEs (Manley 2008; Khan *et. al.*, 2015).

Over years, the construction industry is challenged to satisfy the needs and aspirations of clients (Boyd and Chinyio, 2006), in terms of improved building performance (both functionally and aesthetically), and reduced initial capital and on-going operational and maintenance costs (Barrett *et. al.*, 2008). Seen in this light, a burgeoning group of scholars has specifically directed their works towards project-based industry of construction nature (Gann, 1994; Slaughter, 2000; Barrett and Sexton, 2006; Manley, 2008; Brochner, 2010;

Pellicer *et. al*., 2012; Ozorhon *et. al*., 2013). Nonetheless, there is a dearth of innovation study in connection to construction firms of smaller size (Manley, 2008). In contrast to larger firms that tend to display innovative advantage mostly in resources, innovation engaged by SMEs is found to confer with behavioural advantages. In this view, both entrepreneurship and inter-firm networking have been demonstrated as parts of SMEs' capabilities that result in superior performance. In empirical sense, they are known as important contributors to long-term success of SMEs throughout different domain (Chetty and Holm, 2000; Keh *et. al*., 2007; Gronum *et. al*., 2012; Engelen *et. al*., 2014). Nonetheless, to what extent these concepts are interrelated to each other and how innovation can be achieved within the resource-constrained firms remain unclear. Given the huge proportion of number and contribution of SMEs reported globally, such as Australia (ABS, 2006), UK (Department of the Environment, Transport and the Regions [DETR], 2000), Malaysia (SME Corporation Malaysia, 2012), empirical investigation is needed to capture the essence of prior works within the realm of construction.

Therefore, the present study aims to investigate the effect of entrepreneurship and networking in spurring construction SMEs to undertake innovation, which potentially lead to higher performance in firms. Specifically, the analysis of innovation is centred on two different types of activities – technological and organizational innovations (*see* Figure 1). A quantitative approach constitutes of questionnaire and PLS technique is used to collect, analyse and interpret empirical data collected from a sample of 750 construction SMEs located in Kuala Lumpur, operating on general and/or specialized contracting basis. Ultimately, the study aims to develop a new model of innovation for resource-poor businesses characterized by construction nature. In the forthcoming section, related SMEs and innovation literature are overviewed to appropriately underpin hypotheses and research method, both of which, lead to final establishment of innovation model.

LITERATURE REVIEW AND MODEL DEVELOPMENT

In this section, prior works on innovation engaged by SMEs is overviewed to identify factors on which a model of innovation can develop. Particularly, innovation activities, entrepreneurship and networking capabilities, firm performance, and the linkage between these factors are brought together to identify the research gap and underpin hypotheses and model of the present study.

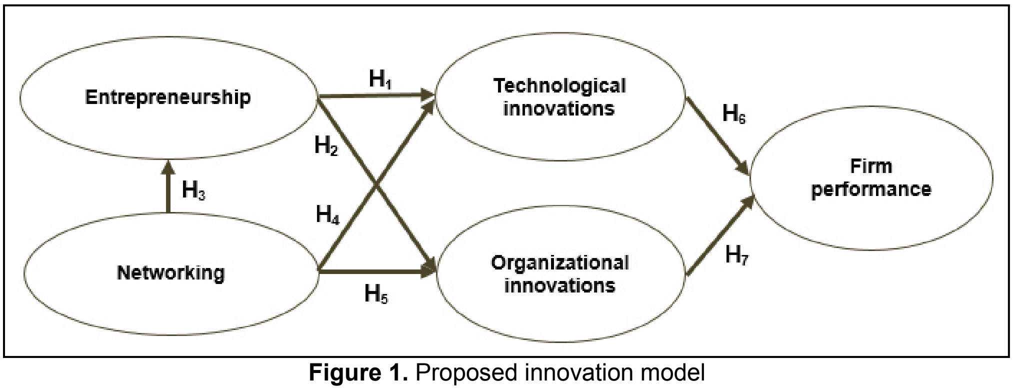

Figure 1. Proposed innovation model

Innovation Activities Engaged by Construction SMEs

When firms execute existing activities in a new approach, this is often regarded as innovation. In a general sense, innovation encompasses a “change in routine” (Nelson and Winter, 1982) as well as the “carrying out of new combinations” (Schumpeter, 1934). In construction specific, Slaughter (1988) relates innovation to “actual use of a non-trivial change and improvement in a process, product or system that is novel to the institution developing the change”. In a broader view, the European Commission (1995) describes innovation as “the renewal and enlargement of the range of products and services and the associated markets; the establishment of new methods of production, supply, and distribution; the introduction of changes in management, work organization, and the working conditions and skills of the workforce”. In firms of smaller size, innovation is defined as “the effective generation and implementation of a new idea, which enhances overall organizational performance” (Sexton and Barrett, 2003). According to Knowles *et. al*. (2008), an innovative firm can be regarded as an enterprise that either invents or adopts innovation. Thus, far, the most prominent type of innovation pursued by construction firms, including SMEs, is the one differentiating between technological and organizational innovations.

For instance, case studies of Sexton and Barrett (2003) note that different types of innovation, such as client relationship development innovation, organizational and managerial innovations at firm and project levels, and technological innovation, have been undertaken by small construction firms. Later, Barrett and Sexton (2006) qualitatively reveal that administrative innovation occurs in the restructuring of organizational process whereas technical innovation occurs in the computerization of operational works in small contracting firms. Meanwhile, Thorpe and Ryan (2007) find that 50 examples of innovations being engaged by the small builders are predominated with product or process innovations those relate to sustainable design and construction of buildings. Echoing this view, Manley (2008) assert that small construction firms are able to overcome their size disadvantages and introduce product innovations to their clients for better project performance. Nevertheless, Hardie and Manley (2008) stress that organizational innovations, such as new management and policies, are important in supporting the development of technological solutions. In other words, both technological and organizational innovations need to be undertaken concurrently to produce synergistic effects on SMEs’ businesses. Rezgui and Miles (2010) investigate the adoption of ICT-enabled alliance modes of operation by construction SMEs and found that such business process innovation enables them to compete in new ways and gain better reward for their work. In the most recent, Hardie *et. al*. (2013) depict how SMEs, which associated with an environmental focus, succeed in delivering technical innovation in projects.

Remarkably, two key themes recur across the diverse range of innovation studies on construction SMEs—innovation is 1) an application of technology, or 2) more than technology related. However, majority of construction studies have focused exclusively on the adoption and implementation of technological product and process innovations (*see* Poirer *et. al*., 2015; Sepasgozar *et. al*., 2016). The implication of organizational innovations, including both marketing and managerial advancements (The Organisation for Economic Co-operation and Development [OECD], 2005), remain nearly non-existent. Given that there is an increasing need for new research works and practical guidance, especially from the perspective of small firms (Barrett and Sexton, 2006), it is therefore important to complement the biased measurement using a broader perspective of innovation.

Entrepreneurship and Innovation

For years, how entrepreneurship is positively intertwined with SMEs has been the subject of scholarly investigation (Wiklund and Shepherd, 2005; Keh *et. al*., 2007; Engelen *et. al*., 2014). In its most primary sense, entrepreneurship is manifested as firm behaviour (Lumpkin and Dess, 1996) as entailing the decision-making, methods, and practices (Wiklund and Shepherd, 2005). Truly entrepreneurs are those with willingness to innovate, search for risks, take self-directed actions, and more proactive and aggressive than the rivals in seizing new marketplace opportunities (Wiklund, 1999). In this connection, a higher level of entrepreneurship implies a higher degree of small firms, having a high degree of entrepreneurial orientation, will be able to discover and capitalize new opportunities which will be better to differentiate them from their rivals (Wiklund and Shepherd, 2005). Accordingly, they could underpin a greater competitive advantage (Engelen *et. al*., 2014).

In reviewing the construction innovation literature, the relevancy of entrepreneurship has not been adequately emphasized by SME scholars. Exceptions are the works by Barrett and Sexton (2006), and Salunke *et. al*. (2011, 2013), and Staniewski *et. al*. (2016), which identify the added value of entrepreneurship. For instance, Barrett and Sexton (2006) observe that small construction firms would persistently display entrepreneurial behaviour to pursue market-based innovation. Meanwhile, Salunke *et. al*. (2011) assert that an entrepreneurial persistence would support the project-oriented service firms, including the SME-sized businesses, in seizing a greater innovation-based competitive advantage. The entrepreneurial project-based firms would, even with limited access to capital, pursue innovation by strategically utilizing scarce resource at hand (Salunke *et. al*., 2013). Entrepreneurs SMEs, therefore, have a higher degree of awareness of the significance of innovativeness concerning the development of a competitive market position (Staniewski *et. al*., 2016). Based on the above notions, the present study contends that construction SMEs with entrepreneurial orientation would have the capabilities to undertake a couple of innovation activities within their business deliveries.

H1: Entrepreneurship is positively related to technological innovations.
H2: Entrepreneurship is positively related to organizational innovations.

Networking and Innovation

Moving a step further from the extant research question, we contend that being highly entrepreneurial in the conduct of business does not constitute competitive strength; but coupled with networking it does. Generally, small firms have little access to critical innovation resources (Mohannak, 2007) and incline to possess insufficient capacity to independently manage the entire innovation process (OECD, 2010). Through inter-firm linkages, these firms can sustain a greater innovation breadth through heterogeneous and intense connections with the peer firms (Gronum *et. al*., 2012). Accordingly, understanding the factors hampering the use of external networking can effectively motivate SMEs to adopt innovation (Bigliardi and Galati, 2016). As remarks by Chetty and Holm (2000), “networks can help firms expose themselves to new opportunities, obtain knowledge, learn from experiences and benefit from the synergistic effect of pooled resources”. Subsequently, the small firms can effectively outsource for resources they do not currently own (Hitt and Ireland, 2002) and acquire size-related advantages of larger firms (Rothwell and Dodgson, 1994).

In dealing with timely completed projects, Lu and Sexton (2006) view network resources of a firm as a result of interactions between individual, firms, and external supplier chain partners. Supporting this view, Manley (2008) emphasize that small innovative firms tend to rely on their external partners in order to gain access to some valuable assets such as professional contacts, reputation and financial strength. In a similar line of reasoning, Hardie *et. al*. (2013) point out that networks enhance construction SMEs' access to social resources embedded therein that promotes innovation activities. Where business provisioning is to be delivered by team approach, competitiveness is no longer based solely on firms' initiatives in accumulating internal resources, rather the capabilities to exploit multiple resources within a framework of business and non-business actors (Hakansson and Ingemansson, 2013). In spite of the pivotal role of networking, the extent by which firms complement it as part of innovation endeavours remains contentious in the case of construction SMEs. Based on the previous ideas, the following hypotheses are postulated:

H3: Networking is positively related to entrepreneurship.
H4: Networking is positively related to technological innovations.
H5: Networking is positively related to organizational innovations.

Innovation and Firm Performance

Generally, innovation is an important competence for small construction firms to outperform their rivals in terms of business performance (Sexton and Barrett, 2003) as well as project outcome (Manley, 2008). However, it is important to note that studies addressing the linkages between innovation and its beneficial outcomes robustly considered the technological product and/or process enhancements (Sexton *et. al*., 2006; Manley 2008; Hardie *et. al*., 2013), rather than all innovation types as described earlier. This is very problematic as the impetus for innovative solution not only necessitates the integration of technical knowledge, but also mandates an in-depth investment into the intangible business routines (Gann and Salter, 2000). In essence, some SME scholars have suggested the importance of organizational innovations (Barrett and Sexton, 2006; Sexton *et. al*., 2006; Hardie and Manley, 2008) to bring about business development. Nonetheless, the investigation of the impact of organizational innovations on performance of construction SMEs remains unclear. Consequently, all these arguments call for further empirical analysis to capture the impacts of both technological and organizational innovations on SMEs that anchored on construction-based services:

H6: The greater the technological innovations, the greater the firm performance.
H7: The greater the organizational innovations, the greater the firm performance.

RESEARCH METHODOLOGY

Prior to data collection, it is important to identify the research design most appropriate for testing, developing and validating the proposed model. In the study, the hypotheses called for a quantitative approach to address research gap presented earlier. To this end, both questionnaire survey (Creswell, 2009) and PLS techniques (Hair *et. al*., 2006) could provide a logical sequence to test and validate the linkage between hypothesized variables.

Questionnaire and Sampling

Through an extensive review of extant literature, a questionnaire consisting of variables with multi-items scales was first formulated. For service industries, including the construction, small firms are those having 5 to 19 full-time employees whereas medium-size firms are those having 20 to 50 full-time employees (National SME Development Council, 2005). In accordance with Bryman and Bell's (2007) assertion that respondents participated in the pre-test should be those who are not part of the sample, the questionnaire was pre-tested with 31 construction SMEs located in Klang Valley (i.e., three architects, four QS consultants, nine engineers and fifteen contractors) and some modification were made to improve the questionnaire. Next, a sampling frame comprising Malaysian project-oriented constructing firms those located in Kuala Lumpur was assembled from the Construction Industry Development Board (CIDB) listing. Following the National SME Development Council (2005), the sampling was then restricted to firms employing 5 to 50 employees and those without missing data, hence, yielded a final frame of 750 firms. The targeted informants were executive-level respondents, that is, owners, founders, and CEOs, who were the 'single most knowledgeable and valid information sources' (Lechner *et. al*., 2006).

Design of Questionnaire

It is important to note that all measures were subjectively measured in this study. For small firms, Pelham and Wilson (1996) viewed that subjective measures is used to deal with difficulties with asking managers to provide sensitive information. Supporting this view, Laforet (2013) claimed the difficulty in obtaining financial accounts of small firms for analysis. 'Entrepreneurship' was measured using 13 reflective items developed by Nasution and Mavondo (2008) that viewed entrepreneurship as three dimensions: risk taking, proactiveness, and autonomy. Respondents were provided with a five-point Likert scale (anchored by 'very strongly disagree' and 'very strongly agree' at the end points) which assumed a conservative versus an entrepreneurial orientation on a continuum. Following Oerlemans and Knoben (2010), 'Networking' was measured on two dimensions: diversity and intensity. Eight categories of external links (clients, competitors, experts/consultants, suppliers, universities, innovation centres, and firms of other industries) adapted from Manley (2008) were self-assessed by respondents on a five-point Likert scale (anchored by 'no importance' and 'very important' at the end points). The scales of innovation activities – 'Technological Innovation' and 'Organizational Innovation' – were adapted from prior works (OECD, 2005; Arditi *et. al*., 2008; Nasution *et. al*., 2011; Gunday *et. al*., 2011; Chang *et. al*., 2012) and comprise 16 items measured on a five-point Likert scale (anchored by 'never practice' and 'always practice' at the end points). Finally, 'Firm Performance' was adapted from Slaughter (2000) and Matear *et. al*. (2002) and all 7 items were self-assessed by respondents on a five-point Likert scale (anchored by 'much worse' and 'much better' at the end points).

Control variable

According to Sorensen and Stuart (2000), firm age might potentially confound the results; such those longer years of establishment furnishes organizations with mature experience and competencies to engage in innovative activities. Hence, it is posited as a control variable. Table 1 shows the descriptive statistic for all variables and the associated correlation matrix.

RESULTS

Through postal survey procedure, a total of 157 valid questionnaires were obtained, representing a response rate of 20.9%. Figure 2 indicated the distribution of the descriptive information of respondents and their firms. Overall, the respondents were homogenous samples of managing director/owners (54.8%), senior managers (40.8%) and others (4.4%). The sample varied between firms that based on business upon main-contracting (47.8%), specialist-contracting (44.6%) or both (7.6%) basis. The distribution by number of full-time employees of the sample denoted the population characteristics in terms of firm size, where 55.4% of the firms were small (5–19 employees) and 44.6% were medium-sized (20–50 employees). Further, the contractor grades of the SMCFs were grade 4 (14%), grade 5 (32.5%), grade 6 (34.4%) and grade 7 (19.1%). The established year of firms distributed as follow: between 1-5 years (3.8 %), between 6-10 years (16.6 %), between 11-15 years (25.5 %), between 16-20 years (29.9 %), and more than 30 years (24.2%). In terms of market size, vast majority (96.8%) of the firms operated in domestic market whereas a small minority (3.2%) operated in both domestic and international markets.

Table 1. Descriptive statistic and the associated correlation matrix

	Variable	R^2	Mean	SD	1	2	3	4	5
1	Entrepreneurship	0.36	3.90	0.83	(0.73)				
2	Networking	-	3.44	1.04	0.56	(0.72)			
3	Technological innovations	0.71	3.67	0.85	0.38	0.43	(0.73)		
4	Organizational innovations	0.58	3.50	0.89	0.31	0.25	0.42	(0.77)	
5	Firm performance	0.56	3.71	0.76	0.25	0.22	0.31	0.22	(0.78)

Note: N=157; R^2=Square multiple correlations; SD=Standard deviation.

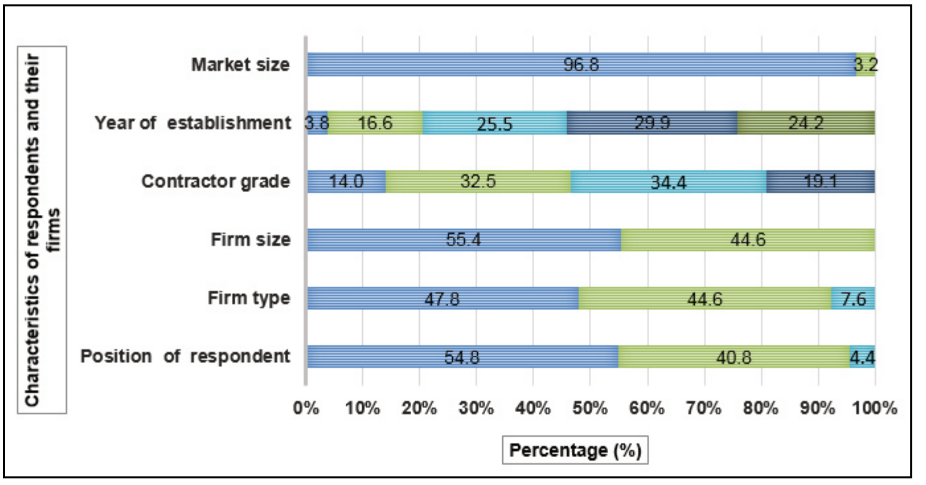

Figure 2. Characteristics of respondent and their firms

Next, PLS technique was used to test the proposed innovation model (*see* Figure 1). According to PLS, a path model is constituted by two elements: structural model (also called inner model) and measurement models (also called outer models) (Hair *et. al*., 2013). The former describes the relationship between the latent variables while the later describes the relationship between the latent constructs and their measures (i.e., indicators).

Measurement Model Analysis

The adequacy of the measurement model was assessed using four criteria – internal consistency, construct reliability, convergent and discriminated validities – to ensure reliability and validity of all constructs. Factor loading, which indicated internal consistency of items, was used to establish underlying structure of a measurement model. As seen in Table 2, only items denoting high factor loading (less than 0.55 means insignificant) (Falk and Miller, 1992) were included in further analyses. As such, 6 items were eliminated from 'Entrepreneurship' variable and 3 items were eliminated from 'Networking' variable. Both 'Innovation activities' and 'Firm performance' variables remained as their initial measurement structure. Also, construct reliability was examined using a threshold value of 0.70 (Nunnally, 1978) and all constructs indicated good reliabilities ranging from 0.84 to 0.92 (*see* Table 2). As recommended by Fornell and Larcker (1981), the average variance extracted (AVE) of all constructs were observed to be more than 0.50, implying a satisfactory convergent validity. For discriminated validity to exist, the square root of AVE for each construct must be greater than its correlations with any other construct (Hair *et. al*., 2006). Table 2 illustrated the robustness of all measurement models.

Table 2. Measurement model results

Constructs	SL	SE	t-value	CR	AVE
Entrepreneurship				0.8754	0.5014
Enor2: Minimum supervision	0.7214****	0.0510	14.1534		
Enor3: Work prioritization	0.7381****	0.0415	17.7947		
Enor4: Uncertainty as challenge	0.7243****	0.0422	17.1661		
Enor5: Venture into unexplored territories	0.6770****	0.0430	15.7287		
Enor6: Acceptance on failure	0.6889****	0.0481	14.3120		
Enor7: Emphasis on success rather than failure	0.7466****	0.0365	21.3464		
Enor9: Seek for new opportunities for present operations	0.6556****	0.0549	11.9432		
Networking				0.8454	0.5250
Inor1: Heterogeneity of linkages	0.6679****	0.0559	11.9566		
Inor2: Depth of linkage with customers	0.7979****	0.0298	26.7810		
Inor3: Depth of linkage with suppliers	0.8108****	0.0322	25.1762		
Inor4: Depth of linkage with competitors	0.6202****	0.0614	10.0936		
Inor5: Depth of linkage with experts and consultancy firms	0.7071****	0.0444	15.9414		
Technological innovations				0.8864	0.5287
Tech2: Improve existing goods/services	0.6480****	0.0515	12.5916		
Tech3: Seek on new goods/services	0.7096****	0.0373	19.0438		
Tech4: Offer new goods/services	0.6474****	0.0523	12.3878		
Tech5: Updated production to increase productivity	0.7697****	0.0355	21.7018		
Tech6: Use of technologies	0.7832****	0.0364	21.5356		
Tech7: New production to improve quality and/or decrease cost	0.7877****	0.0357	22.0539		
Tech8: Removal of non-value added activities	0.7292****	0.0433	16.8482		
Organizational innovations				0.9224	0.5980
Ntec1: New management approaches	0.8161****	0.0235	34.7643		
Ntec2: Investment in updating management procedures	0.7505****	0.0369	20.3662		
Ntec3: Seek to improve management	0.7471****	0.0373	20.0102		
Ntec4: Renew organizational structure	0.7554****	0.0324	23.2880		
Ntec5: Extended/customized service	0.7768****	0.0346	22.4298		
Ntec6: New market	0.7697****	0.0321	24.0095		
Ntec7: New promotion techniques	0.8244****	0.0241	34.2148		
Ntec8: Renew pricing strategies	0.7420****	0.0399	18.5755		
Firm performance				0.9130	0.6010
Fper1: Profitability	0.6633****	0.0569	11.6602		
Fper2: Annual sales growth	0.8221****	0.0248	33.1586		
Fper3: Market share	0.7942****	0.0310	25.6083		
Fper4: Labour productivity	0.7553****	0.0382	19.7823		
Fper5: Customer satisfaction	0.7881****	0.0270	29.2101		
Fper6: Repeat business	0.7754****	0.0306	25.3494		
Fper7: Reputation	0.8172****	0.0256	31.9483		
Age	1.0000	0.0000	0.0000	1.0000	1.0000

Note: SL= Standardized loading; SE= Standard error; CR= Composite reliability; AVE= Average variance extracted.
* [t] = 1:65, at p .1 level.
** [t] = 1:96, at p .05 level.
*** [t] = 2:58, at p .01 level.
**** [t] = 3:29, at p .001 level.

Structural Model Analysis

Once it is confirmed that the variables have good reliability and validity, the PLS proceeded with assessment of structural model using two parameters: explanatory power and path coefficients. The square multiple correlations (R^2) computed by PLS is similar to that of traditional regression (Chin, 1998), and therefore, is foundational in evaluating a structural model (Breiman and Friedman, 1985). As shown in Table 1, the R^2 value for the latent constructs largely exceed the minimum of 0.10 recommended by Falk and Miller (1992). The R^2 value for both the intermediate endogenous constructs (technological innovations = 0.71; organizational innovations = 0.58) and the endogenous construct (firm performance = 0.56) indicated a very satisfactory level of predictability for the proposed model. Figure 3 summarized the path results of the structural model.

To test hypothesized relationships, path coefficients (β) of all constructs were assessed to determine the significance of t-value. As shown in Table 3, all seven paths were statistically significant. A significant and positive relationship exists between entrepreneurship and technological innovations (β=0.22, t=3.626); a significant and positive relationship exists between entrepreneurship and organizational innovations (β=0.49, t=9.021); a significant and positive relationship exists between networking and entrepreneurship (β=0.60, t=12.645); a positive relationship exists between networking and technological innovations (β=0.12, t=1.900); a significant and positive relationship exists between networking and organizational innovations (β=0.35, t=5.597); a significant positive relationship exists between technological innovations and firm performance (β=0.35, t=3.293); a significant positive exists relationship between organizational innovations and firm performance (β=0.44, t=4.046). Interestingly, a significant and positive relationship is found between organizational innovations and technological innovations (β=0.59, t=9.978). However, firm age was an insignificant controlled variable in the model.

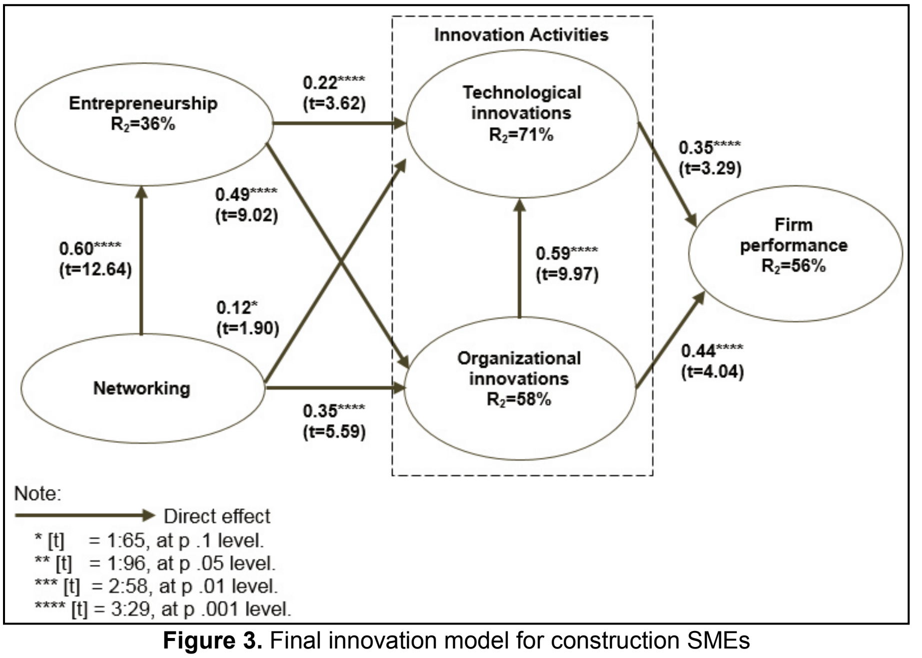

Figure 3. Final innovation model for construction SMEs

DISCUSSIONS

Empirically, the study places the research setting on both general and specialized contracting SMEs to inform several insights valuable to construction business literature. To this end, the effect of capabilities spurring the performance of innovative SMEs is explored, thereby underpinning the development of a new model of innovation. First, the model affirmed that innovation activities engaged by general and/or specialized contracting SMEs were consolidated on two different dimensions, that is, technological and organizational innovations. While the emphasis towards tangible, technical-based advancements is inherently valuable (Sexton *et. al*., 2006; Manley, 2008; Hardie *et. al*., 2013; Poirer *et. al*., 2015), the finding informs that innovative offerings of these resource-poor firms are equally intertwined with intangible, non-technical innovations. For firms that rely upon projects to deliver their services, marketing and managerial innovations are practically undertaken in concurrent with product and process innovations. This is attributed to their complementary nature that can synergistically lead to final success of firms (Hardie and Manley, 2008). Accordingly, the finding adds new insight that analysis of innovation in SMEs necessitates the inclusion of both technological and organizational innovations to appropriately capture their impact within construction business provisioning.

Table 3. Structural equation model results

	Path coefficient	t-value	Hypothesized path
Hypothesized links			
Entrepreneurship → Technological innovations	0.2199****	3.6257	H1 supported
Entrepreneurship → Organizational innovations	0.4919****	9.0205	H2 supported
Networking → Entrepreneurship	0.5981****	12.6452	H3 supported
Networking → Technological innovations	0.1171*	1.8999	H4 supported
Networking → Organizational innovations	0.3535****	5.5970	H5 supported
Technological innovations → Firm performance	0.3500****	3.2929	H6 supported
Organizational innovations → Firm performance	0.4354****	4.0457	H7 supported
Age → Firm performance	0.048n.s.	1.2752	
Non-hypothesized links			
Organizational innovations →Technological innovations	0.5859****	9.9777	

Note: n.s.= Non-significant.
* [t] = 1:65, at p .1 level.
** [t] = 1:96, at p .05 level.
*** [t] = 2:58, at p .01 level.
**** [t] = 3:29, at p .001 level.

Second, the model extends the understanding on the role of capabilities in supporting the innovation practices engaged by smaller construction firms (Sexton and Barrett, 2003; Sexton *et. al*., 2006; Manley, 2008). More particularly, entrepreneurship has found to play a favouring role in supporting both the technological and organizational innovations. Such finding is compatible with the work of Staniewski *et. al*. (2016) that entrepreneurial level of SMEs in construction industry is highly related to the level of innovativeness and market position of these companies. Further, the models reveal that networking, akin to entrepreneurship, has a positive effect on innovation. Clearly, the ability to use external relationship facilitates smaller firms to be better in realizing innovation performance (Parida and Ortqvist, 2015). Instead of R&D-related units (Manley, 2008), the linkage with customers and supply chain partners are more crucial to support these firms towards a better innovative performance (Lu and Sexton, 2006).

Finally, the model addresses the foregoing knowledge gaps by affirming a positive effect of innovation and performance in both general and specialized contracting SMEs. It advances the extant knowledge to a more complete picture by exploring simultaneous effects of both technological and organizational innovations on firm performance. On top of the dominating role of technological innovations as emphasized in extant literature (Khan *et. al*., 2015), the finding reveals a slight greater impact that organizational innovations have on firm performance. This is an interesting finding such that in actualizing new offerings, the non-technical initiatives appeared to have a better translation on the performance of SMEs, as compared to the technical changes. As such, it is affirmed that organizational innovations are also influential factors to lead to better business performance in construction SMEs (Barrett and Sexton, 2006; Sexton *et. al*., 2006; Hardie and Manley, 2008).

CONCLUSIONS

Through a quantitative approach, the study has developed a new model of innovation for SMEs operating on general and/or specialized contracting basis. Importantly, the model established the statistical linkage between entrepreneurship, networking, innovation activities and firm performance, and thereby, contributing to the construction field upon two fonts. First, it enlightened SMEs' practitioners in their decision making pertaining to commitment on capabilities and innovation activities. For SMEs in construction sector, being entrepreneurial in operating business as well as external interaction with other organizations are important for final occurrence of innovation. By strengthening these capabilities, the firms are capable to exploit new value and achieve superior performance. Second, differ from past studies that ubiquitously exploring the implication of technological innovation, the model is designed to underpin innovation along two different activities. Unlike manufacturing-based SMEs that depend much on R&D efforts in their pattern of innovation, service-based SMEs exhibit a clear-cut discrepancy from that technology-driven approach. Based on the findings, it is identified that the SMEs could work innovatively by pursuing non-R&D-related activities, such as adopting new products, production processes, managerial practices and marketing strategies. Accordingly, the model contributes to a better appreciation of smaller businesses by offering key input for SME-focused policies. Eventually, it is expected to motivate continuous and innovative growth within and among construction SMEs.

Nonetheless, several limitations must be noted. First, a cross-sectional design was applied in the present study and it prevents an accurate understanding on the causality nature between the constructs. Future empirical studies should draw longitudinal data to allow a full consideration in analysing the causality of relationships. Next, the empirical setting is placed within a project-oriented construction context. Demand caution is required in generalizing the results in other services sectors. Third, this study does not consider all capabilities-based factors influencing performance of the innovative SMEs. Further research should examine others factors, such as learning capability and market competency, which could potentially extend the proposition of this study. Despite these limitations, this study presents an important step towards a better understanding of the capabilities of construction SMEs in supporting their innovation activities, which eventually gear up the performance of their businesses in the competitive marketplace.

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REFERENCES

Australian Bureau of Statistics (ABS). (2006). Innovation in Australian business (Cat. No. 8158.0). Canberra: ABS.

Arditi, D., Polat, G. and Makinde, S. A. (2008) Marketing practices of U.S. contractors. *Journal of Management in Engineering*, 24(4): 255-264.

Barrett, P. and Sexton, M. (2006) Innovation in small, project-based construction firms. *British Journal of Management*, 17(4): 331-346.

Barrett, P., Sexton, M. and Lee, A. (2008) Innovation in small construction firms. Oxfordshire, UK: Routledge.

Bigliardi, B. and Galati, F. (2016) Which factors hinder the adoption of open innovation in SMEs? Technology Analysis and Strategic Management: doi. 10.1080/09537325.2016.1180353

Boyd, D. and Chinyio, E. (2006) Understanding the Construction Client. Oxford: Blackwell Publishing.

Breiman, L. and Friedman, J. H. (1985) Estimating optimal transformations for multiple regression and correlation. *Journal of the American Statistical Association*, 80: 580-598.

Brochner, J. (2010) *Construction contractors as service innovators*. Building Research and Information, 38(3): 235-246.

Bryman, A. and Bell, E. (2007) Business research methods (2nd ed.). UK: Oxford University Press.

Chang, Y.-C., Linton, J. D. and Chen, M.-N. (2012) *Service regime: An empirical analysis of innovation patterns in service firms*. Technological Forecasting & Social Change, 79: 1569-1582.

Chetty, S. and Holm, D. B. (2000) Internationalisation of small to medium-sized manufacturing firms: A network approach. International Business Review, 9(1): 77-93.

Chin, W. W. (1998). The partial least squares approach to structural equation modelling. In Marcoulides G.A. (eds.) Modern Methods for Business Research. Mahwah, NJ: Lawrence Erlbaum Associates, 295-336.

Creswell, J. W. (2009) Research design: Qualitative, quantitative and mixed methods approaches (3rd ed.). Thousand Oaks, CA: Sage.

Department of the Environment, Transport and the Regions (DETR). (2000) Construction Statistics Annual: 2000 Edition. London: DETR.

Engelen, A., Kube, H., Schmidt, S. and Flatten, T. C. (2014) *Entrepreneurial orientation in turbulent environments: The moderating role of absorptive capacity*. Research Policy, 43(8): 1353-1369.

European Commission. (1995). European Commission: Green paper on innovation. European Union.

Falk, R. F. and Miller, N. B. (1992) A Primer for Soft Modelling. Akron, OH: The University of Akron.

Fornell, C. and Larcker, D. (1981) Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18: 39-50.

Gann, D. M. (1994) *Innovation in the construction sector*. In Dodgson M. and Rothwell R. (eds.) The Handbook of Innovation. Cheltenham, UK: Edward Elgar Publishing, 202-212.

Gann, D. M. and Salter, A. J. (2000) *Innovation in project-based, service-enhanced firms: The construction of complex products and systems.* Research Policy, 29: 955-972.

Gronum, S., Verreynne, M. L. and Kastelle, T. (2012) The role of networks in small and medium-sized enterprise innovation and firm performance. *Journal of Small Business Management,* 50(2): 257-282.

Gunday, G., Ulusoy, G., Kilic, K. and Alpkan, L. (2011) Effects of innovation types on firm performance. *International Journal of Production Economics*, 133: 662-676.

Hair, J. F., Hult, G. T. M., Ringle, C. M. and Sarstedt, M. A. (2013) Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). Thousand Oaks, CA: Sage.

Hair, J., Tatham, R., Anderson, R. and Black, W. (2006) Multivariate Data Analysis. 5th edition. Upper Saddle River, NJ: Prentice-Hall.

Hakansson, H. and Ingemansson, M. (2013) *Industrial renewal within the construction network.* Construction Management and Economics, 31(1): 40-61.

Hardie, M. P. and Manley, K. (2008) *Exemplars of successful innovation delivery by small and medium construction enterprises*. In Brown, K. A., Hampson, K. D., Brandon, P. S. and Pillay, J. (eds.) Clients driving construction innovation: Benefiting from innovation. Brisbane: CRC for Construction Innovation.

Hardie, M., Allen, J. and Newell, G. (2013) *Environmentally driven technical innovation by Australian construction SMEs*. Smart and Sustainable Built Environment, 2(2): 179-191.

Hitt, M. A. and Ireland, R. D. (2002) The essence of strategic leadership: Managing human and social capital. *Journal of Leadership and Organizational Studies*, 9: 3-12.

Keh, H. T., Nguyen, T. T. M. and Ng, H. P. (2007) The effects of entrepreneurial orientation and marketing information on the performance of SMEs. *Journal of Business Venturing*, 22(4): 592-611.

Khan, K.I.A., Flanagan, R. and Lu, S.L. (2015) Managing the complexity of information flow for construction small and medium-sized enterprises (CSMEs) using system dynamics and collaborative technology. *31st ARCOM Conference*. Lincoln, England, 1177-1186.

Knowles, C., Hansen, E. and Shook, S. (2008) Assessing innovativeness in the North American softwood sawmilling industry using three methods. *Canadian Journal of Forest Research*, 38(2): 363-375.

Laforet, S. (2013) Organizational innovation outcome in SMEs: Effects of age, size and sector. *Journal of World Business*, 48(4): 490-502.

Lechner, C., Dowling, M. and Welpe, I. (2006) Firm networks and firm development: The role of the relational mix. *Journal of Business Venturing*, 21(4): 514-540.

Lu, S. L. and Sexton, M. (2006) *Innovation in small construction knowledge-intensive professional service firms: A case study of an architectural practice*. Construction Management and Economics, 24(12): 1269-1282.

Lumpkin, G. T. and Dess, G. G. (1996) Clarifying the entrepreneurial orientation construct and linking it to performance. Academy of Management Review, 21(1): 135-172.

Manley, K. (2008) *Against the odds: Small firms in Australia successfully introducing new technology on construction projects*. Research Policy, 37: 1751-1764.

Matear, S., Osborne, P., Garrett, T. and Gray, B. (2002) How does market orientation contribute to service firm performance? An examination of alternative mechanisms. *European Journal of Marketing*, 36(9/10): 1058-1075.
Mohannak, K. (2007) Innovation Networks and Capability Building in the Australian High-Technology SMEs. *European Journal of Innovation Management*, 10(2): 236-251.
Nasution, H. N., Mavondo, F. T., Matanda, M. J. and Ndubisi, N. O. (2011) *Entrepreneurship: Its relationship with market orientation and learning orientation and as antecedents to innovation and customer value*. Industrial Marketing Management, 40: 336-345.
Nasution, H. N. and Mavondo, F. T. (2008) Organizational capabilities: Antecedents and implications for customer value. *European Journal of Marketing*, 42(3-4): 477-501.
National SME Development Council. (2005) Definitions for small and medium enterprises in Malaysia. Malaysia, Bank Negara.
Nelson, R. and Winter, S. G. (1982) An evolutionary theory of economic change. Cambride, MA: Belknap Press.
Nunnally, J. (1978) Psychometric theory. New York: McGraw-Hill.
Oerlemans, L. A. G. and Knoben, J. (2010) Configurations of knowledge transfer relations: An empirically based taxonomy and its determinants. *Journal of Engineering and Technology Management*, 27(1-2): 33-51.
Ozorhon, B., Abbott, C. and Aouad, G. (2013) Integration and leadership as enablers of innovation in construction: Case Study. *Journal of Management in Engineering*, 30(2): 256-263.
Parida, V. and Ortqvist, D. (2015) Interative effects of network capability, ICT capability, and financial slack on technology-based small firm innovation performance. *Journal of Small Business Management*, 53: 278-298.
Pellicer, E., Yepes, V., Correa, C. L. and Alarcon, L. F. (2012) Organizational improvement through standardization of the innovation process in construction firms. *Engineering Management Journal*, 24(2): 40-53.
Poirer, E., Staub-French, S. and Forgues, D. (2015) *Embedded contexts of innovation: BIM adoption and implementation for a specialty contracting SME*. Construction Innovation, 1: 42-65.
Rezgui, Y. and Miles, J. (2010) Exploring the potential of SME alliances in the construction sector. *Journal of Construction, Engineering and Management*, 136(5): 558-567.
Rothwell, R. and Dodgson, M. (1994) *Innovation and firm size. In Dodgson, M. and Rothwell R.* (eds.) The Handbook of Industrial Innovation. Cheltenham, UK: Edward Elgar Publishing, 310-324.
Salunke, S., Weerawardena, J. and McColl-Kennedy, J. R. (2011) *Towards a model of dynamic capabilities in innovation-based competitive strategy: Insights from project-oriented service firms*. Industrial Marketing Management, 40(8): 1251-1263.
Salunke, S., Weerawardena, J. and McColl-Kennedy, J. R. (2013) Competing through service innovation: The role of bricolage and entrepreneurship in project-oriented firms. *Journal of Business Research*, 66(8): 1085-1097.
Schumpeter, J. A. (1934) The theory of economic development. Cambridge, MA: Harvard University Press.
Sexton, M. and Barrett, P. (2003) *A literature synthesis of innovation in small construction firms: insights, ambiguities and questions*. Construction Management and Economics, 21(6): 613-622.

Sexton, M., Barrett, P. and Aouad, G. (2006) *Motivating small construction companies to adopt new technology*. Building Research and Information, 34(1): 11-22.
Sepasgozar, S. M., Loosemore, M. and Davis, S. R. (2016) *Conceptualising information and equipment technology adoption in construction*. Engineering, Construction and Architectural Management, 23(2): 158-176.
SME Corporation Malaysia. (2012) SME annual report 2011/2012. Malaysia: National SME Development Council.
SME Corporation Malaysia. (2015) Annual report 2014/2015. Malaysia: National SME Development Council.
Slaughter, E. S. (1998) Models of construction innovation. *Journal of Construction Engineering and Management*, 124(3): 226-232.
Slaughter, E.S. (2000). Implementation of construction innovation. Building Research and Information, 28(1): 1-17.
Sorensen, J. B. and Stuart, T. E. (2000) *Aging, obsolescence, and organizational innovation*. Administrative Science Quarterly, 45(1): 81-112.
Staniewski, M. W., Nowacki, R. and Awruk, K. (2016) Entrepreneurship and innovativeness of small and medium-sized construction enterprises. *International Entrepreneurship and Management Journals*: 1-17.
The Organisation for Economic Co-operation and Development (OECD). (2005) Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data (3rd Edition). Paris: OECD EUROSTAT.
The Organisation for Economic Co-operation and Development (OECD). (2010) OECD Studies on SMEs and Entrepreneurship: SMEs, Entrepreneurship and Innovation. Paris: OECD EUROSTAT.
Thorpe, D. and Ryan, N. (2007) Responding to global issues: sustainability and innovation in the Australian SME residential building construction sector. *ICCPM/ICCEM 2007 Proceedings*. Singapore: Building and Construction Authority, Nanyang Technological University, Korea institute of Construction Engineering and Management.
Wiklund, J. (1999) *The sustainability of the entrepreneurial orientation–performance relationship*. Entrepreneurship Theory and Practice, 24(1): 37-48.
Wiklund, J. and Shepherd, D. (2005) Entrepreneurial orientation and small business performance: A configurational approach. *Journal of Business Venturing*, 20(1): 71-91.

LIFE CYCLE COST AND PERFORMANCE ASSESSMENT: COMPARISON BETWEEN RECONSTRUCTION AND COLD-IN-PLACE RECYCLING (CIPR) METHODS

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Abstract
The Malaysian government has spent a large amount of money to keep maintaining the quality of Federal roads in Malaysia. In the face of high cost of road maintenance, increasing demands of road users, changing volume of traffic condition, in company with scarce of funds and limited budget allocated, the clients, including the government agencies and private investors, are looking for the most appropriate road rehabilitation method, which able to produce high-quality pavement performance and facilitate them to achieve potential cost saving and the best value for money. The reconstruction work is a conventional method that usually applied to rehabilitate flexible pavement. The cold-in-place recycling (CIPR) is an alternative method, which has been employed in many countries worldwide, including Malaysia to rehabilitate flexible pavement. The objective of this paper is to present the outcomes of the comparative study of life cycle cost and pavement performance between two exclusive alternatives of road rehabilitation for flexible pavement, i.e. cold-in-place recycling (CIPR) and reconstruction. The life cycle cost and performance of the flexible pavement, which has been rehabilitated using the CIPR and reconstruction methods, were evaluated to identify the correlation between the costs incurred against the performance gained. Theoretically a high strength pavement should be able to sustain longer life. The results have established that the total cost of the reconstruction method is cheaper than the CIPR. However, looking at the performance of the flexible pavement, the CIPR method is superior to the reconstruction method for both the functional and structural strength performance.

Keywords: *Cold-in-place recycling (CIPR), reconstruction, life cycle cost, pavement performance*

INTRODUCTION

Roads have become important infrastructure in Malaysia, which act as an enabler to the economic and social development of the country (Redhuan, 2015; Mohd Salleh, 2015). The contribution of the road and its network system to the national economy is very vast, which have become the most important means for 96% of transported goods and passengers (Sufiyan & Zulakmal, 2009; Redhuan, 2015). The road pavement types in the Malaysian construction industry can be divided into flexible pavement and rigid pavement (Public Work Department (PWD), 2013; PWD, 2015).

Both of these pavement types are constructed using hard pavement material, however, these pavement types need to be properly maintained to preserve the quality and to prolong the life so that the service life can be exceeded than the design life span (Peterson, 1985; ISO, 1997; Caltran, 2007; Jahren, 2007; Velado, 2007; Santero *et. al.,* 2010). Roads that are properly maintained with appropriate corrective and preventive methods can produce high-quality pavement performance and provide an efficient and comfortable ride to the road users. The road authorities in Malaysia are finding ways to choose the most cost-effective methods, which produce a high-quality performance of road pavement that can make the road network system sustainable for long term.

The maintenance of road pavement involves two processes known as maintenance and rehabilitation (M&R): either normal maintenance repairing work or rehabilitation (Wan Omar and Ali, 2014; Wan Omar, 2015). Reconstruction work is the usual method adopted by responsible agencies to rehabilitate the road structural failures (TRL, 1993; JKR-S4, 2008). Alternatively, cold-in-place recycling (CIPR) is an optional method that has been employed in many countries to rehabilitate distressed flexible pavements worldwide (Cross *et. al.,* 2010; Copeland, 2011; Wirtgen, 2012), including Malaysia (REAM, 2005; Sufian *et. al.,* 2009; JKR *et. al.,* 2010). The literature study reported that there has been a study carried out in the past to investigate the performance of recycled pavements involved in the upgrading and rehabilitation of federal road in Pahang, Malaysia (Chong *et. al.,* 2004). However, there is no study has been carried out to compare the advantages and cost benefits between the CIPR and reconstruction methods in terms of both life cycle cost and performance with specific reference to flexible road pavement in the Malaysian construction industry. In the face of high cost of road pavement maintenance, increasing demands of road users, changing volume of traffic condition, in company with scarce of funds and limited budget allocated, the clients, including the government and private investors, are looking for the most appropriate road rehabilitation method, which produces the most optimum life cycle cost and highest quality pavement performance amongst the exclusive alternatives in facilitating them to achieve potential cost saving and best value for money (Ayob, 2014; Wan Omar and Ali, 2014; Wan Omar, 2015).

The objective of this paper is to present the outcomes of the comparative study of life cycle cost and pavement performance between two exclusive alternatives of road rehabilitation for flexible road pavement, i.e. cold-in-place recycling (CIPR) and reconstruction methods. This paper follows the other three papers that have been presented elsewhere by the authors (Wan Omar and Ali, 2014; Wan Omar, 2015; Ayob *et. al.,* 2015).

LITERATURE REVIEW

The Malaysia Government has allocated a large amount of money over the years to maintain, rehabilitate and improve the quality of the road pavements in Malaysia. It was reported in New Strait Times (2010) as cited in Wan Omar (2015), that approximately RM5 billion has been spent between 2001 and 2010 to keep sustaining all the Federal roads in Malaysia. Besides that, a study by Muhammad Arif in Mohd Salleh (2015) mentioned that the length of roads in Malaysia that require appropriate maintenance and rehabilitation is 138,885.48km that includes of toll expressways (1,666km), federal roads (18,920km) and state roads (118,299km). The administer of maintenance works for the federal and state roads is the technical agency of the Government, i.e. Public Works Department, whilst for the road expressways the concession companies are required to maintain and rehabilitate the road throughout the agreed concession period (Wan Omar, 2015; Mohd Salleh, 2015).

The budget allocated for road maintenance and rehabilitation works does not only includes covers road pavement structure, but also other various components of road network system, which include road shoulder, drainage system and road accessories, e.g. streetlight, guardrail, road marking, road furniture, etc. (Mohd Salleh, 2015). The literature study has established that there are five common methods of road maintenance and rehabilitation work which can be carried in routine or periodically bases (Mohd Salleh, 2015). These include crack sealing, pothole patching, shoulder rectification, resurfacing and reconstruction. In the rehabilitation of flexible pavement, alternatives method to the reconstruction method is identified as cold-in-place recycling (CIPR). The CIPR method has been employed in many countries worldwide, including Malaysia, to improve the overall performance of road pavement into a higher better quality (Wan Omar & Ali, 2014; Wan Omar, 2015).

Road Pavement in Malaysia

The two types of road pavement in Malaysia are flexible pavement and rigid pavement (PWD, 2013; PWD, 2015). The flexible pavement is addressed by a capital F for Pavement Classification Number (PCN). The pavement components consist of five layers which are sub-grade, sub-base, road base, bituminous binder course and bituminous wearing course with different thickness of each layer (Atakilti & Satish, 2009). Each layer must be properly compacted to ensure the pavement is structurally formed in quality and adequately strong to support traffic load (Pavement Interactive, 2009). The functions of each layer of flexible pavement are presented in Table 1.

Table 1 The materials used and function of each layer of flexible pavement

The layers of flexible pavement	Materials used	The function of layers
Sub-grade	The compacted soil layer that forms the foundation of the pavement system.	It acts as a foundation of a pavement structure by provides platform for construction traffic and a sound foundation for the pavement.
Sub-base	Stabilized or properly compacted granular material.	It places directly on the sub-grade to support the upper road base and to distribute traffic induced stresses.
Road base	Bituminous mixtures or granular layer stabilized with cement, emulsion, or mechanically stabilized	It is the main structural layer of pavement to distribute traffic load so that sub-base and sub-grade are not subjected to excessive stresses and strains.
Base course	Hard and durable aggregates, which generally fall into two main classes: stabilized (such as Portland cement or bitumen) and granular.	The base course must have sufficient quality and thickness to prevent failure in the sub-grade and/or sub-base, withstand the stresses produced in the base itself, resists vertical pressures that tend to produce consolidation and result in distortion of the surface course, and resist volume changes caused by fluctuations in its moisture content.
Wearing course	A mixture of various selected aggregates bound together with asphalt cement or other bituminous binders.	This surface prevents the penetration of surface water to the base course; It provides a smooth, well-bonded surface free from loose particles, which might endanger aircraft or people.

(Sources: Public Work Department, 2013; The Constructor, 2014)

Rigid pavement or concrete pavement is addressed by a capital R for Pavement Classification Number (PCN). Concrete surfaces and bases are frequently classed as “rigid” pavements which the term “rigid” implying that pavements constructed of this material possess a certain degree of beam strength that allows them to cover some minor irregularities in the sub-grade or sub-base upon which they rest (Koting *et. al.,* 2011). According to PWD

(2014), the basis for classification of concrete pavement types is the jointing and reinforcing system adopted. The need for jointing and reinforcing of slabs is to cater for the expected cracking. Briefly, this need arises from the following facts (PWD, 2014):

a) Concrete pavements are subject to contraction strains due mainly to the temperature drop and concrete drying shrinkage.
b) Contraction is restrained due to friction between the base and the sub-base, thereby inducing tensile stress in the base.
c) Concrete is a rigid material, with a relatively low tensile strength.

The majority of road pavement constructed in Malaysia is flexible pavement, which represents 80% of the road pavement types in Malaysia. The flexible pavement is preferable rather than rigid pavement because of its lower construction cost (ASAPP, 2012). The construction of the rigid pavement layer is similar to the flexible pavement, except the surface structure is made of concrete slab. The functions of each layer of rigid pavement are shown in Table 2.

Table 2 The materials used and function of each layer in rigid pavement

The layers of rigid pavement	Materials used	The function of layers
Sub-grade	Layers of soil or rock formation and consists of a prepared cut or compacted soil	It acts as a foundation of a pavement structure by provides platform for construction traffic and a sound foundation for the pavement.
Sub-base	It is an optional layer of specified material composition, stiffness, and thickness. Generally, consists of lower quality materials such as aggregate.	Considered as a lower base course that functioning as structural supports of the upper base course and aid in distributing traffic induced stresses.
Base course	Usually made of plain concrete with a high ratio of aggregate to cement (lean concrete). It also can be consists of aggregate or stabilized sub-grade.	The non-structural layer used to regulate surface of sub-grade to form a working platform for concrete pavement construction. It provides additional load distribution.
Surface course	Consists of concrete slab and steel reinforcing bars depending on the type of pavement.	It is the stiffest and provides the majority of strength. It provides characteristics such as friction, smoothness, noise control and drainage. It also serves as a waterproofing layer to the underlying base, sub-base and sub-grade.

(Sources: Pavement Interactive, 2009; PWD, 2014)

The concrete slab has the highest stiffness and provides the majority of strength. The use of steel bars is depending on the type of pavement that being constructed which, to handle thermal stresses and reduce the potential of cracks. According to Table 1 and 2, it is apparent that there is a slight difference between these two types of pavement in terms of the numbers of road layers. Generally, flexible pavement consists of five layers (sub-grade, sub-base, road base, base course and wearing course), while rigid pavement construction consists of four layers (sub-grade, sub-base, base course and concrete surface course).

Road Rehabilitation Methods

There are several methods to rehabilitate flexible pavement, and the selection of the method depends on the type of road failure (Wan Omar, 2015). The study focuses only to review two exclusive alternatives of road rehabilitation for flexible pavement, which are reconstruction and cold-in-place recycling (CIPR).

Reconstruction Method

Reconstruction is a conventional method of road rehabilitation work, which replaces the existing flexible pavement structure with new and/or recycled materials. However, this method is more expensive and the nature of work is larger than the other road maintenance and rehabilitation methods, i.e. crack sealing, pothole patching, shoulder rectification, resurfacing. Nevertheless, the reconstruction has been identified as the most preferred method of rehabilitation works for flexible road pavement based on the following conditions (Harvey, 2012, as cited in Mohd Salleh, 2015):

i. No convertible of pavement life when pavement ends at is serviceable life
ii. Major corrections to the pavement especially correction works of the sub-grade layer
iii. Changes of roadway geometrics alignments
iv. Construction and placement of new utilities which affect the existing condition of road pavement
v. Planning and development carried by the authorities which affect the road network system

Cold In-Place Recycling Method

Cold in-place recycling (sometimes referred to as CIPR) is a method of rejuvenating flexible roadways by using special equipment to mill up the existing road pavement, process it over onboard screens, mix it with emulsions or additives, and then once cured is overlaid with a wearing course surface for permanent placement with a paver and rollers (Wan Omar and Ali, 2014; Wan Omar, 2015). Before placing the next pavement course, the CIPR mixture should be allowed to cure for a minimum of at least 2 days and in addition, there must be less than 1.5% moisture remaining in the CIPR mixture. With conventional emulsions, curing of a new CIPR mix, at least in the initial time period after placement, depends on the evaporation of water from the surface of the layer (Cross *et. al.,* 2010). Therefore, it is important to consider the effect of significant amounts of shaded areas can have on curing as the minimum 1.5% moisture content may not be achievable. Similar slow curing problems may also occur when work takes place in damp or cold weather conditions. A second curing criterion, less than 0.5% moisture remaining in the CIPR mixture above the residual moisture content of the pavement prior to recycling, is recommended to address these situations (Wan Omar and Ali, 2014; Wan Omar, 2015).

In Malaysia, the CIPR technique was first introduced in 1985 by the rehabilitation of FT02 Kuala Lumpur to Kuantan (Temerloh), and the followed in 1988 by the rehabilitation of FT08 Pagar Sasak to Merapoh, Pahang (Wan Omar, 2015). Approximately 10% of Federal Roads in Malaysia have currently been treated using CIPR method (JKR *et. al.,* 2010). The CIPR can be used to rehabilitate all types of flexible road pavement, ranging from minor roads to multiple lanes of the highway.

Pavement Evaluation

The actual functional and structural performances of both alternatives are measured and compared against the prediction using the performance condition index (PCI) (REAM SP 1, 2005; Sufian *et. al.,* 2009). The functional performance of the flexible pavement is evaluated by using the International Roughness Index (IRI), the percentage of cracks and rut depth. Whilst, the structural performance is measured in terms of mean Falling Weight Deflectometer (FWD) central deflection and Resilient Modulus (E-modulus value (REAM SP 1, 2005; Sufian *et. al.,* 2009). Table 3 shows the condition criteria for each parameter of functional performance with regard to the International Roughness Index (IRI), the percentage of cracks and rut depth. In addition to this, the condition criteria for each parameter of structural performance with regard to FWD central deflection and Resilient Modulus are illustrated in Tables 4 and 5. As referred to Table 5, the good pavement condition for CIPR method is achieved when the layer stiffness is between 1,200 to 2,000 Mpa. For the reconstruction method, the pavement condition is considered good if the layer stiffness is in the range between 500 to 1,000 Mpa.

Table 3 Functional Condition Criteria

Parameter /Condition criteria	Roughness, IRI (m/km)	Rut Depth (mm)	Crack (%)
Good	< 2.0	< 5.0	< 5.0
Fair	2.0 – 3.0	5.0 – 10.0	5.0 – 10.0
Poor	> 3.0	> 10.0	> 10.0

(Source: REAM SP 1, 2005; Sufian *et. al.,* 2009)

Table 4 Falling Weight Deflectometer (FWD) central deflection

Parameter	Falling Weight Deflectometer (FWD) (microns)
Good	Less than 400
Fair	Between 400 to 700
Poor	More than 700

(Source: REAM SP 1, 2005; Sufian *et. al.,* 2009)

Table 5 Resilient Modulus (E Modulus) Condition criteria

Pavement condition	Layer Stiffness (Mpa)
Cement treated base (CIPR)	1,200 – 2,000
Granular Road Base (Reconstruction)	500 – 1,000

(Source: REAM SP 1, 2005; Sufian *et. al.,* 2009)

Pavement condition index (PCI)

The PCI is a typical measurement that tracks pavement performance on a yearly basis (Waldenmaier and Abdelrahman, 2012). By using the performance prediction models, the future condition of the road is predicted and proper maintenance could be scheduled before the reconstruction of the road can even occur. The models are derived from many years of road inspection and data collection. The regression model is used in the analysis to predict the lifecycle cost of both the CIPR and the conventional method. The quality and overall condition of the pavement after 5 years was determined by the visual assessment performed on-site. Each segment of the pavement was assessed for the presence of distress, which was counted and rated on its severity by a trained inspector. For each distress, the total occurrence and severity are tallied and given a total deduction value, which was a point value the distresses taken away from perfect condition. On an overall basis, the Pavement Condition Index (PCI) groups these distresses together into a single number on a scale from 1 to 100 (100 is equivalent to perfect condition, as shown in Table 6), which allows the prioritization of road repair needs (Waldenmaier and Abdelrahman, 2012).

Table 6 PCI Action Guidelines

PCI	Action
>85	Do nothing
71-84	Maintenance
51-70	Major Rehabilitation
< 50	Reconstruction

(Source: Waldenmaier and Abdelrahman, 2012)

Life Cycle Cost (LCC) Analysis

Life Cycle Cost (LCC) is an economic assessment technique that uses the mathematical method to estimate total ownership costs of the road, which connects the initial capital cost with the future costs of the asset (BS ISO 15686-5, 2008; BSI, 2008; Davis Langdon, 2010). LCC analysis is applied to provide cost information, which is useful to facilitate the Government, clients, LCC practitioners and researchers to make a better decision in the process of determining the most optimum total ownership costs of an asset or to compare the long-term economic worth of mutually exclusive alternatives (Kelly and Hunter, 2009; RSM International, 2010). The information provided by LCC analysis is useful to identify potential cost saving and demonstrate value for money procurement (Davis Langdon Management Consulting, 2007; ASTM International, 2010). It was reported that LCC technique was first used in the United Kingdom before the First World War (year 1914-1918) to determine the most cost-effective between the stone set road pavements and water-bound macadam for highway construction (Croney, 1977 as cited in Robinson, 1993). For pavement design, the appropriate time for conducting the LCC is during the project design stage. The LCC level of detail should be consistent with the level of investment. Typical LCC models based on primary pavement management strategies can be used to reduce unnecessarily repetitive analyses. The procedural steps involved in conducting an LCC are identified as follows (Wall *et. al.,* 1998):

i. Establish alternative pavement design strategies for the analysis period.
ii. Determine performance periods and activity timing.
iii. Estimate agency costs.
iv. Estimate user costs.
v. Develop expenditure stream diagrams.
vi. Compute net present value.
vii. Analyse results.
viii. Re-evaluate design strategies.

LCC incorporates initial capital costs and discounted future agency and user costs over the period of the analysis (Wimsatt *et. al.,* 2009). The agency costs are the cost that directly incurred by the agency over the life of the project. These include the preliminary engineering, contract administration, construction supervision, associated administrative costs, and the maintenance and rehabilitation costs. User costs, which are more complex to calculate, consist of an aggregation of three separate cost components, i.e. the vehicle operating costs (VOC), user delay costs, and crash costs. Some models such as Highway Design and Standards Model (HDM) developed by the World Bank incorporate and embedded vehicle operating cost (VOC) in it (Wimsatt *et. al.,* 2009).

There are six kinds of mathematical cost models that can be found from the LCC literature, which include the Simple Payback, Discount Payback (DPP), Net Present Value (NPV), Equivalent Annual Cost (EAC), Internal Rate of Return (IRR) and Net Saving (NS) (Schade, 2007; BS ISO 15686-5, 2008). The two most popular techniques to assess pavement rehabilitation options are the Net Present Value (NPV) method and the Internal Rate of Return (IRR) method. However, several researchers and scholars asserted that presently the Net Present Value (NPV) is the most popular mathematical cost model to estimate the total cost of the asset (Mohd Mazlan, 2010; Davis Langdon, 2010; ASTM International; 2010). In the NPV analysis, the most cost effective rehabilitation option amongst the competing alternatives is that with the lowest NPV (Flanagan and Jewell, 2005). The NPV formula used in the LCC analysis of pavement rehabilitation options is shown in Equation 1 (Waldenmaier and Abdelrahman, 2012):

$$PV = F\,\frac{(1+r)^n}{(1+i)^n} \qquad \text{(Eq. 1)}$$

Where,
- PV = Present Value ($)
- F = the cost at the year ($)
- n = the year of the cost (years)
- r = the inflation rate, set as 0%
- i = the interest rate, set as 4% (use 0.04)

STUDY METHODOLOGY

Case Study

The section of road chosen as case study should have the same criteria in terms of project size, location, surrounding environment, traffic loads and source of materials such as the wearing course asphalt. This similarity is important in the analysis to reflect an accurate result on the difference in performance and cost relationship between the two methods. However, to get the said criteria is not easy, but the samples that constitute the best representation have been chosen; i.e. An existing Felda road at Pekoti Timur. The road was subdivided into two equal sections of 200-meter length each, one for rehabilitation using conventional method (CM), and the other for CIPR that used cement as the stabilizer agent. Therefore, the external factors such as the traffic load and weather are the same for both types of pavement. Relevant pre-construction laboratory tests were carried out to determine the engineering properties of the existing materials, their quality, and suitability for recycling.

Data collection

The research site was monitored for both the functional and structural performance. The quality and overall condition of the pavement after 5 years was determined by the visual assessment performed on-site. Each segment of the pavement was assessed for the presence of distress, which was counted and rated on its severity by a trained inspector. Data collected are roughness, rut depth using falling weight deflectometer (FWD) and percentage of cracks per unit area. The structural performance is measured in terms of mean FWD central deflection and Resilient Modulus (E-modulus value).

For LCC, data collected are the initial cost and maintenance cost (agency cost). The user cost is very complex to compute and getting the necessary data is a problem, thus, it is not considered in the analysis.

Data Analysis

There were two types of analysis performed for both methods: the pavement performance and the cost analysis. The performance analysis is based on the usual visual inspection techniques for the functional, and samples testing for structural strength. Relevant established tables of references in categorizing the strength and performance of the pavement are referred. As for the cost analysis, the life cycle cost (LCC) analysis is performed for each construction method. Both the performance and cost analysis were integrated to provide a composite view of the correlation between the two major elements, thus, the optimum method that provides the least cost coupled with high performance can be identified.

Performance Evaluation

For the mechanistic design analysis, the assumptions are used with the Shell transfer functions for fatigue and permanent deformation, as detailed in Table 7.

Table 7 Layer Stiffness Seed Values

Material	Layer Stiffness (MPa)	Poisson's Ratio
Asphalt concrete	2500 – 3200	0.40
Dense Bituminous Macadam	1800 – 2500	0.40
Bitumen treated base	1500 – 2000	0.40
Cement/lime treated base	1200 – 2000	0.30
Granular road base	500 – 1000	0.35
Granular sub base	200 – 500	0.35
Sub-grade	50 – 180	0.35

PCI Models

The Performance Criteria is derived from performance model on overall pavement condition index (PCI). The method used in this study is based on the pavement age. In this case, models follow the form of Equation 2.

$$PCI = c_0 + c_{1x^1} + c_{2x^2} + c_{3x^3} + c_{4x^4} \quad \text{(Eq. 2)}$$

Where, PCI = the resulting Pavement Condition Index
c_0, c_1, c_2, c_3, c_4 = model constants (based on long-term field experience)
x = pavement age (years)

Eq. 1 is derived from the regression analysis method demonstrated in *Traffic and Highway Engineering* (Garbel and Hoel, 2009). The PCI values for several years of data are plotted graphically and fitted with a polynomial equation based on statistical interpolation.

Life Cycle Cost (LCC) Analysis

The two pavement rehabilitation alternatives were thoroughly compared using the LCC analysis to determine the most optimal cost solution. In order to calculate the total life-cycle cost, the initial costs and maintenance costs must be considered and bring them to a single point in time. Considering the simplicity of the analysis, the manual method by using Microsoft Excel for computation was adopted. Usually after completion, all LCC should be subjected to a sensitivity analysis to identify and rank the factors or input values in accordance with their impact on the overall LCC results (Walls and Smith, 1998). However due to time limitation, sensitivity analysis cannot be performed.

RESULTS AND DISCUSSIONS

Pavement Functional Performance

Table 8 shows the parameters of functional performance for CIPR and Conventional methods, which include the Roughness Index (IRI), the percentage of cracks and rut depth. From Table 7, it is found that the Roughness Index (IRI) ranging from 2.8 m/km to 3.3 m/km after rehabilitation. When compared to the functional condition criteria in Table 3, these values indicate the pavement condition is between fair to poor riding quality. These IRI values gradually increased for 6 months, after which they remain almost constant. At 60 months' time period, the conventional method records higher roughness than CIPR with the IRI value of 5.9 m/km against 4.8m/km.

Table 8 Parameters of functional performance for CIPR and Conventional methods

Parameter	Duration	Conventional	CIPR
Roughness Index (IRI)	6 months	3. m/km	2.8 m/km
Roughness index (IRI)	60 months	5.9 m/km	4.8 m/km
Cracks (%)	24 months	4%	4.5%
Rut Depth (mm)	60 months	6.3mm	5mm

After 24 months, cracks began to appear on both types of pavement with the CIPR covered an area of 4.5% whilst the conventional method 4.0%. These values are considered good a seen in Table 5. The rut depth appeared after 60 months with conventional method significantly higher at 6.3mm comparing to CIPR of 5 mm. But both methods are categorized as fair, which is well below the poor value of 10 mm.

Pavement Structural Performance

Table 9 shows the result for FWD central deflection data and E-modulus. Most of the sections on the site were in relatively fair to poor structural condition based on the FWD central deflection data. Conventional method section was observed to record the highest central deflection exceeding 700 microns after 6 months of recycling. However, the deflection of conventional method varied from 600 to 1600 microns throughout the 60 months' period. Conversely, the deflection of CIPR method is more consistent as it lies within the range of 400 to 600 microns.

Table 9 Results of FWD Central Deflection Data and E-Modulus for CIPR and Conventional Methods

Parameter	Duration	Conventional	CIPR
FWD central deflection	6 months	600 micron	400 micron
FWD central deflection	60 months	1600 micron	600 micron
E modulus	24 months	700 MPa	2500 MPa
E modulus	60 months	500 MPa	1400 MPa

For the E-modulus, the CIPR resilient is much higher with the maximum value of 2500 MPa achieved after 6 months, before it almost gradually dropped to about 1400 MPa after 60 months. For the conventional method, the resilient modulus reached the highest value of about 700 MPa after 6 months after which it maintains a constant value of below 500 MPa from 12 to 60 months.

Unfortunately, due to lack of data, an accurate analysis on the effects of traffic loads throughout the life cycle cannot be performed. Considering this is a FELDA road without any significant economic development within the area that involves a dramatic increase of traffic using the road, the heavy traffic transporting the palm fruits to nearby factories is the only major contribution to the annual increase of traffic loads.

Performance Prediction using PCI

The pavement functional performance based on the pavement condition index (PCI) for the next 10 years can be predicted using the established equations:
For conventional method,

$$PCI = 99.84 - (3.99*age) + (0.12*age^2) - (0.030*age^3) \quad \text{(Eq. 3)}$$

For CIPR,

$$PCI = 98.22 - (4.22*age) + (0.09*age^2) - (0.074*age^3) \quad \text{(Eq. 4)}$$

Using the Excel spreadsheet, the following table is produced to show comparative pavement condition index (PCI) of the two methods under study.

As shown in Table 10, the differences in the predicted PCI values between the two methods is very low at the beginning, but the difference keeps increasing over time until it reaches about 50.92 at the end of design life on the 10th year. Comparing the predicted PCI values with the observation by visual inspection, the difference between the two methods during the 5th year is minimal. However, the predicted value of CIPR (PCI = 70.12) is slightly lower than conventional method (PCI = 79.14), while the observed value is more or better than the conventional method. The slight error in the Equation 4 for CIPR prediction is probably attributed to the inaccurate factors used in the equation. As admitted by Waldenmaier and Abdelrahman (2012), this error is due to the details knowledge about the material properties and physical strength of the existing recycled asphaltic pavement or CIPR is still in infancy and inadequate; therefore, more research over time is required to improve the prediction by this method.

Table 10 Prediction using PCI model for CIPR and Conventional Methods

Analysis Year	PCI Conventional	PCI for CIPR	Difference in PCI
0	99.84	98.22	1.62
1	95.94	94.02	1.92
2	92.10	89.55	2.55
3	88.14	84.37	3.77
4	83.88	78.04	5.84
5	79.14	70.12	9.02
6	73.74	60.16	13.58
7	67.50	47.71	19.79
8	60.24	32.33	27.91
9	51.78	13.58	38.20
10	41.94	-8.98	50.92

Table 11 shows the summary of pavement condition values at 5th year. From this table, it found that the CIPR performance is better than the conventional method for both the functional and structural strength. This is against the statistical prediction of functional prediction index (PCI) in which the conventional is predicted to be slightly better than CIPR. If based on the PCI Action Guidelines in Table 5, the conventional method requires maintenance on the 4th year, when the PCI number falls to 83.88, which is below 85. From observation, both the functional and structural defects on the 5th year for the two types of construction have reached a fair to poor values and thus both require maintenance. Therefore, the prediction and actual values are consistent in this aspect.

Table 11 Summary of Pavement Condition Values at 5th year

Functional/Structural Criteria	Conventional	CIPR
PCI Prediction	79.14	70.12
Roughness Index, IRI	5.9 m/km	4.8 m/km
Rut Depth	6.3 mm	5 mm
*FWD Central Deflection	600 - 1600 micron	400 - 600 micron
*E-modulus	500 MPa	1400 MPa

(Note: * structural parameters)

LCC Comparison of Conventional and CIPR Methods

The LCC is performed based on the design life of 10 years. The cost incurred for both methods during that period and the associated present values are tabulated as shown in Table 12.

Based on the area of 4m by 200m, the rehabilitation cost on the 5th year is RM84.58 per m^2 for conventional method, while for CIPR the cost is RM76.36. Therefore, the rehabilitation cost for CIPR method is cheaper than the conventional method by about 10%.

Table 12 LCC comparison of conventional and CIPR

Year, *n*	LCC of Conventional (CM)		LCC of CIPR	
	Cost (RM)	Present Value	Cost (RM)	Present Value
0 (Initial 2006)	45,600	45,600	66,880	66,880
5	67,664	55,615	61,088	50,210
10	71,047	47,997	64,142	43,332
Total Cost		149,212		160,422

The predicted future cost at the 10th year is assumed to be subject to an increment of 5% of the 5th year cost, which is due to mainly the increase in the price of materials and labour or workmanship.

Overall, the total LCC for the conventional method is slightly cheaper than the CIPR method with a difference of RM11, 210 that corresponds to about 7%. Considering the total area under the study of only 4m x 200m = 800m^2 and the corresponding total cost of less than RM200, 000 the 7% difference is considerably low. From Table 9, it can be seen that the initial cost of CIPR is much higher than the conventional method. This is attributed to the existing road which was originally unpaved and, therefore, the rehabilitation design demanded a thick layer of the fresh crusher-run base for the CIPR method, instead of recycling the existing recycled asphaltic pavement (RAP). This additional cost contributes to the higher cost of CIPR as compared to usual asphalt paved road.

CONCLUSION

Even though the initial cost of the reconstruction method is cheaper, but its total cost at 5th and 10th year is more expensive than the CIPR method. By looking at the integration of both performance and cost analysis, the conventional method is cheaper than the CIPR by 7%, but its corresponding performance is considerably less, particularly the structural strength, which is observed to reduce approximately by 1/3. For this particular site and project, the most optimum alternative is the CIPR method because, for a slight 7% increase in cost, the performance of the pavement over a life cycle of the 5-year and 10-year period is about 1/3 better than the conventional method. Due to greater strength performance, the future maintenance cost of the flexible pavement which treated by the CIPR method could become lower than the reconstruction method. Therefore, this study has established that the cheaper option is not necessarily the most optimum alternative when both the life cycle cost and performance are considered. The amount of extra strength provided by the minimal additional cost incurred is of high value that deserves a recommendation as the most economical choice.

Based on this aspect, the CIPR is the best alternative for pavement rehabilitation method. The research is limited by constraint in getting details information on the behaviour of existing recycled asphaltic pavement as the CIPR practice is still at infancy stage. Further research is encouraged to examine the behaviour of recycled materials used in the CIPR method in order to improve the accuracy of the performance prediction.

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REFERENCES

ASAPP Media Pt. Ltd. (2012). Rigid Pavement: A cost effective way to a well connected road network. Retrieved on 3 February 2016 from http://www.indiancementreview. com/News.aspx? nid=/ndrF2F2a9bQ3neX17OFlQ

ASTM International (2010). *E917-05: Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*. United States: ASTM International. Retrieved November 2, 2011 from Georgia Institute of Technology database.

Atakilti, G. B. & Satish, C. (2009). Comparative Study of Flexible and Rigid Pavements for Different Soil and Traffic Conditions. Journal of the Indian Roads Congress, 153-162.

Ayob, M. F. (2014). Development of Life Cycle Cost Strategy and Protocol on Cost Data Input in Malaysia. Unpublished doctoral dissertation, International Islamic University Malaysia.

Ayob, M. F., Wan Omar, W. I., and Ali, M. (2015). *Comparative Study of Life Cycle Cost and Pavement Performance on Road Rehabilitation Methods*. Special Paper in the 14th Management in Construction Research's Association (MiCRA) Annual Conference and General Meeting (2015), 12th & 13th November 2015, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia (Unpublished).

BS ISO 15686-5 (2008). *International Standard: Buildings and constructed assets-Service Life Planning. Part 5: Life Cycle Costing* (pp 1-40). Standards Policy and Strategy Committee. Retrieved Jun 9, 2010, from University of Bradford database.

BSI (2008). *Standardized method of life cycle costing for construction procurement: A supplement to BS ISO 15686-5 Buildings and constructed assets-Service Life Planning. Part 5: Life Cycle Costing* (pp 1-87). London: British Standards Institutions. Retrieved August 4, 2011, from Universiti Tun Hussein Onn Malaysia database

Caltrans (2007) Life Cycle Cost Analysis Procedure Manual, California Department of Transportation, USA

Chong, K.P., Mat Zin, H., Yazip, M. (2004). "Malaysian Experience with Cold-In-Place Recycling: A Case Study", *Proceedings of the 8th Conference on Asphalt Pavements for Southern Africa* (CAPSA'04), Sun City, South Africa

Copeland, A. (2011). Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice, Federal Highway Administration, McLean, USA

Cross, S.A., Kearney, E.R., Justus, H.G. and Chesner, W.H. (2010). Cold-In-Place Recycling in New York State, Chesner Engineering P.C., Long Beach, New York

Davis Langdon Management Consulting. (2007). *Final guidance: Life cycle costing (LCC) as a contribution to sustainable construction: Guidance on the use of methodology and its application in public procurement*. United Kingdom: Davis Langdon Management Consulting. Retrieved November 17, 2011. http://ec.europa.eu/enterprise/sectors/construction/files/compet/life_cycle_costing/guidance__case_study_en.pdf

Davis Langdon. (2010). *Development of a promotional campaign for Life Cycle Costing in construction*. United Kingdom: Davis Langdon. Retrieved November 20, 2011. ec.europa.eu/index_en.htm

Flanagan, R. & Jewell, C. (2005). Whole life appraisal for construction. Oxford, UK: Blackwell Publishing Ltd.

Garber, N. J. and Hoel L.A. (2009). *Traffic and Highway Engineering*, 4th Edition, Toronto, Ontario, Canada: Cengage Learning

ISO (1997). International Organization for Standardization: Environmental Management–Life Cycle Assessment-Prioritization and Framework. ISO 14040:1997

Jahren, C. (2007). Performance of Cold In-Placed Recycled Roads, Centre for Transportation Research and Education, Iowa State University, Ames, USA

JKR, IKRAM and Roadcare (2010). Research on Fundamental Characteristics of Stabilised Full Depth Reclaimed Pavement Layers in Malaysia, PowerPoint Presentation, ASAP WG2 Regional Asian Workshop on (Cold) Recycling, Malaysian Roads Conference, October 2010

JKR-S4 (2008). Standard Specification for Road Works, Section 4: Flexible Pavement, Jabatan Kerja Raya Malaysia

Kelly, J. R. & Hunter, K. (2009). *Life Cycle Costing of sustainable design*. London: RICS. Retrieved Jun 14, 2010. http://www.rics.org/site/scripts/download _info.aspx?downloadID=4529 - 24k.

Koting, S., Karim, M. R., Mahmud, H., & Abdul Hamid, N. A. (2011). Development of cement-bitumen composites for semi-flexible pavement surfacing.

Mohd Mazlan, M. Z. (2010). Application of Life Cycle Costing for construction projects in Malaysian Government-Linked Companies. Unpublished master dissertation, Faculty of Architecture, Planning and Surveying, Universiti Teknologi Mara, Malaysia.

Mohd Salleh, N. A. (2015). Flexible Road Pavement: A study On the Cost of Road Maintenance. Unpublished bachelor degree dissertation, International Islamic University Malaysia.

Pavement Interactive (2009). PCC Pavement. Retrieved on 27 January 2016 from http://www.pavementinteractive.org/article/pcc-pavement/

Pavement interactive (2009). Surface preparation. Retrieved on 3 February 2016 from http://www.pavementinteractive. org/article/ constructionsurface-preparation/

Peterson, D.E. (1985). Life-Cycle Cost Analysis of Pavements, NCHRP Synthesis 122, TRB, Washington, D.C., USA

Public Work Department (2013). Manual for the Structural Design of Flexible pavement. ATJ 5/85 (Pindaan 2013) JKR21300-0041-13. Public Work Department Malaysia.

Public Work Department (2014). A Guide to the Visual Assessment of Concrete Pavement, Public Work Department Malaysia

Redhuan, P. Z. H. (2015). Life Cycle Cost In Road Pavement Construction. Unpublished bachelor degree dissertation, International Islamic University Malaysia.

REAM SP 1 (2005). Specification for Cold-In-Place Recycling, the Road Engineering Association of Malaysia, Shah Alam, Selangor, Malaysia

Robinson, R. (1993). Life cycle costing of highways. In Bull, J. W. (ed.), *Life cycle costing for construction* (pp: 53-83). UK: Blackie Academic & Professional.

RSMS01 (March 2004). *Recycled Materials Resource Center*, University of New Hampshire, Durham, NH, USA

Santero, N., Masanet, E. and Horvath, A. (2010). Life Cycle Assessment of Pavements: A Critical Review of Existing Literature and Research, SN3119a, Portland Cement Association, Skokie, Illtrlinois, U.S.A.

Schade, J. (2007). *Life Cycle Cost calculation models for buildings*. Retrieved May 25, 2010. www.rics.org.

Sufian, Z., Aziz, N., Matori, Y., Hussin, M. Z., and Azmi, A. (2009). Full Depth Reclaimed Pavements Using Cement and Hydrated Lime as Stabilizing Agents, REAAA Conference, Incheon, Korea

The Constructor (2014). Flexible pavement composition and structure. Retrieved December 2, 2014 from http://theconstructor.org/transportation/flexible-pavement-composition-and-structure/5499/

TRL (1993).A Guide To The Structural Design of Bitumen-Surfaced Roads in Tropical and Sub-Tropical Countries. 4th Edition, Overseas road note 31, Transport Research Laboratory, Crowthorne, Berkshire, UK

Velado, M. (2007). Life-Cycle Cost Analysis Procedures Manual. California Department of Transportation (Caltrans), Sacramento, California, USA

Waldenmaier, A. and Abdelrahman, M. (2012).A Life-Cycle Cost Approach of Recycled Materials in Infrastructure Rehabilitation, Department of Civil Engineering, North Dakota State University, USA

Wall,J., and Smith, M.R. (1998). Life-Cycle Cost Analysis in Pavement Design-In Search of Better Investment Decisions, Publication No FHWA-SA-98-079, US Department of Transport, Washington D.C. USA

Wan Omar, W. I., and Ali, M. (2014). Life Cycle Cost and Performance Evaluation between CIPR and Reconstruction Method. In: 13th Management in Construction Researchers' Association (MiCRA) Annual Conference and General Meeting 2014, 6th November 2014, Gombak, Kuala Lumpur (Unpublished).

Wan Omar, W. I., (2015). Evaluating Life Cycle Cost (LCC) and Performance Between Cold In-Place Recycling (CIPR) And Reconstruction Method. Unpublished dissertation for Master of Business Administration in Construction Business, International Islamic University Malaysia.

Wimsatt, A.J., Chang-Albitres, C.M., Krugler, P.E., Scullion, T., Freeman, T.J. and Valdovinos, M.B. (2009). Considerations for Rigid vs. Flexible Pavement Designs When Allowed as Alternative Bids: Technical Report, Texas Department of Transport, Texas, USA

Wirtgen (2012).Wirtgen Cold Recycling Technology Manual, Windhagen, Germany

PROFESSIONALS' VIEWS ON MATERIAL WASTAGE LEVEL AND CAUSES OF CONSTRUCTION WASTE GENERATION IN MALAYSIA

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Abstract
Material wastage has been recognized as a common cause of construction waste generation. Ineffective planning and control of materials on sites could lead to poor performance and undesirable project outcomes. In response to the Construction Industry Development Board's (CIDB) effort in developing the Standard Code of Practice for Construction Solid Waste Management, the present study attempts to establish a list of percentage wastage level for commonly used building materials in the Malaysian construction industry. Such list will act as a reference to facilitate industry stakeholders in construction waste estimation. By conducting questionnaire survey, responses on material wastage level from the professional quantity surveyors (QS), project managers (PM), and site engineer (SE) were obtained. Perceptions on the major causes of construction waste generation were then studied, and any significant differences found among the responses due mainly to the different professions were examined. The study successfully determined the level of material wastage through median test, and further revealed that off-cuts from cutting materials to length and packaging are the major contributor of waste generation. By conducting Kruskal-Wallis and the respective post-hoc test, opinion given by PM and SE on the level of material wastage were found to be very much similar as compared to QS. This indicates that the extent to which one person involves in the project has significant influence on the perceived material wastage level as well as the causes of construction waste generation.

Keywords: *Material wastage, construction, quantity surveyor, project manager, site engineer*

INTRODUCTION

Wastes in construction occur throughout the process of operation, irrespective of the size of the project, the value and duration of the contract, and the variety of building type (Adnan, 1996). Wastes are generated in various construction stages ranging from foundation works to finishing, emanated from sources such as wooden materials, concrete, gravels, aggregate, masonry, metals, plastic, plumbing and electrical fixtures, glass, and material handling (Napier, 2012). Five major sources of building material wastes are concrete, reinforcement, formwork, brick and block, and tiles (Table 1).

According to Mahayuddin and Wan Zaharuddin (2013), building material surplus is the largest contributor to the generation of construction waste, due mainly to the great amount of material usage. In actual practice, materials delivered to construction sites are not used totally for the purpose of which they were intended (Skoyles and Hssey, 1974). Approximately 5 to 10% of the construction materials will eventually end up as waste. Cheung *et. al.,* (1993) through their study found that waste generated typically represents 10 – 20% of the total weight of building materials delivered to a building site. Meanwhile, Bossink and Brouwers (1996) found that the level of waste at construction sites, for instance in Brazil construction industry, is 20 – 30% of the total weight of materials on site. In the Netherlands, the amount of waste for each building material lies between 1% and 10% of the amount purchased, depending on the type of material. In the UK, a research indicated that at least 10% of all raw materials delivered to most sites are wasted through damage, loss and over-ordering (Guthrie *et. al*., 1998). Meanwhile, a study conducted in Palestine revealed that 5 – 11% of the purchased materials were not used well and ended up as waste (Enshassi, 1996).

Table 1. Typical building materials and reasons for their wastages

Construction materials	The way of waste generation	Reason of waste generation
Concrete	Ordering too much	Required quantity of products unknown due to imperfect planning
	Loss during transportation	Settlement of concrete on long transportation time
	Scraping off	Method to lay the foundations of a building
Reinforcement	Cutting	Use of steel bars whose size does not fit
Formwork	Cutting	Use of timber boards whose size does not fit
Brick/block	Cutting	Use of products whose size does not fit
	Damaged during transportation	Unpacked supply
Tiles	Sawing consequently on the design of the surface	Attention not paid to sizes of the used products in design; designer not familiar with possibilities of different products; information about that will be used late; types and sizes of the different products do not fit
	Cracking during transportation	Negligent handling by the supplier

(*Source: Tam et. al., 2007*)

Material wastage significantly contributes additional cost to the overall construction because new purchases are usually made to replace wasted materials. Cost of rework, delays, and disposal also cause financial losses to the contractor (Ekanayake and Ofori, 2000). Extra construction materials are usually purchased due to material wastage during construction (Teo *et. al*., 2009). Previous studies from various counties have confirmed that waste represent relatively larger percentage of production cost. For example, a UK study reported an additional cost of 15% to construction projects cost overruns as a result of material wastage (Tam *et. al*., 2007). A study conducted by the Hong Kong Polytechnic and the Hong Kong Construction Association put material wastage contribution to cost overruns at 11% (Poon, 2001). Bossink and Bounwers (1996) in a similar study of material wastage in the Netherlands concluded that material wastage account for 20 to 30% of project cost overruns. Also, there is a growing consensus within the built environment in Nigeria that building materials account for over 50% of the total cost of a building project (Akinkurolere and Franklin, 2005).

To note, the conventional construction is still a common practice in the Malaysian construction industry. A study on the adoption level of Industrialized Building System (IBS) in Malaysia indicates that 84.7% of the new building construction project in 2013 was adopting the conventional construction approach (Foo *et. al*., 2015), which consists of a reinforced concrete frame and brick, beam, column, wall, and roof, which is cast in situ using timber framework. This type of construction involves three major on-site trades, namely steel bending, formwork fabrication, and concreting, which is labour intensive and requires many wet trades, such as skill carpenters, plasterers, and brick workers. The generated construction debris typically consists of trim scraps of timber, masonry, plaster and plastics. Realizing that on-site trades are the main activity in the conventional construction, the identification of the extent of waste generated by various building materials and their respective implication on the construction project is of immense benefit. It is evidenced that proper management of building material waste can achieve higher construction productivity, save time, and leading to safety improvement. While some level of material wastage is unavoidable, the potential benefit of preventing waste generation on site can be substantial, especially if the materials form bulk of the project cost structure. As shown by Koshy and Apte (2012), material cost contributes to about 40% of the total construction cost, of which cement and steel account for 60% of that cost. This indicates that improper management of construction materials can really result to a considerable wastage in the construction site.

STUDY BACKGROUND

Construction waste needs proper control and management so that excessive disposal activities and impacts on the environment can be avoided. The critical step in implementing effective waste management is to estimate the quantity and composition of construction waste generated (Gavilan and Bernold, 1994). However, waste generation in construction site is unpredictable due to the lack of construction waste data and an established system or platform for recording those data. Construction companies are not able to provide relevant and appropriate data because they are not obliged to record or report any data on waste generated on sites (Mahayuddin *et. al*., 2008). Furthermore, they are rewarded a project for speed instead of their concern on the environmental impact of their work. Coupled with the low awareness on proper construction waste management and irresponsible attitude, contractors tend to dispose of construction waste in an uncontrolled manner or at inappropriate sites as to maximize profit by avoiding transportation cost and payment charge to the gazette landfill. In order to have an adequate record of waste for the development of waste reduction or management tools, there is a need to identify the sources of waste and to analyse the rates of contribution of these sources. Knowing the sources of waste and their rates of contribution will sure enhance a more accurate estimation of the cost of waste, thereby enabling reasonable comparison with the cost of measures that can be adopted in managing waste.

The motivation for conducting this study comes from the realization of the importance of waste quantification to the overall waste management. The present study attempts (i) to obtain responses from the professional quantity surveyors (QS), project managers (PM), and site engineer (SE) upon the wastage level of an identified list of commonly used construction materials; and (ii) to evaluate the level of contribution of several factors to the construction waste generation as perceived by the respondents. The results of the study are expected to act as an input to the Standard Code of Practice for Construction Solid Waste Management, which is under developed by the Construction Industry Development Board (CIDB), with the aim of providing relevant stakeholders an appropriate guidance of construction waste storage, collection, transportation, recycling, and final disposal.

Apart from that, this study also seeks to explore if any significant difference exists among the professionals (QS, PM, and SE) with regard to the level of material wastage and the perceived causes that contribute to the on-site construction waste generation. While Adewuyi and Odesola (2015) found no significant difference between the consultants' and contractors' perception about the factors affecting construction waste generation on building sites in Rivers State, Nigeria; it is believed that the extent to which one person involves in the project has significant influence on his/her perceived level of material wastage and the causes of construction waste generation. Such hypothesis is made because each professional (QS, PM, SE) plays different role in the construction project. For example, a QS mainly involves in cost estimation during the design stage of the project, while both the PM and SE manage/supervise the whole construction project and involve directly in day-to-day site monitoring, respectively. By having different degree of involvement in the construction project, perceptions and opinions on construction waste issue tend to be vary among different professionals.

METHODOLOGY

There are several ways of data collection with regard to the wastage level and causes of waste generations. These include the on-site investigation, personal interviews, and questionnaire survey. According to Naoum (2003), the research approach depends on the type of investigation and the data that are needed and obtainable. Recent research trend in this field pointed out that survey and case study are the main methodologies for data collection (Yuan and Shen, 2011). However, on-site investigation is deemed not suitable to be adopted here as the present study seeks to establish a list of material wastage level that can be referred to for waste estimation irrespective of the nature of the project. To note, every construction site is unique, where construction waste generation from each of these projects are affected by various factors, such as types of project (i.e. residential, commercial, infrastructure, social amenities), types of building (i.e. landed, high-rise), construction technologies (i.e. conventional construction, IBS), contractor's management, building design (i.e. timber house, steel frame) etc. Results extracted from one particular study site are not enough to present a general view of the construction waste issue in the industry. While a more representative result can be obtained by conducting several case studies, time consuming is another problem to be dealt with. Tam *et. al.* (2007), for example, conducted a research in Hong Kong to assess the wastage level of different building material through on-site investigation of 19 construction projects from year 2003 to 2005. Data accessibility is also another challenge for on-site investigation because construction companies are not obliged to provide info on their construction waste management. Even on the local level there may be significant barriers to this method because obtaining permission to conduct on-site investigation at construction site can be a major challenge. Most of the time, the construction companies may be suspicious of an onlooker.

Personal interview is not adopted, too, in this study, as the info captured only from the limited perspective that may cause the question on reliability. As pointed out by Naoum (2003), personal interview is subjective in nature, in the sense that the info are verbally described and the raw data are what people have said or a description of what they have seen. This approach is likely to be adopted when researchers have limited knowledge about the subject, which is, however, not appropriate for the present study that aims to obtain a general point of view from the professionals. Besides, bias may happen in the process of data interpretation as there is a temptation of using only data that fits the researcher's explanatory framework while ignoring data which is not supportive, despite its capability of providing certain level of in-depth opinion sometimes.

After consideration of different methods, questionnaire survey is selected as the principal instrument for eliciting responses on the percentage of material wastage from the professional quantity surveyors (QS), project managers (PM), and site engineer (SE). The respondents are asked about their perception on the percentage of wastage from a list of building materials.

Since the main survey respondents in this study are the professionals who involve in project management and are responsible in controlling the cost of construction, the questionnaire survey will provide a rather fast and efficient means of gathering information. Moreover, the aim of this study is to provide references on wastage level for those commonly used building materials, so as to facilitate the industry players when estimating the quantity of waste generated, irrespective of the types project, types of building, construction technologies, contractor's management, or building design. As such, the percentage of material wastage given by the experienced QS, PM, and SE based on their "norm" estimation is rather useful than in-depth insight derived from a personal interview which is hardly to be generalized. On top of that, the questionnaire survey provides faster results but with lower cost, as compared to the on-site investigation which high cost may incur due to the longer period of study.

Design of Questionnaire

The survey instrument consists of three parts. Part 1 seeks to know the profile of the respondents and that of their organization, while Part 2 requests the respondents to indicate how many percent of each of the twelve identified building materials are deemed to end up as waste during a common construction operation, based on their experience. In Part 3, the respondents are asked to rate nine identified factors that contribute to material wastage on site in order of magnitude by responding on a 5-point Likert scale, ranging from 1 = very low; 2 = low; 3 = medium; 4 = high; to 5 = very high. More detailed discussion on the design of questionnaire is given the following sections.

Sources of Material Waste

In this study, construction waste is described as the difference between the quantities of material used in a project to that purchased. The identification of building materials used will facilitate the prediction of types of waste generated on-site, which then provides useful info on the trend of waste throughout the construction stages. With this regard, a list of building materials is generated through literature review and the consultation with experienced project manager and quantity surveyor. The list of materials are concrete, bricks and blocks, tiles and ceramics, steel, cement, wood, gypsum and cement boards, packaging materials, plaster, glass, PVC pipe, and conduit and wiring. These materials are selected and to be included in the survey because:

- they represent a significant percentage of the total cost of building in most traditionally built residential and commercial buildings in Malaysia;
- they are among the categories of materials that tend to have a high percentage of waste; and
- they are mainly employed during the same stages of work – structure, brickwork, and plastering.

Causes of construction waste

Construction material waste arises from design, logistics, and physical construction processes (Fadiya *et. al.*, 2014). According to Ekanayake and Ofori (2000), design, operational procurement, and material handling attributes contribute to waste on construction site. These indicate that the reduction of waste should not be the sole responsibility of the construction company, as the client and designer can make environment friendly choices in the program of demands and designs. Gavilan and Bernold (1994) subdivided sources of construction waste into six categories: (1) design; (2) procurement; (3) material handling; (4) operations; (5) residuals; and (6) others. These six categories were supported and similarly regrouped into categories by Ekanayake and Ofori (2000): design, operational, material handling, and procurement. According to Navon and Berkovich (2006), lack of up-to-date information regarding on-site stocks is a typical problem on large construction projects; for lack of information about supply and location of materials on site, the same materials are ordered again resulting in waste. Furthermore, waste can occur at any stage of construction not only because of construction activities but also due to external factors such as theft and vandalism (Bossink and Brouwers, 1996). Hence, the aforementioned sources of waste were combined in this study and categorized as shown in Table 2, which was then adopted for the purpose of conducting the survey in this study.

Table 2. Sources and causes of construction waste

Sources of waste	Causes
Procurement	Ordering error, supplier's error resulting in excessive materials on site
Design	Changes to design, documentation error
Material handling	Transportation, off-loading, and inappropriate storage
Operations	Tradesperson's error, for example, installing wrong materials and having to remove such materials
Weather	Humidity, temperature
Vandalism	Inadequate security
Misplacement	Untraceable materials, abandonment
Residual	Cutting materials to sizes
Others	Lack of waste management plan

Determination of Sample Size

In normal practice, statistical methods are used to design a representative sample which then derives findings that are reflecting the whole population. However, a small random sampling is adopted in this study due to the homogeneous nature of the targeted population – professional quantity surveyors (QS), project managers (PM), and site engineers (SE). According to de Vaus (2002), a small sample size can suffice in a homogenous population in which most people is expected to answer a question similarly. Besides, the more uniform and consistent a population is the smaller a sample that can be drawn from it for a research purpose is (Carmichael *et. al*., 2007). Since the respondents are highly experienced construction professionals, and they are requested to provide info on material wastage which tends to be the "rules-of-thumb" in their common practice of the whole project management flow, their responses are expected to be uniform and consistent in relation to the issue of construction waste. Thus, a sample size of 75 is drawn in this study – 31 QS, 19 PM, and 25 SE – with all of them operate locally. Besides, when a sample size is more than thirty, it is considered sufficiently large to apply central limit theorem to model the sample mean (Mann, 2005). In this case, the sample size might not be able to represent the whole population, but the mean of the sample size could represent the mean of the population (Chong and Zin, 2010).

The survey was conducted through phone instead of postal, as the cost is lower, less time-consuming, and providing an easy and quick way to collect data from numerous respondents. To further facilitate the process of phone survey, only respondents within the Klang Valley region were selected since the region possesses the highest number of building construction projects in the country. It is also believed that the survey will not be affected geographically because the problem of material waste is more likely to be related to the practice of the contractor.

Data Analysis

Statistical Packages for Social Sciences (SPSS) was used for data analysis. Both the median test and Relative Importance Index (RII) were conducted to find out the average value of the material wastage level for each identified building material and the causes of construction waste generation, respectively; while the Kruskal Wallis and Mann-Whitney U tests were carried out to identify if any significant differences exist between two or more groups' opinion on criteria importance. Further details of each mentioned test are given in the following sections:

Median Test

Instead of mean, the median was preferred because the obtained data is not distributed symmetrically. This is evident by plotting the frequency graph of wastage level for each identified building material (Appendix 1). Since most of the data are skewed, the median can provide a more accurate reflection of an average value as it is not likely to be distorted by the outliers and hence, giving a better idea of any general tendency in the data. Apart from that, there is a big advantage of using median and quartiles, instead of the mean and standard deviation, to check for outliers. The farther out an outlier is, the more effect it will have on the mean and standard deviation. In contrast, the median and quartiles are not affected by observations beyond the quartiles. As long as the observation stays beyond a quartile, the quartile, and hence the hinges, hinge spread, and fences, will be unaffected by its value, revealing the presence of the outlier more clearly.

Relative Importance Index

Relative Importance Index (RII) was calculated to rank statements with 5-point Likert scale, especially for the causes of material waste generation. To determine the relative ranking of each statement, the scores were transformed to important indices based on Equation 1 (Kometa *et. al.*, 1994; Tam *et. al.*, 2000; Tam, 2008). The closer the RII tends to 1, the higher the importance of the factor perceived by the respondents.

Equation 1. Relative importance index (RII)

$$RII = \frac{\sum w}{An}$$

Where:

w	=	Weight given to each factor by the respondent
A	=	The highest weight in this study, which is 5
n	=	The total number of sample
RII	=	The relative important index, $0<RII<1$

Non-parametrical Test

Non-parametrical test – Kruskal Wallis – was used to examine (i) if there are any significant differences on material wastage level, and (ii) causes of construction waste generation among the QS, PM, and SE. To note, the Kruskal-Wallis test is an omnibus test statistic that only shows at least two groups are different but not which specific groups of the independent variable that are statistically significantly different from each other. It is, thus, necessary to inspect the group means or medians to decide precisely how they differ. In the case of Kruskal-Wallis test, the associated post host test to examine the unique pairs is the Mann-Whitney U test. Two hypotheses were posited for the study as follow:

- **H_1**: There is no significant difference on the level of material wastage among the professionals (QS, PM, and SE).
- **H_2**: There is no significant difference on the perceived causes that contribute to the on-site construction waste generation among the professionals (QS, PM, and SE).

The role for the rejection of the hypotheses is that when the p-value > 0.05, the test fails to reject the hypotheses, however, when the p-value ≤ 0.05, the test rejects the hypotheses.

RESULTS AND DISCUSSION

Descriptive analysis was carried out to give an overall picture on the respondents' demographic data (Figure 1). Among the 75 respondents, 25 of them were from the consulting firm while the remaining was from the construction company. Majority of the respondents (30) involved in the construction industry for more than 10 years, 25 with 5 to 10 years, 12 with 2 to 5 years, and 8 of them have less than 2 years of experience.

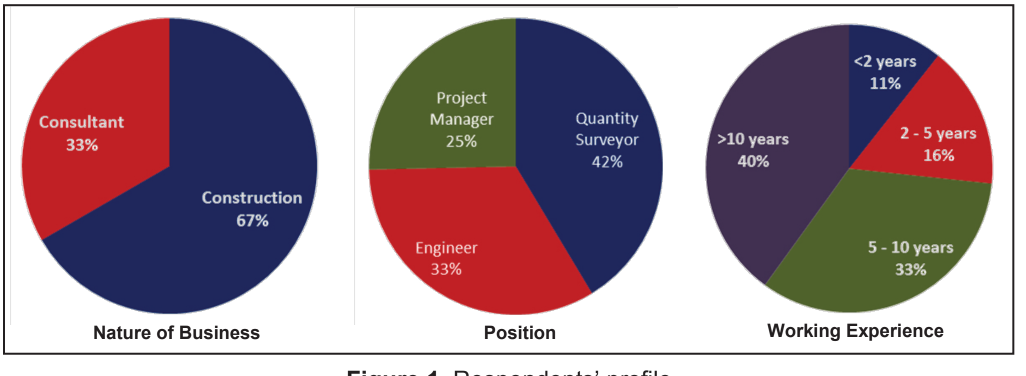


Figure 1. Respondents' profile

Material Wastage Level

A box plot is a graphical representation of the distribution in a data set using quartiles, minimum and maximum values on a number line. It enables the study on the distributional characteristics of the wastage level of each material, as well as providing a useful way to visualize the range and other characteristics of responses for a large group. In the present, the boxplots for each of the building material wastes are drawn to show the overall patterns of the survey response (Figure 2). The median marks the mid-point of the data that divides the box into two parts. Half the scores are greater than or equal to this value and half are less. As observed, most of the boxplots are comparatively short. This suggests that the overall respondents have a high level of agreement with each other. Some boxplots are comparatively tall (i.e. paper, cardboard, plastics) which indicates that the respondents hold quite different opinions about this aspect or sub-aspect. One may also notice that the extreme maximum is pretty far away from the box (for timber formwork, paper, cardboard, and plastics). This means that the data is partially skewed and that the extreme maximum is an outlier. Table 3 presents the details of the boxplot, by showing the extreme value (min, max) and the three quartiles of each material.

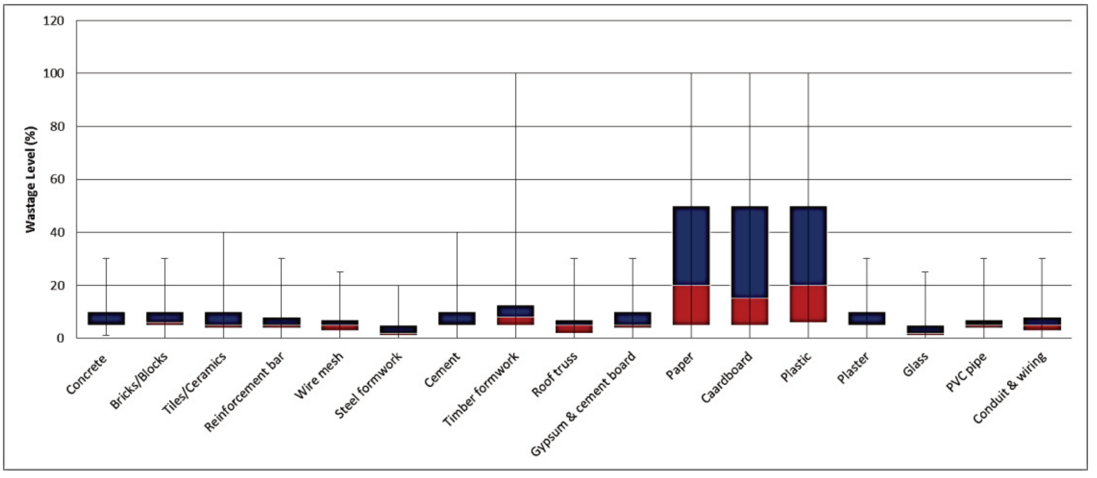


Figure 2. Boxplot of the material wastage level

Table 3. Descriptive statistical info of wastage level

Material	Data Info				
	Min	Max	Lower Quartile	Median	Upper Quartile
Concrete	1	30	5	5	10
Bricks/Blocks	0	30	5	6	10
Tiles/ceramics	0	40	4	5	10
Reinforcement bar	0	30	4	5	8
Wire mesh	0	25	3	5	7
Steel formwork	0	20	1	2	5
Cement	0	40	5	5	10

Material	Data Info				
	Min	Max	Lower Quartile	Median	Upper Quartile
Timber formwork	0	100	5	8	13
Roof truss	0	30	2	5	7
Gypsum & cement board	0	30	4	5	10
Paper	0	100	5	20	50
Cardboard	0	100	5	15	50
Plastic	0	100	6	20	50
Plaster	0	30	5	5	10
Glass	0	25	1	2	5
PVC pipe	0	30	4	5	7
Conduit & wiring	0	30	3	5	8

Through phone interviews with several randomly selected survey respondents, steel reinforcement bar and other metals such as scaffolding and ceiling brackets are the only materials that worth for the recycling purposes. Timber is usually reusable up to 3 – 4 times before eventually disposed. The wastage level for the building materials is shown in Table 4, where the percentages of each material and the rage of percentage were extracted from the median and lower-upper quartile, respectively.

Controlling the use of steel reinforcement in building sites is relatively difficult because it is cumbersome to handle due to its weight and shape. Three main reasons can be pointed out for steel reinforcement waste: some short unusable pieces are produced when bars are cut; some bars may have an excessively large diameter due to fabrication problems; and trespassing. To note, the worst-performing sites were usually the ones in which the structural design was poor in terms of standardization and detailing, causing waste due to non-optimized cutting of bars. Many problems related to poor handling of materials were also observed, resulting in large disorganized stocks, which often caused waste for the unnecessary replacement of bars by others of larger diameter.

Table 4. Wastage level for building materials

Material	Wastage Level (%)	Range of Wastage Level (%)
Concrete (*in-situ concreting*)	5	5 – 10
Bricks and Blocks	6	5 – 10
Tiles and ceramic (*eg. roofing tiles, floor tiles, wall tiles*)	5	4 – 10
Steel		
Reinforcement bar	5	4 – 8
Wire mesh	5	3 – 7
Steel formwork	2	1 – 5
Cement (*eg. wall/floor screeding*)	5	5 – 10

Material	Wastage Level (%)	Range of Wastage Level (%)
Wood		
Timber formwork	8	5 – 13
Roof truss	5	2 – 7
Gypsum and Cement boards	5	4 – 10
Packaging materials		
Paper	20	5 – 50
Cardboard	15	5 – 50
Plastic	20	6 – 50
Plaster (*eg. wall and ceiling plastering*)	5	5 – 10
Glass (*eg. window glass*)	2	1 – 5
PVC pipe (*eg. plumbing works*)	5	4 – 7
Conduit & wiring (*eg. electrical works*)	5	3 – 8

There is a combination of causes related to the waste of bricks and blocks in most poorly performing sites. There were problems related to the delivery of materials, such as the lack of control in the amount of bricks or blocks actually delivered and the damage of bricks or blocks during the unloading operation. Poor handling and transportation were the major sources of waste for bricks and blocks. As in the case of mortar, multiple handling of the same batch of bricks, due to intermediate stocks along the process flow, was observed at many sites. Insufficient planning of the site layout, lack of properly maintained pathways, and the use of inadequate equipment were among the main causes of waste. Another source of waste was the need to cut blocks and bricks, due to the lack of modular coordination in design.

The poor performance of ceramic tiles is mostly due to the lack of modular coordination and flaws in the integration between architectural and structural design. At some sites, it was the lack of planning in the distribution of materials contributed to increased waste. Most of the time, the whole package of ceramic tiles are sent to the installation places, based on the demand by the work crews. When necessary, pieces are cut, and some are left as debris when the crew moves to the next work face. In contrast, a few companies adopt the strategy of sending to the work face the exact amount of tiles in a kit, including all necessary precut pieces. This allows the operation of cutting tiles to be centralized and thereby optimized and avoids unnecessary handling of wasted parts.

Keeping track of the causes of waste of electrical popes, electrical wires, and hydraulic and sewage pipes is a fairly complex task. Both electrical and plumbing services are usually subcontracted, and the materials are sometimes provided by the specialist subcontractor. As this activity tends to be very fragmented on site, such materials are often moved into and out of the site. Another difficulty related to the measurement of waste is the fact that both plumbing and electrical service designs are often poorly detailed, and many changes in the routings of pipes are made during the installation. The most important causes of waste for these materials are short unusable pieces produced when pipes are cut; poor planning in the distribution of materials, which does not encourage cutting optimization; and replacement of elements by others that have superior performance.

Causes of Construction Waste Generation

The ranking of causes of material waste generation is shown in Table 5. It is revealed that off-cuts from cutting materials to length and packaging is the major contributor of waste generation, followed by the damage due to weather, and mishandling of materials, lack of site materials control. Change of design is ranked the 5th, followed by damage on construction site due to vandalism (6th), ordering error (7th), materials misplacement (8th), and tradesperson's error (9th). Further discussions are given as follow:

Table 5. Ranking of causes of material waste generation

Causes	∑w	RII	Rank
Residual such as off-cuts from cutting materials to length and packaging	245	0.653	**1**
Damage due to weather such as temperature and humidity	223	0.595	**2**
Materials handling such as damage during transportation, off-loading, on-site distribution, and inappropriate storage	215	0.573	**3**
Lack of site materials control and waste management plans	210	0.560	**4**
Design such as changes to design and contract document errors	189	0.504	**5**
Security such as damage on construction site due to vandalism	188	0.501	**6**
Procurement such as ordering error and supplier's error due to inaccurate data	184	0.491	**7**
Materials misplacement on site	184	0.491	**7**
Operation such as tradesperson's error and equipment malfunction	178	0.475	**9**

Residual

One of the major sources of waste was the residual scrap resulting from cutting materials, such as bricks, blocks, dimensional lumber, and sheetrock panels. In the case of wood, much of the waste involved non-reusable consumables, that is, materials that aid in the production process but do not end as part of the building. In terms of roof tiles, waste was mainly caused by sawing that becomes necessary when insufficient attention is paid to the dimensions of the available tiles in the design phase. Residual wastes could be minimized if design dimensions adapt to standard dimensions of materials. Although some residual seems unavoidable, the potential cost reduction by preventing the generation of construction waste on site is substantial and can be an incentive for participants in construction projects to put efforts in minimizing construction waste.

Weather

Weather is one of the influential factors that causes the generation of construction works. Some of the site works, such as concreting and excavation have to stop due to the severe weather condition. Heavy rain with strong storm spoils many construction materials at site, such as formwork broken, wet concrete diluted, and steel bar become rusty. Besides, hot sun with high temperature also creates problems for example it quickly hardens the wet concrete before use and this will end up as physical waste at site. Apart from that, the effect of weather is also the main contributor for non-physical waste where the weather or climate change cause delay in construction works. Site works, such as concreting and excavation work will be disturbed due to heavy rain and storm. Many constructions projects have to be rescheduled due to this unpredictable factor.

Material handling

Waste caused by the material handling can be effectively reduced by establishing procedures for the reception of goods, plan in advance adequate storage space, and provide adequate storage space and provide adequate handling resources and methods, taking into account a variety of factors including means of access. Effective procedures should be developed for the receipt and issue of materials within the site by giving adequate instructions to fixers, handlers, and others regarding the most effective practices relating to their respective tasks.

Waste management plans

Contracting companies usually have a plan to manage the materials in construction projects. These plans represent the management of material purchasing, delivery, inventories, stockiest, handling, and transportation. However, these plans are often neglected by site managers. According to Jaillon *et. al*. (2009), the lack of strategy for waste minimization was the main source of construction waste in Hong Kong. Poor planning, coupled with less attention paid to workers during material handling on site, contributing to the generation of construction waste. Having a waste management plan is the effective way in eliminating wastes. A waste management plan (WMP) puts the waste issue on the map, making it the first step to identify whether potential waste problems exist. The WMP lists specific wastes and identifies the amounts to be targeted for reduction, salvage, reuse, or recycling (McDonald and Smithers, 1998). The inclusion of a timeline in the plan allows it to identify when in the construction process specific wastes will be generated (i.e. packaging waste from interior finishing). In addition, by means of prior planning, waste prevention goals for specific materials can be established, as well as arrangements for its storage, reuse, transportation, and disposal. It is a cyclical process incorporating planning, acting, reviewing, and improving.

Design

Changes to the design while construction is in progress can cause wastes in many ways. Firstly, if the construction materials have already been purchased based on the original design, waste will result if the materials cannot be resold or returned to the supplier. Similarly, if a structure has already been constructed, a change in design may result in partial demolition, thus resulting in material wastage. Faniran and Caben (1998) revealed that design changes were the most significant source of construction waste which was ranked the highest. Similarly, Ekanayake and Ofori (2000) found that design changes were ranked as the most significant factor leading to site waste. Having a good communication throughout the project implementation among contractors, designers, and clients can help to avoid last minute changes.

Vandalism

Inadequate security is the main cause of vandalism in the construction site. Pipeline collapse, broken windows, robbery etc. can cause significant losses to the project. According to Berg and Hinze (2005), theft and vandalism can be major cost components of a construction project because of their effects and associated problems. Theft and vandalism may lead to waste whereby part of materials like cement is stolen by partially opening the sack and was hidden for a period of time until the cement caked or about to be removed from store, being oblivious it was opened, and the content get spilled away leading to waste.

Procurement

Ordering error, either over ordering or under ordering, is the main cause of waste generation. As such, the procurement must specify quality, quantity and the timing of deliveries of materials precisely. Methods of delivery and packaging and the standards by which materials are to be judged and rejected must be stated. Communications between supplier and recipient should be such that details regarding transportation, eventual site location, order of delivery, labelling and packaging sizes are available to all those involved.

Misplacement

Misplacement of materials can be the main contributor of waste in many ways. Leftover materials on site such as cut off steel bar, used formworks, or broken bricks, are mainly caused by the poor on-site management. According to Enshassi (1996), inadequate stacking and insufficient storage of materials was one of the material waste factors in Gaza Strip. Similarly, studies by Faniran and Caben (1998) and Poon *et. al*. (2004) concluded that inappropriate storage of material was the main cause of wastage on construction projects.

Operation

Worker's mistakes may be a result of their inefficiency, inexperience, or the contractor's bad supervision. According to Ekanayake and Ofori (2000), errors by trade labours were considered one of the main causes of material waste in operational group in Singapore construction industry. This is also consistent with a study in Nigeria in which poor supervision, poor workmanship, facilities for storage and re-work were identified as having high contribution to on-site material wastage. Lack of experience may also result the lack of trade's skills which lead to waste. Jaillon *et. al*. (2009) indicated that lack of experience of skilled labour was the main cause of building waste on sites in Hong Kong. Meanwhile, Alwi *et. al*. (2002) revealed that lack of trade's skill was the main cause of construction waste and the contractors are still facing a lack of trade's skills to complete a project satisfactorily in Indonesian construction projects. This indicates the need for proper training for all site personnel ranging from the site manager to various work packages headsmen on material wastage on site.

Test of Hypotheses

In order to identify if the differences in wastage level, dependent on the respondents' position (QS, PE, and SE), were statistically significant, the Kruskal-Wallis test was conducted. Table 6 summarizes the results of the Kruskal-Wallis test, which revealed that there was a statistically significant difference ($p < 0.05$) of perceived wastage level among the QS, PM, and SE for materials such as tiles and ceramic ($p = 0.000$), wire mesh ($p = 0.040$), paper ($p = 0.006$), cardboard ($p = 0.001$), plastic ($p = 0.004$), plaster ($p = 0.020$), glass ($p =$

0.000), and PVC pipe (p = 0.040). By further running the past hoc test (Table 7), it is shown that significant differences most likely occurred between QS and PM or SE; while not between PM and SE.

Table 6. Results of the Kruskal-Wallis test

Material	Chi-Square	df	Asymp. Sig.
Concrete	4.532	2	0.104
Bricks and Blocks	3.961	2	0.138
Tiles and ceramic	17.232	2	0.000*
Steel			
Reinforcement bar	2.033	2	0.362
Wire mesh	6.446	2	0.040*
Steel formwork	0.492	2	0.782
Cement	3.157	2	0.206
Wood			
Timber formwork	1.120	2	0.571
Roof truss	0.676	2	0.713
Gypsum and Cement boards	3.718	2	0.156
Packaging materials			
Paper	10.189	2	0.006*
Cardboard	14.091	2	0.001*
Plastic	10.913	2	0.004*
Plaster	7.848	2	0.020*
Glass	18.267	2	0.000*
PVC pipe	6.449	2	0.040*
Conduit & wiring	5.173	2	0.075

(* $p < 0.05$)

Table 7. Summary of *p*-value for different materials with varying group pairs

Materials	Group Pairs		
	QS – PM	QS – SE	PM – SE
Tiles and Ceramic	0.001*	0.000*	0.924
Wire mesh	0.050	0.022*	0.738
Paper	0.003*	0.064	0.096
Cardboard	0.000*	0.026*	0.130
Plastic	0.001*	0.040*	0.208
Plaster	0.016*	0.023*	0.572
Glass	0.000*	0.000*	0.369
PVC pipe	0.061	0.018*	0.790

(* $p < 0.05$)

The results on the degree of variation among professionals on causes of waste generation are shown in Table 8. The consensuses of the following causes are highly shared by the professionals: (i) operation such as tradesperson's error and equipment malfunction; (ii) damage due to weather such as temperature and humidity; (iii) security such as damage on construction site; and (iv) residual such as off-cuts from cutting materials to length and packaging; which indicate that no significant differences found among the professionals on these four causes, while the degree of variation is high for the remaining causes. By further running the past hoc test (Table 9), the similar conclusion can be drawn significant differences were found between QS and PM or SE, but not between PM and SE.

Table 8. Results of the Kruskal-Wallis test

Causes	Chi-Square	df	Asymp. Sig.
Procurement such as ordering error and supplier's error due to inaccurate data	18.169	2	0.000*
Design such as changes to design and contract document errors	13.488	2	0.001*
Materials handling such as damage during transportation, off-loading, on-site distribution, and inappropriate storage	6.464	2	0.039*
Operation such as tradesperson's error and equipment malfunction	4.043	2	0.132
Damage due to weather such as temperature and humidity	0.461	2	0.794
Security such as damage on construction site due to vandalism	0.834	2	0.659
Materials misplacement on site	7.888	2	0.019*
Residual such as off-cuts from cutting materials to length and packaging	0.487	2	0.784
Lack of site materials control and waste management plans	20.300	2	0.000*

(* $p < 0.05$)

Table 9. Summary of *p*-value for different materials with varying group pairs

Materials	Group Pairs		
	QS – PM	QS – SE	PM – SE
Procurement such as ordering error and supplier's error due to inaccurate data	0.001*	0.000*	1.000
Design such as changes to design and contract document errors	0.001*	0.008*	0.350
Materials handling such as damage during transportation, off-loading, on-site distribution, and inappropriate storage	0.055	0.020*	0.815
Operation such as tradesperson's error and equipment malfunction	0.076	0.113	0.803
Damage due to weather such as temperature and humidity	0.767	0.512	0.716
Security such as damage on construction site due to vandalism	0.892	0.379	0.500
Materials misplacement on site	0.006*	0.065	0.457

Materials	Group Pairs		
	QS – PM	QS – SE	PM – SE
Residual such as off-cuts from cutting materials to length and packaging	0.744	0.489	0.751
Lack of site materials control and waste management plans	0.000*	0.000*	0.853

(* $p < 0.05$)

The results of both hypotheses tests indicate that the PM and SE are sharing the same opinion with regard to the level of material wastage, as compared to the QS. This is very much a result of the extent to which one person involves in the project. While the QS does make allowances for waste when assessing the price of a material, most of the time, he/she is just based on his/her own estimation from the desktop assessment or experiences from the past project. Since the activities on a construction site change as the project progresses, the quantity of the associated waste may also change. Waste estimation done in the beginning of the construction project can only provide a "snapshot" of the waste in general. In order to get a picture of the overall quantities of waste arising during the construction of a complete building a series of studies at different stages of the project is required.

In the case of PM and SE, their opinion on material wastage mostly comes from their direct involvement in the project. There are many circumstances which are difficult to be predicted, such as site breakages, vandalism, and theft. The characteristics of many construction projects – a "one-off" design, constructed using a variety of materials that change as the job progresses, by a group of workers and sub-contractors that may not have worked together before – also add particular challenges to the waste quantification. This becomes more obvious when dealing with packaging materials, because estimation of these materials is difficult to be made in the design stage of a project. Most of the time, the PM and SE can make a better and more accurate judgement on material wastage level because they are fully involved during the construction stage and to keep record of the waste disposal. This is especially true for the SE as he/she is the person that makes visual assessment of the main materials in each waste stream, as well as confirming that waste associated with all the main materials being used on-site is represented in the waste stream identified. Depending on the scope of the audit, the waste streams considered may also include concrete or other materials hosed down the drain, subcontractors taking away their own waste and rubble and spoil removed by demolition and excavation contractors.

CONCLUSION

Quantification of construction waste provides a necessary tool for evaluating the true size of the waste, and hence enables proper decision to be made for waste minimization and management. It should be done as early as possible since it involves stakeholders from every stage of the construction project (Poon *et. al.*, 2004). Given that material production for construction work accounts for a significant percentage of all energy consumed nationally in newly developing countries, it becomes vital that the construction industry strives to reduce waste at all stages of construction. Through the present study, the wastage level for different materials commonly used in the construction site, as well as the common causes of the construction waste generation was successfully determined. It is expected that these findings can contribute to improved estimation of C&D waste generation in construction project, thereby enhancing knowledge-based decision-making in developing appropriate strategy for construction waste management. Apart from that, the study reveals that significant difference existed among professional perceptions of wastage level and causes of waste generation. Even though the respondents are experienced construction professionals, involving in the construction process and management flow that have been commonly practiced for decades, their responses are not consistent as expected, especially between the QS and PM or SE. Different extent of involvement in the project has significant impact on their point of view with regard to the construction material wastage level, as well as the causes of construction waste generation.

The present study adopts a survey research design and relies on professionals' perception during construction operation which is considered a subjective assessment. Future study should adopt a case study research design and actual measurement of materials wastage and associated cost overruns. Nevertheless, the presented construction material wastage level can provide interested parties, such as local authorities, policy makers, government, as well as the contractors and practitioners with a guideline to consider in order to make more informed and sustainable decisions about the construction waste management. The different rankings of the causes can be of useful in assisting the placement of levels of importance during the development of construction waste management strategy.

REFERENCE

Adewuyi, T.O. and Odesola, I.A. (2015). Factors affecting material waste on construction sites in Nigeria. *Journal of Engineering and Technology*, 6(1), 82 – 99.

Adnan, E. (1996). Materials control and waste on building sites, *Building Research & Information*, 24(1), 31 – 34.

Akinkurolere, O.O. and Franklin, S.O. (2005). Investigation into waste management on construction sites in South Western Nigeria, *American Journal of Applied Sciences*, 2(5), 980 – 984.

Alwi, S., Hampson, K. and Mohamed, S. (2002). Non value-adding activities, a comparative study of Indonesian and Australian construction projects. In Proceedings of the 10th Annual Conference of the International Group of Lean Construction (IGLC '02), Gramado, Brazil, 2002.

Berg, R. & Hinze, J. (2005). Theft and Vandalism on Construction Sites. *Journal of Construction Engineering and Management*, 131(7): 826 – 833.

Bossink, B.A.G. and Brouwers, H.J.H. (1996). Construction waste: Quantification and source evaluation. *Journal of Construction Engineering and Management*, 55 – 60.

Carmichael, R., Edwards, D.J. and Holt, G.D. (2007). Plant managers' perceptions of plant security systems. Engineering, *Construction and Architectural Management*, 14(1): 65 – 78.

Cheung, C.M., Wong, K.W., Fan, C.N. and Poon, C.S. (1993). *Reduction of Construction Waste: Final Report*, Hong Kong Polytechnic University and Hong Kong Construction Association, Hong Kong.

Chong, H. Y., & Zin, R. M. (2010). A case study into the language structure of construction standard form in Malaysia. *International Journal of Project Management*, 28(6), 601-608.

de Vaus, D. (2002). Surveys in Social Research, Routledge, London, UK, 5th edition.

Ekanayake, I.L. and Ofori, G. (2000). Construction material waste source evaluation, in *Proceedings of the Strategies for a Sustainable Built Environment*, Pretoria, South Africa.

Enshassi, A. (1996). Materials control and waste on building sites. *Building Research and Information*, 24(1), 31 – 34.

Fadiya, O.O., Georgakis, P. and Chinyio, E. (2014). Quantitative analysis of the sources of construction waste. *Journal of Construction Engineering*, Volume 2014, 9 pages.

Faniran, O. and Caben, G. (1998). Minimizing waste on construction project sites. Engineering, *Construction and Architectural Management*, 5(2), 182 – 188.

Foo, C.H., Hamid, Z.A., Din, M.I. and Norman, M.R. (2015). Study on Industrialised Building System (IBS) Adoption Level and Contractors' Readiness in Malaysia 2013. *Malaysian Construction Research Journal (MCRJ)*, 17(2), 1 – 19.

Gavilan, R.M. and Bernold, L.E. (1994). Source evaluation of solid waste in building construction, *Journal of Construction Engineering and Management*, 120(3), 536 – 552.

Guthrie, P., Woolveridge, C. and Coventry, S. (1998). *Managing Materials and Components on Site*, Construction Industry Research and Information Association, London.

Jaillon, L., Poon, C.S. and Chiang, Y.H. (2009). Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. *Waste Management*, 29(1), 309 – 320.

Kometa, S.T., Olomolaiye, P.O., and Harris, F.C. (1994). Attributes of UK construction clients influencing project consultants' performance. *Construction Management & Economics*, 12(5): 433.

Koshy, R. and Apte, E.M. (2012). Waste minimization of construction materials on bridge site (cement and reinforcement steel) – a regression and correlation analysis, *International Journal of engineering and Innovative Technology*, 2(1), 6 – 14.

Mahayuddin, S.A., Pereira, J.J., Badaruzzaman, W.H.W. and Mokhtar, M.B. (2008). Construction waste management in a developing country: case study of Ipoh Malaysia. *WIT Transactions on Ecology and the Environment*, Vol. 109, 481 – 489.

Mahayuddin, S.A., Wan Zaharuddin, W.A.Z. (2013). Quantification of Waste in Conventional Construction. *International Journal of Environmental Science and Development*, 4(3), 296 – 299.

Mann, P.S., 2005. *Introductory Statistics Using Technology*, fifth ed. John Wiley & Sons, New York.Matthews J. (1996). A Project Partnering Approach to the Main Contractor-Subcontractor Relationship. Loughborough University.

McDonald, B. and Smithers, M. (1998). Implementing a waste management plan during the construction phase of a project. *Construction Management and Economics*, 16(1): 71 – 78.

Naoum, G.S. (2003). *Dissertation Research and Writing for Construction Students*, Butterworth-Heinemann, London.

Napier, T. (2012). Construction waste management, National Institute of Building Science, http://www.wbdg.org/resources/cwmgmt.php

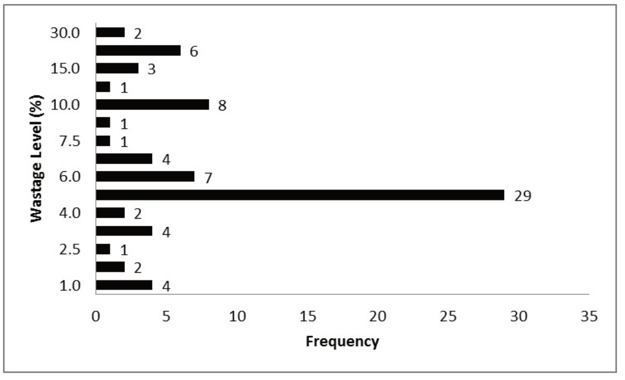
Navon, R. and Berkovich, O. (2006). An automated model for materials management and control. *Construction Management and Economics*, 24(6): 635 – 646.

Poon, C.S., Yu, A.T.W., Wong, S.W. and Cheung, E. (2004). Management of construction waste in public housing projects in Hong Kong. *Construction Management and Economics*, 22(7), 675 – 689.

Poon, C.S., Yu, A.T.W. and Ng, L.H. (2001). *A Guide for Managing and Minimizing Building and Demolition Waste*, The Hong Kong Polytechnic University, Hong Kong.
Skoyles, E.R. and Hssey, H.J. (1974). Wastage of materials, Building Research Establishment current paper, 44/74.
Tam, V.W.Y. (2008). On the effectiveness in implementing a waste-management-plan method in construction. *Waste Management*, 28(6): 1072 – 1080.
Tam, V.M., Shen, L.Y. and Tam, C.M. (2007). Assessing the levels of material wastage affected by sub-contracting relationships and projects types with their correlations, *Building and Environment*, 42(3), 1471 – 1477.
Tam, C.M., Deng, Z.M., Zeng, S.X., and Ho, C.S. (2000). Quest for continuous quality improvement for public housing construction in Hong Kong. *Construction Management and Economics*, 18(4): 437 – 446.
Teo, S.P., Abdelnaser, O. and Abdul, H.K. (2009). Material wastage in Malaysia construction industry, International Conference on Economic and Administration, Faculty of Administration University of Bucharest Romania, 257 – 264.
Yuan, H. and Shen, L. (2011). Trend of the research on construction and demolition waste management. *Journal of Waste Management*, 31(4): 670 – 679.

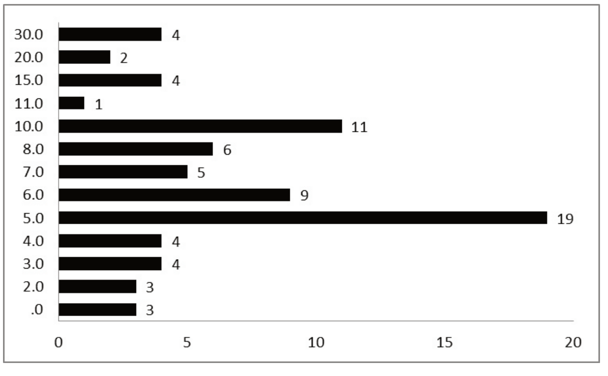
Appendix 1: Frequency Graph

Concrete



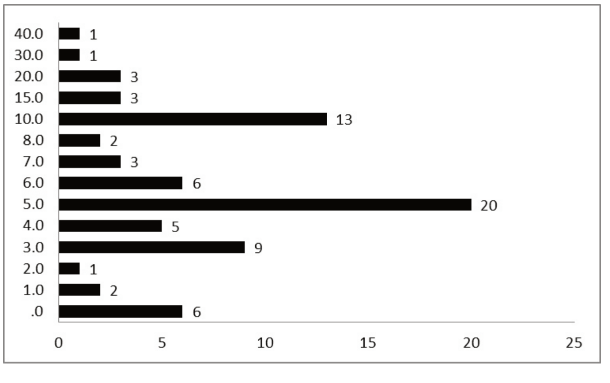
Mean		7.693
Median		5.000
Mode		5.0
Skewness		1.967
Std. Error of Skewness		.277
Minimum		1.0
Maximum		30.0
Percentiles	25	5.000
	50	5.000
	75	10.000

Bricks and Blocks



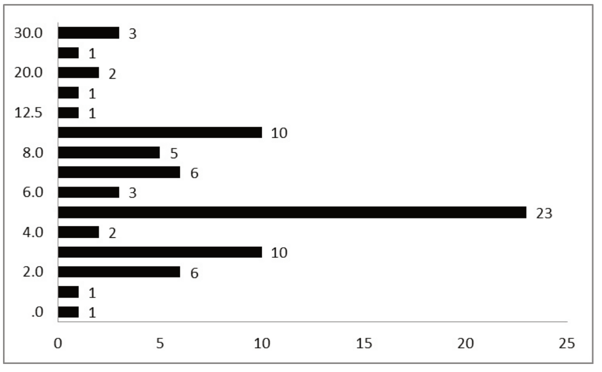
Mean		8.093
Median		6.000
Mode		5.0
Skewness		2.157
Std. Error of Skewness		.277
Minimum		0.0
Maximum		30.0
Percentiles	25	5.000
	50	6.000
	75	10.000

Tiles and Ceramics



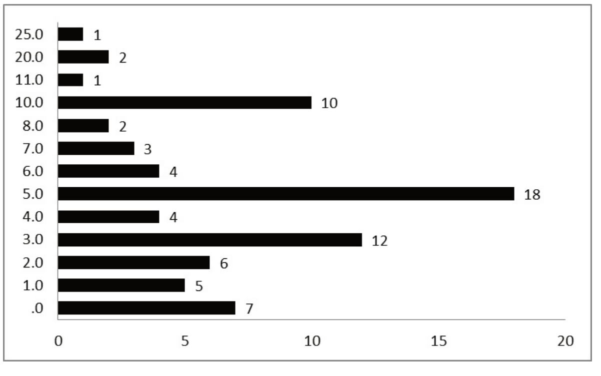
Mean		7.053
Median		5.000
Mode		5.0
Skewness		2.691
Std. Error of Skewness		.277
Minimum		0.0
Maximum		40.0
Percentiles	25	4.000
	50	5.000
	75	10.000

Reinforcement Bar



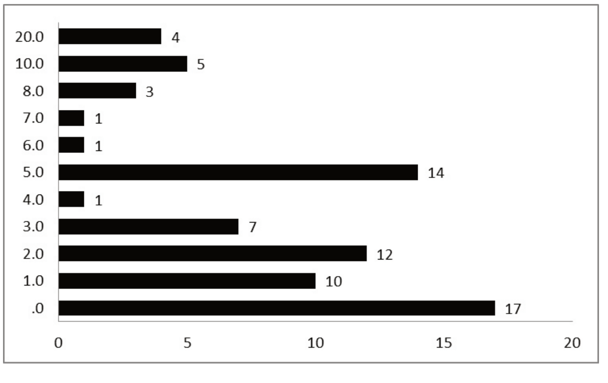
Mean		7.313
Median		5.000
Mode		5.0
Skewness		2.370
Std. Error of Skewness		.277
Minimum		0.0
Maximum		30.0
Percentiles	25	4.000
	50	5.000
	75	8.000

Wire Mesh



Mean		5.280
Median		5.000
Mode		5.0
Skewness		2.012
Std. Error of Skewness		.277
Minimum		0.0
Maximum		25.0
Percentiles	25	3.000
	50	5.000
	75	7.000

Steel Formwork



Mean		3.947
Median		2.000
Mode		0.0
Skewness		2.090
Std. Error of Skewness		.277
Minimum		0.0
Maximum		20.0
Percentiles	25	1.000
	50	2.000
	75	5.000

THE PERCEPTION OF FUTURE DECISION MAKERS ON THE BUILDING PROFESSION

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Abstract
Out of all the professionals involved in the built environment, the most misunderstood is the Professional Builder. To avoid the dearth of the profession and ensure a sustainable profession, the study as a social judgment aims to assess the building profession in the eyes of future decision makers in Nigeria. Through a purposive sampling method, a structured questionnaire was distributed to two hundred and thirty-six (236) final year students of selected private and public universities in Lagos and Ogun state, Nigeria, termed as future decision makers. Using SPSS 17.0, descriptive and inferential statistics test such as Mean Score, Analysis of Variance and Factor analysis were used for the study. The results of this study indicated that future decision makers in the selected institutions in Nigeria had very little awareness of major and evolving roles of the professional builder. In conclusion, two (2) major areas can influence the popularity of the profession which are the Student/Professional builders' participation and the Professional Associations. The study developed a framework to ensure the sustainability of the profession by influencing the awareness level of future decision makers.

Keywords: *Building Profession, Future decision makers, Professional Association, Social Judgment, Sustainability*

INTRODUCTION

The pivotal role of the building and construction industry makes it essentially a service industry that primarily aims at satisfying the clients. The major goals of quality, time and cost are centrally fulfilled with the cautious engagement of stakeholders in the built environment. Apart from these three major goals, Obiegbu (2009) explained that in addition, clients are placing greater demand on project organization, procurement and management. In order to achieve these crucial project requirements, the issues regarding each profession is called to fore. In understanding the term "profession" Vee and Skitmore (2003) defined it as an occupation that requires both advanced study and mastery of a specialized body of knowledge undertaken to promote, ensure and safeguard some matter that significantly affects others well-being. A profession is guided by continuous training and code of ethics. According to Fellows (2003), professionalism in the construction industry involves exercising the body of unique and expert knowledge into constructional activities. Harnessing professionalism brought about the tool of the National Building Code 2006. The National Building Code of the Federal Republic of Nigeria (2006) has clearly stated the professionals actively involved in the construction industry and their roles in order to forestall the challenges posed by quacks and imposter in the construction industry. But this has refused to yield maximum results. Oseghale, Ikpo and Ajayi (2015) argued that until the operational document known as the Urban and Regional Planning Law is implemented in most states in Nigeria, the National Building Code may not yield the desired results. Bamisile (2004) observed that there is still confusion and misinterpretation of the roles of some of the professionals in the management of construction projects in Nigeria. Anyanwu (2013) identified the lack of proper working knowledge on the part of majority of people on the roles of each professional in the building industry as a major factor.

Various issues plaguing the building industry ranging from rework, contract malpractice, delay, time and cost overrun, abandonment, high spate of accident and building collapse can be attributed to questions of unprofessionalism. Majorly, the incidence of building collapse in Nigeria over the last decade has become alarming and does not show any sign of abating. Each collapse carries along with it tremendous effects that cannot be easily forgotten by any of its victims. In 35 percent of the reported cases of building collapse in Nigeria between 1974 – 2010, Windapo and Rotimi (2012) revealed that no fewer than six lives were lost. Apart from the human lives wasted, economic and social waste such as loss of properties, incomes, loss of public trust and dignity for the professionals, exasperation of crises among the stakeholders and environmental disaster are also experienced.

According to Usman, Inuwa and Iro (2012), these unethical practices, which affect the general well-being of a nation, is an indication of the total loss of values, norms and morals that form the foundations of a society. Even the professionals who are trained and therefore expected to exhibit a high level of professionalism are not exempted from this moral decadence (Payne, Chelson and Reavill, 1999). Construction professionals have a duty to clients and the nation. If construction professionals are perceived to be incompetent or their roles unknown with the glaring challenges of the building industry, discharging their duties would become difficult. It is therefore imperative to safeguard ones' profession. With diverse tools to safeguard each profession comes this study. The future of professional Builders in the construction industry is hinged on future decision makers' ability to know the roles of the professional builder and be able to engage them accordingly.

The future decision makers in this study can be likened to individuals categorized as the Generation Z; the new silent generation or the internet generation. These are the generation born between the years 1995 – 2007. These set of people are pioneers in witnessing the rise of the information age, the internet and the digital globalization making the world a global village. Members of Generation Z are typically thought of as being comfortable with technology, and interacting on social media websites for a significant portion of their socializing. Individuals in the Generation Z are between 18 – 24 years of age making them youths according to international practice. According to the National Bureau of Statistics (2012), these group constitutes above 20% of Nigeria's population. Ruhl (2010) argued that these set of individuals constitute not only a formidable demographic force, but also make up the next generation of parents, workers and leaders. Brotheim (2014) suggested that they will be better future employees due to the skills needed to take advantage of advanced technologies, which will be helpful to the typical company in today's high tech world. Levit (2015) and Williams (2015) opined that the Generation Z are always eager to be involved in their community and their futures. This makes these set of individuals valuable to this study. This study intends to assess the social judgment of roles of building profession by people who are potential employers and potential policy makers that may affect the Building profession in the future.

REVIEW OF RELATED LITERATURES

The Building Industry

According to Mbamali and Okotie (2012), buildings have evolved with man's progress and development. The development of the built environment has been hinged on the dynamic nature of human needs (Mosaku, Kehinde and Kuroshi, 2006). Building industry as defined by Akinluyi and Adeleye (2013) is the collection of different licensed professionals (architects, builders, quantity surveyors, etc.) working as one, on construction sites to produce the proposed building. Whereas, Flanagan (2006) defined it as that sector of the economy that is responsible for producing the total life cycle of buildings, excluding the infrastructure and civil engineering works. Buildings, an aspect of housing is regarded as the second most important need to man. According to Towry-Coker (2006) the building sector is adjudged to be the second biggest industry in the world. The National Bureau of Statistics (2015) reported that the Nigerian building and construction industry averages over 18 percent growth rate, contributing an average of 3 percent yearly (over $10 Billion) to the real GDP of the nation. The Gross Capital formation shown in Table 1 shows the net increase in the output of buildings in the measured period (2010 – 2012). This huge financial outlay and added value to the environment are worthy of presentation as legacies for succeeding generations (Dada, 2006; Towry-Coker, 2006).

Table 1. Gross Capital Formation of the Building Industry. (In =N= millions)

Buildings	2010	2011	2012
Purchase or construction of residential building	1,994.95	3,465.26	4,137.30
Purchase or construction of non –residential building	2,258.78	2,824.89	3,353.06
Purchase or construction of other building structure	1,822.73	2,308.10	2,828.17
Major repairs and renovations	1,825.15	2,579.58	2,976.34

(Source: National Bureau of Statistics, 2015)

The Professional Builder

According to Ogunbiyi (2015), the practice of the building profession has been misunderstood to a large extent even by team members in the building and construction industry. This has culminated into situations where professional builders are referred to as contractors, foremen, brick-layers etc. on building construction sites. Olatunji, Oke and Owoeye (2014) defined a professional Builder as an academically trained specialist and statutorily registered professional responsible for Building Production Management, Construction and Maintenance of Buildings for the use and protection of mankind and his assets. Bamisile (2004) explained that the Builder is the professional at the centre of the physical construction of buildings. From the design stage to the completion of the building, the relevance of the Builder is crucial. Although, Bamisile (2004) stated that the Builder's role takes prominence at the construction stage. The building profession was born in Nigeria in 1967 an overseas centre of the Institute of Building (IOB), London. Only the Council of Registered Builders of Nigeria (CORBON) has the mandate and statutory obligation to register and name a person or persons as Builders by virtue of Decree 45 of 1989, now ACT CAP 40, 1990 law of the Federal Republic of Nigeria. The Law also recognizes the Nigerian

Institute of Building (NIOB) as the only professional body for those engaged or about to be engaged in the building profession.

Roles of the Professional Builder

According to the 1996 professional scale of fees for consultants in the Nigerian construction industry, which is a government controlled document used to regulate the fees of all participating professionals in the construction industry. The builders' area of practice as highlighted in the document as stated by Ogunbiyi (2015) includes Building Production/Construction Management, Building Maintenance Management, Project Management, Feasibility and Viability Study, Arbitration and Litigation Services, Report on abandoned projects, Reactivation of abandoned projects, Resident Supervision, Management of direct labour project and Building Survey. Additional services ratified by the professional and statutory bodies of the profession of Building through a document termed the "Yellow book" identified services such as Estimating and pricing for tenderers in Building projects, Risk Management, Value Management, Facilities Management in Buildings, Technical and Project auditing, Preparation of material, labour and plant schedule, Procurement management in DandB and BOT Building projects, Site Visit or attending any site meeting other than the normal monthly meeting, Evaluation and settlement of Building contractors' claims, Development and preparation of Building Bye-laws for Estate, Builders' input in the preparation of Pre-Design technical reports and Environmental Impact Analysis report and Processing of Certificate of Practical Completion and Fitness for Habitation. In recognizing the roles of the Builder, Bamisile (2004) identified three (3) major roles that are peculiar to the profession. The roles are preparing buildability and maintainability analysis, Production management documents and manage the production process on site.

Buildability and Maintainability analysis.

Aina and Wahab (2011) observed that buildability problems arise from complexity of project, faulty and defective working drawings, resistance of client to buildability programmes, budgetary limitation and non-standardization of design. Obiegbu (2009) explained that these buildability problems is as a result of the poor correlation between design and construction. Buildability, though a relatively new concept in Nigeria is increasingly becoming a major requirement in building practice. Aina and Wahab (2011) explained that clients are continuously impatient with the poor delivery of project requirements with buildability problem increasing in proportional to the period of time. Bamisile (2004) defined buildability as the ability to construct a building efficiently, economically and to an agreed or specified standard from its constituent materials, components and sub-assemblies. A widely accepted definition of buildability is that of the Construction Industry Research and Information Association (CIRIA, 1983), stated that buildability is the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building. Ogunbiyi (2015) explained that buildability and maintainability entails the study of the production documents meant for a building project and produced by the other consultants on the project such as working drawings, Bill of quantities, specifications etc. The purpose which is to assess if the building on paper can stand in reality with a minimal no error in construction. Obiegbu (2009) added that it helps to identify the most cost effective methods of site execution (production), future maintenance and to draw the attention of the designers to any part of the design, working drawings, schedules and specifications that could be an impediment in achieving the clients' objective. The buildability and maintainability analysis which is one of the roles of the Professional builder aims to achieve value for the client through cost optimization, time optimization and getting it right at first and only attempt.

Production Management documents.

Section 2.32 of the National Building Code (2006) emphasized the onerous task of a registered builder in preparing construction programme, project quality management plan, project health and safety plan; a major aspect of building production management. Ogunbiyi (2015) referred to this stage of producing these documents as the construction planning stage. At this stage the builder as a consultant prepares these documents. Obiegbu (2009) noted that if the Builder is not in charge of producing these documents, he or she can be involved in vetting the production management documents submitted by the main or sub-contractor. Ogunbiyi (2015) added that at this stage the Builder can also prepare the construction project methodology, project information required schedule and the project early warning system chart.

Managing the production process on site.

In managing the production process on site, Obiegbu (2009) stated that the Builder offers the client the following professional services; Highest quality of work and attention detail, Speed, efficiency and minimum disruption in project execution, Value for money, Compliance with statutory codes and best international practice, Prompt, courteous and efficient dealings with any challenges that might arise on site, Highest standard of safety on construction site and Engaging trained and competent artisans and craftsmen on site. Ogunbiyi (2015) explained that the job of the builder at this stage is multi-varied as the production of buildings differ. These roles are clearly summarized in the National Building Code (2006) in Section 13.12.4. The role of the professional builder according to Obiegbu (2009) is about the dynamics of building construction in order to achieve specified quality standards at first attempt.

Factors affecting Students' Perception of Professional Courses

According to Bandura (1986), the experiences acquired during the formative period of an individual's life leaves an indelible mark on personal decisions he/she makes. Bandura, Barbaranelli, Caprara and Pastorelli (2001) added that the perceived efficacy and academic orientations of youth determine their decisions to pursue different types of careers and also determine which careers they may avoid. With the supply of engineering graduates in decline while the anticipated demand for these skills is on the rise (Archer *et. al.*, 2012), Becker and Park (2011) opined that attracting students to this profession requires using a teacher who understands the engineering design and problem-solving process. This highlights the role a teacher plays in sharpening the perception of students towards a discipline. Apart from this, negative characteristics such as traditional stereotyping and corporate accounting scandals (Allen, 2004; Hammani and Hossain, 2010), financial scandals and irregularities (Jackling, Cooper, Leung and Dellaportas, 2007; Sugahara, Hiramatsu and Boland, 2009), conflict of interest, earnings management and whistleblowing (Jackling *et. al.*, 2007) have defined and further marred the perception of the accounting profession. On the other hand, some students have somewhat positive about the accounting profession (Germanou, Hassall and Tournas, 2009; Hammani and Hossain, 2010). This means that the integrity of a profession can also promote the perception of students towards a profession. According to Karakaya, Quigley, Bingham, Hari and Nasir (2014), misperception is a very powerful tool that propels the reluctance of many college students to consider a career in sales. Negative perceptions of selling may be attributed to a lack of student knowledge about the profession (Stevenson and Bodkin, 1998). The perception can appear in the profession itself, Mackay (2004) argued that attitudes held by one profession or group can have a significant effect on their perception of and behaviour towards another profession. Ethical concerns have been indicated as reasons why some students are hesitant to select personal selling as a career (Burnett, Pettijohn and Keith, 2008) due to the perceived inherent unethical behaviours (Sparks and Johlke, 1996; Lysonski and Durvasula, 1998). Although, students who had taken a course in sales have a significantly more positive image of selling and salespeople and are more optimistic about selling than students who had not taken a sales course (Bristow, Gulati, Amyx and Slack, 2006). Barat and Spillan (2009) and Karakaya *et. al.* (2014) also suggested that nationality and cultural background can influence students' perceptions of and feelings toward a particular profession. In this age of the internet and social media, Nga and Mun (2013) opined that media visibility has a role to play.

METHODOLOGY

This study designed and conducted a quantitative survey as an appropriate method for data collection. Descriptive research design was adopted and was carried out using the questionnaire as the research instrument to achieve the objectives of the study. Purposive sampling method was used to arrive at the samples engaged for this study because a comprehensive and updated list of all registered students in the three institutions could not be obtained as at the time of this research. The students in this study are final year students of selected private and public universities (target respondents) in Lagos and Ota, Ogun state. These students having undertaken four or five year studies in their respective institutions and prepared for life after school are considered as future decision and policy makers in the country in no distant future.

Population and Sample Size

The study was performed in the south-western part of Nigeria, cities notably, Lagos and Ogun state. The study was carried out in University of Lagos, Akoka, Lagos; Covenant University and Bells University of Technology, both in Ota, Ogun state. University of Lagos was chosen because it represents one of the foremost Nigerian universities in the country. While, Covenant University is considered as one of the top-rated institutions in the country, Bells University of Technology is the first private university of Technology in the country. The population of this study included full time registered students of the three higher institutions from faculties/colleges ranging from social sciences, sciences, business administration, arts, law, education, engineering/technology, medical sciences and environmental sciences. The distribution of students from the institutions are shown in Table 1 below.

Table 2. Distribution of students from the selected universities for the study

Cities	Lagos	Ota	
Faculties/Institution	**University of Lagos**	**Covenant University**	**Bells University of Tech**
Social sciences	8	13	9
Sciences	26	15	3
Business Administration	9	5	2
Arts	10	-	-
Law	4	-	-
Education	22	-	-
Engineering/Technology	8	11	10
Medical sciences	1	1	1
Environmental sciences	15	8	6
Total	**103**	**53**	**31**

(Source: Field Survey, 2015)

Out of the 387 copies of research questionnaire distributed, 236 were completed and returned representing a 61% response rate. The returned copies were scrutinized for errors, omissions, completeness and inconsistencies and 187 were found to be adequately completed and therefore used to carry out the analysis.

Questionnaire design

The questionnaire was developed from a thorough literature review. A pilot study was conducted with 3 professional builders and 2 academic lecturers who have relevant experience in their respective field. The aim of the pilot study is to ensure that the questions was phrased correctly for ease of answering, to ensure the appropriateness of the identified roles of professional builders, and provide appropriate measures for the study design. The pilot study results revealed that some roles of builders and associated factors affecting level of awareness of the builders' roles were related or vague and were omitted.

Reliability of the research instrument

The Cronbach alpha reliability test was carried out to determine the reliability of the responses obtained for each of the roles of professional builders and the factors influencing the level of awareness of students to the roles listed in the research instrument. Nunnally and Bernstein (1994) suggested that the Cronbach alpha value must be greater than 0.7. In this study, Cronbach Alpha values of all variables is 0.941 if items are deleted which are beyond the value of reliability needed.

RESULT AND DISCUSSION

In this section, the study assesses the perception of students who are future decision and policy makers on their level of awareness of the roles of professional builders and the significant factors influencing their level of awareness.

Level of awareness of students on the roles of professional builders

Sixteen (16) roles of professional builders as performed in the construction industry and related field identified from literature and corroborated by construction professionals were presented in the survey. Table 3 shows the level of awareness of students on the roles of builders. Students are fairly aware that managing building construction and employing labour for construction activities are few of the roles of professional builders. These outlined roles are more popular functions ascribed to professional builders especially when compared to other "lesser" known roles. It can be inferred that as the name builder implies, this set of professionals are associated with building edifices and managing construction activities. The roles of builders are also known to include but not limited to Building production/construction management and employing labour in direct labour projects. Considerable percentage of private clients (who are also parents to some of the students) adopt direct labour projects as its procurement route because of its lower cost (Dada, 2012; Mbamali and Okotie, 2012; Ogunsanmi, 2013), hence they reckon that builder is best saddled with the responsibility of employing labour for building projects.

Table 3. Level of awareness of students towards roles of professional builders

Roles of professional builders	Mean	Remark
Building production/construction management	3.52	Fairly aware
Employing labour in direct labour projects	3.50	Fairly aware
Building maintenance management	3.38	Very little awareness
Resident supervision of building projects	3.30	Very little awareness
Facilities management in buildings	3.26	Very little awareness
Feasibility and viability studies of building projects	3.24	Very little awareness
Project management services in building projects	3.24	Very little awareness
Health safety and welfare of workers on building sites	3.23	Very little awareness
Preparation of construction quality management plan	3.20	Very little awareness
Preparation of construction programme of works	3.16	Very little awareness
Risk management in buildings	3.11	Very little awareness
Estimating and pricing for tenderers in building projects	3.07	Very little awareness
Building condition survey	3.04	Very little awareness
Value engineering of building projects	2.90	Very little awareness
Expert witness in arbitration and litigation	2.71	Very little awareness
Arbitration and litigation services in disputes settlement	2.69	Very little awareness

As depicted in Table 3, it is imperative to note that students have very little awareness of the remaining other highlighted fourteen (14) roles of professional builders in the study. Supervision of building projects, health, safety and welfare of workers on site, preparation of construction programme of works, building condition survey, value engineering of building projects are some of the roles of builders that students are rarely aware about as it relates to builders.

The study also assessed the significant difference among the colleges/faculties of students on the level of awareness of roles of professional builders. The significant difference was evaluated with the analysis of variance (ANOVA). The result was hitherto presented in Table 4.

Table 4. Significant difference among faculties of students on their level of awareness

		Sum of Squares	df	Mean Square	F	P value.	Sig
Feasibility studies of building projects	Between Groups	4.940	2	2.470	1.432	.242	NS
	Within Groups	310.481	180	1.725			
	Total	**315.421**	**182**				
Resident supervision of building projects	Between Groups	21.647	2	10.823	7.329	.001	S
	Within Groups	264.331	179	1.477			
	Total	**285.978**	**181**				
Arbitration and litigation services in disputes settlement	Between Groups	3.255	2	1.628	1.252	.288	NS
	Within Groups	231.419	178	1.300			
	Total	**234.674**	**180**				
Building production/construction management	Between Groups	12.285	2	6.142	4.203	.016	S
	Within Groups	258.665	177	1.461			
	Total	**270.950**	**179**				
Expert witness in arbitration and litigation	Between Groups	5.427	2	2.713	1.894	.153	NS
	Within Groups	253.551	177	1.432			
	Total	**258.978**	**179**				
Health safety and welfare of workers on building sites	Between Groups	5.560	2	2.780	1.723	.182	NS
	Within Groups	287.225	178	1.614			
	Total	**292.785**	**180**				
Preparation of construction programme of works	Between Groups	6.760	2	3.380	2.292	.104	NS
	Within Groups	259.541	176	1.475			
	Total	**266.302**	**178**				
Value engineering of building projects	Between Groups	5.490	2	2.745	1.974	.142	NS
	Within Groups	247.515	178	1.391			
	Total	**253.006**	**180**				
Preparation of construction quality management plan	Between Groups	8.401	2	4.201	2.932	.056	NS
	Within Groups	256.478	179	1.433			
	Total	**264.879**	**181**				

		Sum of Squares	df	Mean Square	F	P value.	Sig
Building maintenance management	Between Groups	13.065	2	6.532	4.378	.014	S
	Within Groups	270.060	181	1.492			
	Total	**283.125**	**183**				
Project management services in building projects	Between Groups	1.712	2	.856	.552	.577	NS
	Within Groups	272.959	176	1.551			
	Total	**274.670**	**178**				
Building condition survey	Between Groups	6.462	2	3.231	1.781	.172	NS
	Within Groups	321.182	177	1.815			
	Total	**327.644**	**179**				
Estimating and pricing for tenderers in building projects	Between Groups	2.837	2	1.418	.847	.430	NS
	Within Groups	301.240	180	1.674			
	Total	**304.077**	**182**				
Risk management in buildings	Between Groups	3.944	2	1.972	1.163	.315	NS
	Within Groups	301.846	178	1.696			
	Total	**305.790**	**180**				
Employing labour in direct labour projects	Between Groups	8.321	2	4.160	2.405	.093	NS
	Within Groups	311.395	180	1.730			
	Total	**319.716**	**182**				
Facilities management in buildings	Between Groups	2.481	2	1.241	.789	.456	NS
	Within Groups	284.513	181	1.572			
	Total	**286.995**	**183**				

Table 4 indicated that among the sixteen (16) roles of professional builders, only resident supervision of building projects, building production/construction management and building maintenance management are the roles of professional builders with significant difference among the different faculties within the selected universities in the study. This is inferred from their p-value which is less than 0.05 (5% level of significance); signifying they are significant. This means that the colleges and/or faculties student are, have an effect on level of awareness of three (3) major roles of the professional builder. This could be as a result of the fact that few individuals are conversant with the three roles highlighted. In a similar scenario, it can be concluded that faculties or colleges do not have significant effect on the other thirteen roles of professional builders. The p value is greater than 0.05 ($p > 0.05$). This result is borne out of the fact that majority of the thirteen (13) roles are evolving roles of professional builders and hence will only be known when concerted efforts are made by students or related stakeholders to increase the awareness of the profession in tertiary education and in the industry at large. Ogunbiyi (2015) argued that the professional builder is one of the most misunderstood professional in the built environment. Essentially, the professional builder who is responsible for the translation of the design at the construction stage is most times not engaged. The Council for the Regulation of Engineering in Nigeria (COREN) in a press release asserted that most of the collapsed buildings belong to private developers who deliberately refuse to engage qualified professionals to supervise the construction after receiving approvals from development control authorities (Alum, 2012). A coalition of professionals from the seven built environment professions in Nigeria, Building Collapse Prevention Guild (BCPG), in a recent press release blamed quacks or use of wrong professionals for virtually all the buildings that have collapsed in the country. They argued that the best design in the world is worthless if it is not faithfully implemented at the construction site, of which the professional Builder must play a crucial part.

Factors influencing the level of awareness of the roles of professional builders.

The study identified eleven (11) factors influencing the level of awareness of the roles of professional builders on building projects from literature. These factors are considered separately with significantly different mean score assigned to each of them.

Table 5. Factors influencing the awareness level of the roles of professional builder

Factors influencing awareness level	Mean	Remark
Social interaction with building/building technology students	3.41	Very little influence
Clarity of the profession's name (the name fully describes what it does)	3.35	Very little influence
Information about the profession in books periodical etc.	3.18	Very little influence
Students activities such as students' week	3.16	Very little influence
Orientation programmes student seminar	3.13	Very little influence
Personal contact with a professional builder	3.08	Very little influence
Media adverts and publications about Builders' activities in the public media	3.04	Very little influence
Web presence and mention in relevant construction websites blogs social media	3.03	Very little influence
Government engagement of professional builders on its projects	3.03	Very little influence
Publicity efforts by building firms	3.00	Very little influence
Advocacy and branding efforts by Nigerian institute of building or its regulatory body	2.74	Very little influence

From Table 5, it showed that social interactions with building technology students, clarity of the profession's name and information about the profession in books, periodicals had very little influence on the level of awareness of the professional builders among students. The relative importance of students studying building technology in publicizing the functions of building professionals in institutions cannot be overemphasized as they are the first contact other students have about the course. As Icbay (2008) noted that education is essentially a social action, and thus depends on social interaction. Bremme and Erickson (1977) stated that this social interaction produces an infinite number of actions. It is through these different talks-in-interaction at different contexts that social institutions and actions are produced and composed (Watson, 1992). Bremme and Erickson (1977) argued that sharing personal experiences through a conversational style of interaction, individuals give little thought to the complexity of the interactional work they perform. So, evidently what the student builders know about their course is what they will pass across to other students in other profession.

Similarly, the study revealed that the clarity of the profession's name has not played a significant role in increasing the level of awareness of the profession with students. The courses according to the Nigerian University Commission NUC) are either called Building, Building Technology or Building Engineering in rare cases. The salient point associated with this factor is whether the profession's name fully describes what it does or not. The word 'professional builder' have little or no effect on raising the level of awareness of the profession among the students. This is premised on the fact that quacks lay claim to be called builders or engineers.

The study also examined the most significant factors influencing the level of awareness of professional builders among students of tertiary institutions. Factor analysis was used to achieve this purpose. Principle factor extraction analysis with Varimax rotation was performed using SPSS 17. To assess the suitability of the data for factor analysis, the KMO measure of sampling adequacy and Bartlett's test of Sphericity were conducted. Cronbach's Alpha was calculated for reliability. Table 6 showed that the KMO measure for sampling adequacy was 0.892, which is larger than 0.7, suggesting that the sample was acceptable for factor analysis. The Bartlett's test was 968.415 and the associated significance level was p-value < 0.001, indicating that the population correlation matrix was not an identity matrix. Both of the tests showed that the obtained data supported the use of factor analysis. Cronbach's Alpha of 0.658 suggested that the reliability of the research instrument used was also acceptable.

Table 6. KMO and Bartlett's Test of factors influencing awareness level of students

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.892
Bartlett's Test of Sphericity:	Approx. Chi-square	968.415
	Degree of freedom	55
	Significant level	0.000

Table 7 lists the eigenvalues associated with each linear component before extraction, after extraction and after rotation.

Figure 1 presents the scree plot, which resulted in two factors, because the regression line was divided into two components and then became a nearly straight line. After extraction, Factor 1 explains 31.862% of the total variance, while the second factor explains 30.817% of the total variance.

Table 7. Component transformation matrix of the factor influencing awareness level

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.818	52.888	52.888	5.818	52.888	52.888	3.505	31.862	31.862
2	1.077	9.790	62.679	1.077	9.790	62.679	3.390	30.817	62.679
3	.871	7.920	70.599						
4	.651	5.916	76.515						
5	.536	4.870	81.385						
6	.534	4.851	86.236						
7	.383	3.481	89.717						
8	.354	3.214	92.931						
9	.319	2.903	95.834						
10	.273	2.479	98.314						
11	.185	1.686	100.000						

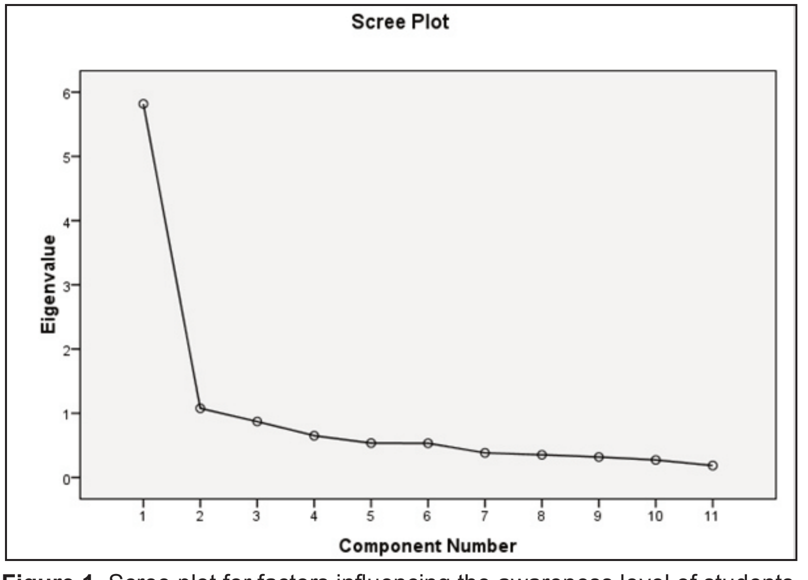

Figure 1. Scree plot for factors influencing the awareness level of students.

Using exploratory factor analysis, the factor analysis extracted two factors with eigenvalues greater than 1.0, which explained 62.679% of the total variance. The two-factor solution with the respective loading scores is shown in Table 8. The factor loading of 0.50 was considered to be the cut-off point.

Factor 1: Student/professional builders' effort

The first factor titled student/professional builders' effort which has the largest total variance of 31.86%, can explain the efforts made by potential and professional builders; students and practitioners, to ensure that the profession and its importance is known in the country. This factor contains four factors related to direct efforts made by registered builders, current building students in tertiary institutions and building firms. The majority of the factors influencing awareness level of students have relatively high factor loadings (≥ 0.50). As illustrated in Table 8, the highest factor loading attribute of the first factor was "Personal contact with a professional builder". This means that any individual (students, families, colleagues, etc.) or organization that comes in contact with a professional builder will come to terms with the need and significance of employing a registered builder on any building projects. This contact can be in the form of conversation about related construction matters and service delivery in the construction process. This is imperative because prospective clients may not be aware of the importance of engaging professionals when they believe they can pay less money for quacks. The second highest factor loading attribute is "social interacting with building students". This was an extension of the first factor, students in building department are expected to communicate effectively the functions of professional builders when causally asked by friends from other departments/faculties either from the same or different institutions. Gold, Rodgers and Smith (2002) suggested that the future of professions and professionals is mainly the responsibility of professionals themselves. Meintjes and Niemann-Struweg (2009) argued that the public will judge professionals by the quality of the values that they ascribe to, by their commitment to solid ethical values and integrity in relationships, the extent to which they are prepared to take responsibility for what they do, and the passion, courage and creativity with which they deal with problematic and challenging situation.

Table 8. Factor loading for factors influencing awareness level (Rotated Component Matrix)

Rotated Component Matrix	1	2
Personal contact with a professional builder	0.995	
Social interacting with building students	0.873	
Government engagement of professional builders on its projects	0.756	
Media adverts and publications about builder's activities in the public media	0.609	
Web presence and mention in relevant construction website		0.912
Advocacy and branding efforts by Nigerian institute of building or its regulatory body		0.893
Information about the profession in books, periodical etc.		0.756
Orientation programmes student seminar		0.578
Students activities such as hall week		0.505

Factor 2: Professional and regulatory bodies' effort

The second factor is labelled professional and regulatory bodies' effort, which is the second largest variance of 30.88% and comprises four attributes. The first attribute with the highest factor loading is "Web presence and mention in relevant construction website". This indicated that web presence and mention in construction related website run by professional bodies, regulatory bodies and construction organizations would go a long way to ensure prospective clients are fully aware of what gains are inherent in employing the services of professional builders. Also, advocacy and branding efforts by its professional body (Nigerian Institute of Building) and regulatory body (Council of Registered Builders of Nigeria) is expected to drive up the knowledge of the profession in the country. A profession is only as strong as its professional association. According to the Green (2015) central to the purpose of professional bodies is to provide trust. For the layperson, even for experts, gauging the potential quality of the service offered by a professional can be extremely hard. Therefore, Palea (2012) noted that professional associations play a key role in developing, promoting and strengthening a profession before various and dynamic audiences (clients, practitioners, educators, legislators, journalists, researchers etc.) thereby inhibiting access to the unqualified. For example, clearly stated on the Association of Trainers in Journalism and Communication – AFCOM website in the 15th article of the Association's Statute which states that "the association operates with the purpose to protect the members' professional rights and interests, their social and cultural needs, as well as to promote and protect their professional status, in accordance with national and international standards of the domain". By this Palea (2012) argued that the association has not assumed solely a role of regulation, restriction or sanction by imposing professional conduct standards, but they actively support and encourage the training and development of specialists within their profession. The activities undertaken by the professional associations contribute to defining and developing the profession, specifically by raising awareness about the domain and supporting the professionalization of practitioners.

Conclusion, Recommendation and areas of further studies

The aim of this paper is to assess the building profession in the eyes of future decision and policy makers in Nigeria. The study evaluated the level of awareness of future policy makers on the roles of professional builders and the factors influencing the level of awareness of students. The results of this study indicated that future decision makers in Nigeria were fairly aware about two (2) major roles of the professional builder which are building production/construction management and employing labour in direct labour projects. The study revealed that the background courses of the future decision makers were significant in identifying three (3) major roles of the professional builders such as resident supervision of building projects, building production/construction management and building maintenance management. Majority of students (prospective client) are however not aware of some of the evolving roles of professional builders such as building condition survey, facility management functions, project management and value engineering.

The current study revealed that several significant factors had little influence on increasing the level of awareness about professional builders in the construction industry. Upon factor analysis, the study showed that two major areas can influence the popularity of the profession which are the student/professional builders' participation and the professional associations. Figure 2 showed a framework for influencing awareness level of future decision makers. As shown in Figure 2, every contact with good service delivery of professional builders during the building process will lead to client satisfaction and value creation in such projects. Students, registered builders and professional bodies have a significant role to play in ensuring the profession is embraced in the country at large.

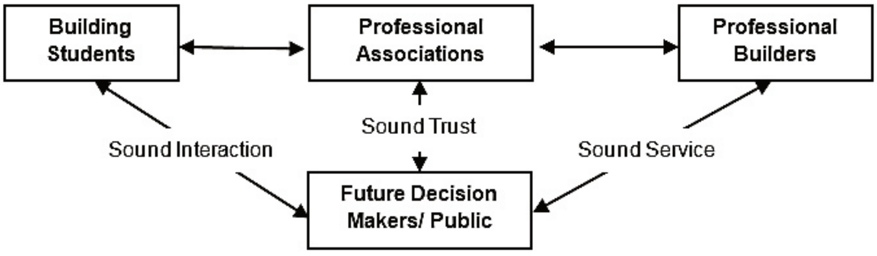

Figure 2. Framework for influencing awareness level of future decision makers
Source: Author's design

The study recommended that building students should increase their social interaction with their peers about the profession while professional builders should ensure good service delivery when given opportunities on building projects so they can get referrals for other projects thereby increasing the knowledge of the professions among clients/prospective clients. The Nigerian Institute of Building (NIOB) and the Council of Registered Builders (CORBON) should improve on their advocacy and branding efforts of the profession by ensuring adequate web presence and mention on construction related sites. Lecturers in tertiary institutions should ensure that frequent site visits, group works on construction related activities and the use instructional aids should be encouraged to increase participation and knowledge base of building students in the course work, thereby increasing the knowledge to friends and prospective clients within their academic community.

The research presented in this paper is considered an initial step to measuring the awareness of building profession in the eyes of future decision makers using a quantitative research method. Hence, qualitative approaches, such as interviews and focus groups, are required to validate the findings obtained in this study. Since this research is limited to selected universities, future research needs to assess the perceptions of final year students in universities in all geographical regions of the country. It would also be interesting to carry out a comparative evaluation between the perception of building professionals in Nigeria and other countries.

The significant contribution of the study to knowledge is that it adds to the growing number of literature and reference materials on work theory value, particularly on the subject of perception of building professions to tender which had received little attention from researchers and where there has been comparatively little objective research. The study explored the areas of having a sustainable profession by increasing knowledge. Finally, the study provides a platform on which future research can be undertaken.

REFERENCES

Aina, O. O. and Wahab, A. B. (2011) An Assessment of Build-ability Problems in the Nigerian Construction Industry. *Global Journal of Research Engineering*, 11 (2): 42-52.

Akinluyi, M. L. and Adeleye, O. O. (2013) The Building Industry in the Housing Programme: Technology, Materials and Labour towards addressing Housing Shortage in Nigeria. *Global Journal of Arts Humanities and Social Sciences*, 1 (3): 58-70.

Allen, C. L. (2004) Business students' perception of the image of accounting. *Managerial Auditing Journal*, 19 (2): 235-258.
Anyanwu, C. I. (2013) The Role of Building Construction Project Team Members in Building Projects Delivery. *Journal of Business and Management*, 14 (1): 30 – 34.
Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. and Wong, B. (2012) Science Aspirations and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, 49 (5): 881–908.
Bamisile, A. (2004) *Building Production Management*. Lagos, Nigeria: Foresight Publishers.
Bandura. A. (1986) *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice-Hall.
Bandura, A., Barbaranelli, C., Caprara, V. G. and Pastorelli, C. (2001) Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development,* 72 (1): 187-206.
Barat, S. and Spillan, J. (2009) A cross country comparative analysis of students' perceptions of the sales profession: A look at U.S., Peru, and Guatemala. *Marketing Management Journal*, *19*: 52–63.
Becker, K. and Park, K. (2011) Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education*, 12 (5): 23-37.
Bremme, D. W. and Erickson, F. (1977) Relationships among verbal and nonverbal classroom behaviors. *Theory into Practice*, 5 (3): 153-161.
Bristow, D., Gulati, R., Amyx, D. and Slack, J. (2006) An empirical look at professional selling from a student perspective. *Journal of Education for Business*, *81*: 242–250.
Brotheim, Hal (2014) Introducing Generation Z. *American Jail Association*. p. 15 Assessed online from http://www.readperiodicals.com/201411/3554415761.html
Burnett, M., Pettijohn, C. and Keith, N. (2008) A comparison of the ethical perceptions of prospective personal selling and advertising employees. *Marketing Management Journal*, *18*, 77–83.
Construction Industry Research and Information Association, CIRIA (1983) *Buildability: an assessment*. London, UK: Construction Industry Research and Information Association (CIRIA).
Dada, M. O. (2006) The threat of building collapse to sustainable built environment. *Proceedings of the 36th Annual Conference of the Nigerian Institute of Building on Sustainable Development and the Built Environment*, Jos, Nigeria, 69-75.
Dada, M. O. (2012) A second look: Stakeholders' Perceptions of some issues in Design - Bid-Build Procurement Practice in Nigeria. *Journal of Sustainable Development* 5 (1): 55-63.
Fellows, R. (2003) Professionalism in construction: Culture and Ethics. *CIB TG 23 International Conference, Hong Kong*, 1 – 11.
Flanagan, R. (2000) The impact of global business issues on design and construction. *In P. Knox and P. Ozolins (eds), Design Professionals and the built environment: An introduction*, Chichaster: John Wiley, 341-349.
Germanou, E., Hassall, T. and Tournas, Y. (2009) Students' perceptions of accounting profession: work value approach. *Asian Review of Accounting*, 17 (2): 136-148.
Gold, J., Rodgers, H. and Smith, V. (2002) The future of the professions: are they up to it? *Foresight,* 4 (2): 46-52.

Green, B. (2015) *Understanding the value of professionals and professional bodies*. Chartered Institute of Building (CIOB), 1 – 40.
Hammani, H. and Hossain, M. (2010) Perception of the accountant held by business students and business professionals in an emerging country: the case of Qatar. *Education, Business and Society*, 3 (1): 48-62.
Icbay, M. A. (2008) The role of classroom interaction in the construction of classroom order: A conversation analytic study. *Unpublished doctoral dissertation, Middle East Technical University*, Ankara, Turkey.
Jackling, B., Cooper, B.J., Leung, P. and Dellaportas, S. (2007) Professional accounting bodies' perception of ethical issues, causes of ethical failure and ethics education. *Managerial Accounting Journal*, 22 (9): 928-944.
Karakaya, F., Quigley, C., Bingham, F., Hari, J. and Nasir, A. (2014) Business Students' Perception of Sales Careers: Differences between Students in Switzerland, Turkey, and the United States. *Journal of Education for Business*, 89 (1): 13-19.
Levit, Alexandra (Mar. 28, 2015) Make Way for Generation Z. *The New York Times*. Retrieved online from http://www.nytimes.com/2015/03/29/jobs/make-way-for-generation-z.html?_r=0 on September 15, 2015.
Lysonski, S. and Durvasula, S. (1998) A cross-national investigation of student attitudes toward personal selling: Implications for marketing education. *Journal of Marketing Education*, 20, 161–173.
Mackay, S. (2004) The role perception questionnaire (RPQ): a tool for assessing undergraduate students' perceptions of the role of other professions. *Journal of Inter-Professional Care*, 18 (3): 289-302.
Mbamali, I. and Okotie, A. J. (2012) An Assessment of the Threats and Opportunities of Globalization on Building Practice in Nigeria. *American International Journal of Contemporary Research,* 2 (4): 143 – 150.
Meintjes, C. and Niemann-Struweg, I. (2009) The role of a professional body in professionalization: The South African public relations case. *Prism*, 6 (2). Assessed online on December 25, 2015 from http://praxis.massey.ac.nz/prism_on-line_journ.html.
Mosaku, T. O., Kehinde, J. O. and Kuroshi, P. A. (2006) Control of Building Practice for Sustainable Development in Nigeria: Matters Arising. *Proceeding of the International Conference on the Built Environment; Innovation, Policy and Sustainable Development. Department of Architecture, Covenant University, Ota, Nigeria,* 26 – 33.
National Building Code, NBC (2006) *The National Building Code of Federal Republic of Nigeria*. NBC, 1st Edition, South Africa: Lexis, Nexis, Butterwoths.
National Bureau of Statistics, (NBS) (2012) The Nigeria Poverty Profile 2010. *Report of the National Bureau of Statistics Harmonized Nigeria Living Standard Survey (HNLSS).*
National Bureau of Statistics, (NBS) (2015) *Nigerian Construction summary report 2010 – 2012*. Central Business District, Abuja.
Nga, J. K. H. and Mun, S. W. (2013) The perception of undergraduate students towards accountants and the role of accountants in driving organizational change. *Education + Training*, 55 (6): 500 – 519.
Nunnally, J. C. and Bernstein, I. H. (1994) *Psychometric theory* (3rd ed.). New York, NY: McGraw-Hill, Inc.
Obiegbu, M. E. (2009) Unique Roles of Professional Builders in the Society. *Being a paper presented at the One Day Seminar organized by the Rivers and Bayelsa States Chapter of the Nigerian Institute of Building* held at Porthacourt, Nigeria on the 18th November.

Ogunbiyi, M. A. (2015) *Elements of Professional Practice and Procedure for Builders*. Lagos, Nigeria: Tony Terry Prints.

Ogunsanmi, O. E. (2013) Effects of procurement related factors on construction project performance in Nigeria. *Ethiopian Journal of Environmental Studies and Management*, 6 (2), 215 – 222.

Olatunji, S. O., Oke, A. E. and Owoeye, L. C. (2014) Factors Affecting Performance of Construction Professionals in Nigeria. *International Journal of Engineering and Advanced Technology (IJEAT),* 3 (6): 76-78.

Oseghale, G. E., Ikpo, I. J. and Ajayi, O. D. (2015) Causes and Effects of Building Collapse in Lagos State, Nigeria. *Civil and Environmental Research*, 7 (4): 34 – 43.

Palea, A. (2012) The role of professional associations in defining the public relations profession. The Romanian case. *Professional communication and translation studies*, 5 (1-2): 17 – 24.

Payne A. C., Chelsom J. V. and Reavill L. R. P. (1999) *Management for Engineers*. London: John Wiley and Sons.

Ruhl, O. (2010) Nigeria's Youth: Turning Challenge into Opportunity. *Nigerian Youth Paper presented at Federal University of Technology*, Owerri. Available online- http://siteresources.worldbank.org/NIGERIAEXTN/Resources/Nigerian-Youth-Paper-Onno Ruhl.pdf.

Sparks, J. and Johlke, M. (1996) Factors influencing student perceptions of unethical behavior by personal salespeople: An experimental investigation. *Journal of Business Ethics*, *15*: 871–887.

Stevenson, T. and Bodkin, C. (1998) A cross-national comparison of university students' perceptions regarding the ethics and acceptability of sales practices. *Journal of Business Ethics*, *17*: 45–55.

Sugahara, S., Hiramatsu, K. and Boland, G. (2009) The factors influencing accounting school students' career intention to become certified public accountant in Japan. *Asian Review of Accounting*, 17 (1): 5-22.

Towry-Coker, L (Nov. 20, 2006) Economy can't grow without improving housing. *The Punch*, 44.

Usman, N. D., Inuwa, I. I. and Iro, A. I. (2012) The influence of unethical Professional practices on the Management of construction projects in North-Eastern States of Nigeria. *International Journal of Economic Development Research and Investment*, 3 (2): 124-129.

Vee, C. and Skitmore, M. (2003) Professional Ethics in the Construction Industry. *Engineering, Construction and Architectural Management,* 19 (21), 117-127.

Watson, D. R. (1992). Ethnomethodology, conversation analysis and education: An overview. *International Review of Education*, 38 (3): 257-274.

Williams, A. (Sept. 19, 2015) Meet Alpha: The Next 'Next Generation. *New York Times*. Retrieved online from http://www.nytimes.com/2015/09/19/fashion/meet-alpha-the-next-next-generation.html on December 15, 2015

Windapo, A. O. and Rotimi, J. O. (2012) Contemporary Issues in Building Collapse and Its Implications for Sustainable Development. *Buildings, 2*: 283-299.

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PULL-OUT STRENGTH OF POLYETHYLENE TEREPHTHALATE BOTTLE FIBRE IN CONCRETE MATRIX

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Abstract
Polyethylene Terephthalates (PET) is one of the most plastic containers that are normally being discarded by people, which resulted in environmental pollution. For example, plastic bottle which is made from polyethylene terephthalates (PET) are known as one of the famous products that contributes to the environment pollution. One of the best ways to reduce the environmental pollution is by recycling PET as a ring-shaped PET (RPET) fibre in concrete. Therefore, it is appropriate to investigate the RPET fibre in term of pull-out strength of RPET fibre from matrix concrete by pull-out test. Three sizes of fibres were used in the experiment which was 5, 7.5 and 10 mm width of RPET namely as RPET-5, RPET-7.5, and RPET-10 respectively. It can be concluded that the RPET-10 fibre exhibited the highest pull-out load of 103.6% and 33.6% compared with RPET-5 and RPET-7.5 fibres, respectively, at 15 mm embedded length. This finding shows a similar pattern for 20 mm and 25 mm embedded lengths RPET-10 fibre obtained 77.2% to 91.7% and 13.7% to 29.2% increases in pull-out strength compared with RPET-5 and RPET-7.5 fibres, respectively, at 20 to 25 mm embedded lengths.

Keywords: *waste bottle, pull strength fibre & interfacial bond strength*

INTRODUCTION

The development of new construction materials using recycled PET fibres is important in the construction and PET recycling industries. In the field of civil engineering, the recycled PET has begun to be adopted in the concrete. These studies have shown that recycled PET fibres produce different results depending on their shape and content (Fraternali *et. al.*, 2011, Foti 2011, Frigione, 2010, Ochi *et. al.,* 2007 & Faisal, 2016). The shape of a fibre is important because of the weak interfacial bond with cement paste in the pull-out load caused by the lamellar shape of 10 mm-long fibres (Fraternali *et. al.*, 2011 & Frigione, 2010). Ochi *et. al.* (2007) determined that using 30 mm-long PET fibres can increase tensile strength for volume replacements up to 1.5% compared with 20 mm-long fibres. They claimed that long fibres have the capability to interlock fibre bridges in concrete because such fibres can be inserted between aggregates compared with 20 mm-long fibres. Previous research has also indicated that FC depends on the shape of the recycled PET fibres used (Irwan *et. al.*, 2013a, 2013b & Ochi *et. al.* 2007). However, recycled PET fibres exhibit limited performance because of the weak interfacial bond strength of PET surface during fibre bridge stress, particularly in fibres with lamellar and irregular shapes (Irwan *et. al.*, 2013a & 2013b; Fraternali *et. al.*, 2011; Frigione, 2010; Ochi *et. al.,* 2007).

Foti (2011) studied that the possibility of using fibres from polyethylene terephthalates (PET) in bottles is to increase the ductility of the concrete. The author determined the tensile strength of PET ring shape with 0.20 mm thickness, 335 total length, and 5.0 mm width of fibre. The author showed that ring ‘0’ shape PET obtains an average value of tensile strength equal to 180 MPa. A study conducted by Ochi *et. al.* (2007) used polyethylene terephthalate, PET, polypropylene, PP, and polyvinyl alcohol, PVA fibre to determine the tensile strength in different types of manufactured synthetic fibre. The PET, PP, and PVA have different sizes of fibre which are 0.75 mm, 1.21 mm, and 0.71 mm width of fibre respectively and fixed at 30 mm length of fibre. The author found that PVA obtains higher in tensile strength compared to PET and PP fibre. The author claimed that PET tensile strength has 172 MPa which is the lowest tensile strength among other fibre studies. Ali *et. al.* (2013) studied the effect of fibre embedded lengths, diameters, and concrete mix design ratio on the bond strength between single coconut fibre and concrete. the author found that fibre has the maximum pull-out strength with concrete as embedded length is increasing. the author showed that the embedded length more than 30 mm is significant compared to the embedded length less than 20 mm. the author found that increase diameter of fibre would increase the area of fibre that connected to concrete. the author claimed the coconut fibre with a diameter of 0.35 mm obtained surface embedded area which is connected to concrete matrix on averages of 22 mm^2 to 33 mm^2 surface areas. Shannon (2011) studied the melt extrusion and tensile strength of different materials of polyethylene namely HDPE and PP fibre with 1.76 mm of width fibres. Shannon constructed a pull-out load test with two different embedded lengths which are 15 mm and 20 mm. Shannon found that fibre with the different materials, but in similar size of width and embedded length would tend to show differences in pull-out load. it can be pointed out that HDPE 1.76 mm of width obtains higher in load strength compared to pp 1.76 mm of width fibre at both 15 mm and 20 mm embedded of length.

Richardson *et. al.* (2009) examined the behaviour of polypropylene fibre in 0.19 mm diameter with a different embedded length of fibre. The authors found that the load was increased as the embedded length of fibre increased. The author confirmed that the increases on averages of 39.3% to 48.1% strength from an embedded length of 45 mm to 55 mm. Singh (2010) investigated the pull-out behaviour of polypropylene fibre from an embedded length on the pull-out fibre characteristics and interfacial bond fibre with matrix concrete. The author recognized that the embedded length of fibre in concrete shows significant effects on pull-out characteristic. The author said that the increase of the embedded of length from 19 mm to 38 mm would increase 39% to 68.2% of load strength. Singh (2010) also mentioned that the embedded of length significantly affected on pull-out load due to the treated surface of the fibre.

In this experiment, a series of pull-out tests were performed by using recycled PET fibre in concrete matrix. The main objective of this experiment is to investigate the pull-out load of recycled PET in different embedded lengths and sizes of PET fibre. The results of this research are important for a better understanding of the effects of the fibre characteristics, geometry of fibre, and the mechanism bond of recycled RPET fibre.

EXPERIMENTAL

Three sizes of fibres were used in the experiment which was RPET-5, RPET-7.5, and RPET-10 fibres, respectively. The diameter of the fibre is 60 ± 5 mm cross section. The bottle was first cleaned to remove impurities and then cut into dog bone–shaped rings, as shown in Figures 1(a) to 1(c). The bottom of the dog bone–shaped rings was cut to confirm that fibre slipped during the pull-out test. This is due to the full rounded RPET fibre was failed by tensile load.

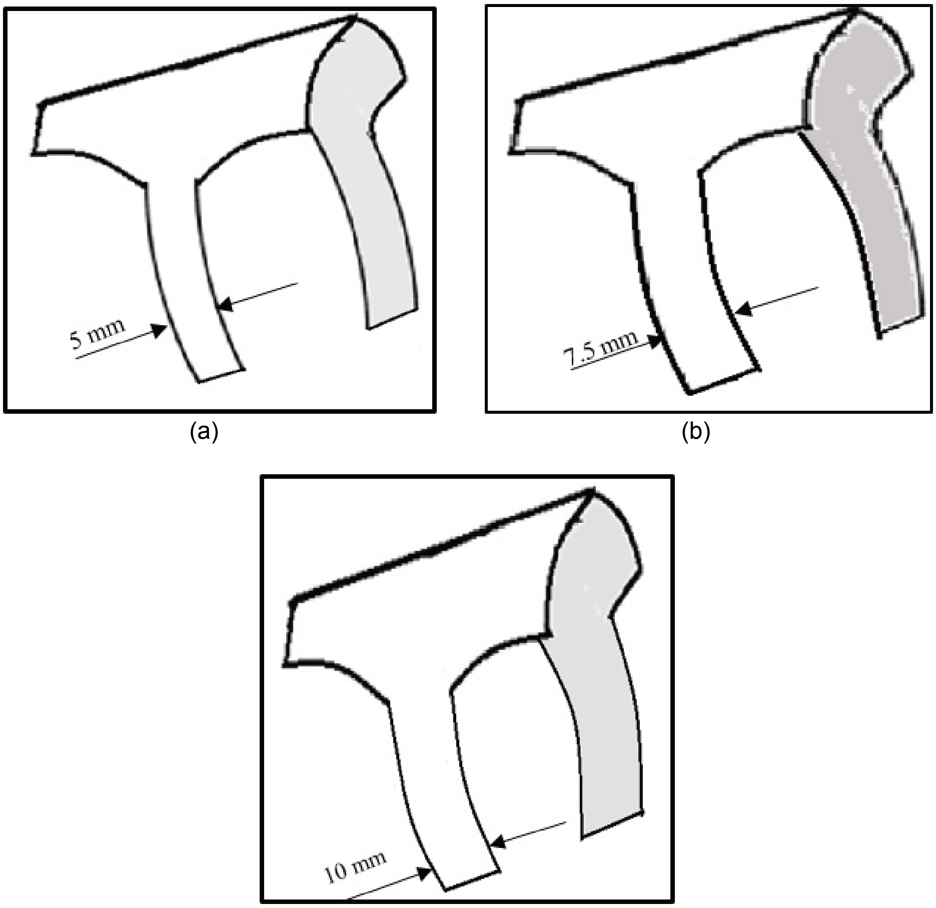

Figure 1. (a) RPET-5, (b) RPET-7.5, and (c) RPET-10 fiber

Concrete was basically prepared by adopting the mixing procedure proposed by Liao *et. al.* (2006) and Irwan *et. al.* (2013a & 2013b). The absolute volume method was used to calculate the volume of each component to occupy 1 m^3 of concrete, as shown in Table 1. The batch amount was calculated based on the amount of concrete required to cast moulds with dimension of 100 mm × 100 mm × 100 mm.

Table 1. Mix proportion of SCC to test pull-out strength of RPET fibre

Mix Designation	Cement (kg/m^3)	Fly Ash (kg/m^3)	Coarse Aggregates (kg/m^3)	Fine Aggregates (kg/m^3)	Water (kg/m^3)	Super-plasticizer (Kg/m^3)
0.55	300	45	805	980	189.8	4.7

A total of 45 cubes for the fibre pull-out test were made with three embedded fibre length sizes. RPET-5, RPET-7.5, and RPET-10 fibres were used in the fibre pull-out test. The experiment was conducted at the embedment length of 15, 20, and 25 mm according to previous research (Singh *et. al.*, 2010 & Shannon *et. al.*, 2011).

Concrete was inserted into the mould at certain levels, as shown in Figures 2(a) to 2(c). Half-round polystyrene was placed at the centre of the cube mould. This polystyrene maintained the form of RPET fibres during the insertion of RPET into the concrete mould. Then, the process was continued by pushing RPET fibres into the desired embedment length. The concrete was placed around the fibre until the top level of the mould was reached. The samples were covered with wet gunny sacks and allowed to harden at room temperature for a minimum of 28 days. The hardened cube specimens for the pull-out test are shown in Figure 3.

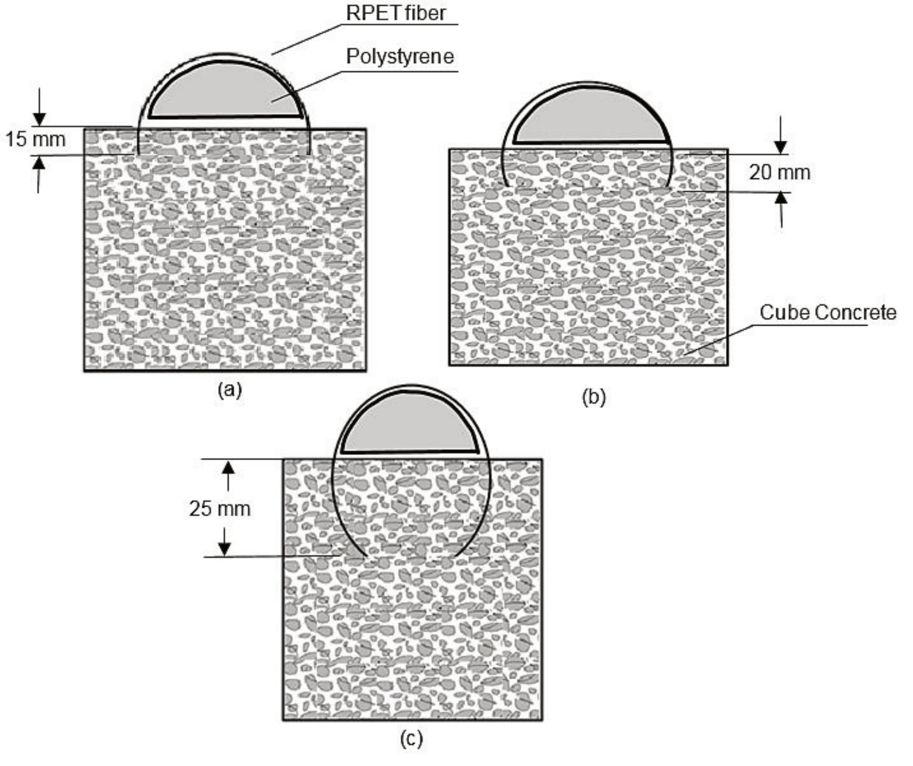

Figure 2. (a) Embedment 15 mm of RPET, (b): Embedment 20 mm of RPET, and (c): Embedment 25 mm of RPET

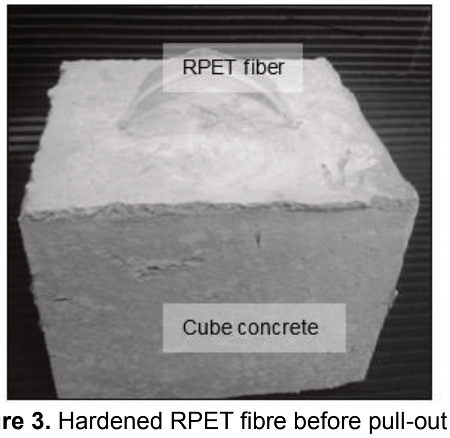

Figure 3. Hardened RPET fibre before pull-out test

The end of RPET fibres at the top was restrained using the customized fixture illustrated in Figure 4. This fixture reduced local stresses around the clamped section of the fibres. The threaded rod was adjusted, such that the specimen satisfied the upper restraining plate. Adjustments were made carefully to avoid tightness, which induces compression. The fixture was designed to restrain the specimen with minimal addition of lateral compressive forces around fibres.

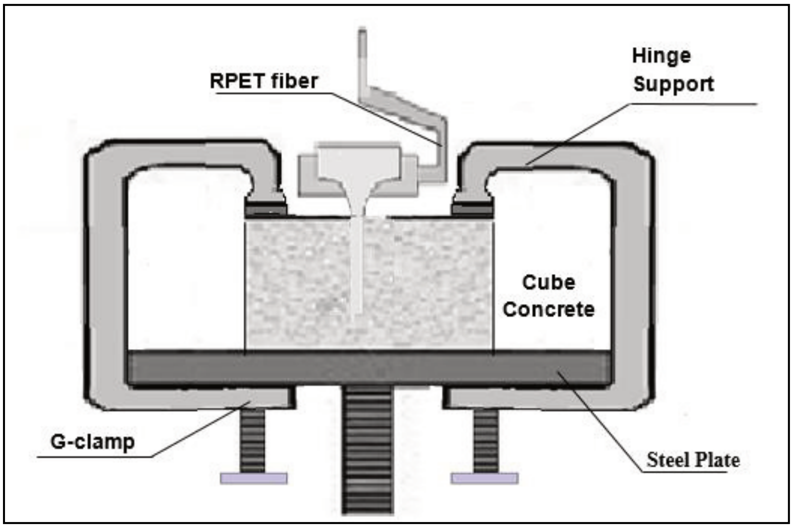

Figure 4. Minimized lateral compressive forces on RPET fiber

Specimens were handled cautiously to ensure that no twisting or stretching would occur during the set up. An initial tension was applied to ensure that no slack or kink was present in the sample. Pull-out test was conducted at a constant displacement rate of 2.5 mm/min (Shannon, 2011). Each test was conducted until complete pull-out of the fibres was achieved or fibre ruptured. The complete pull-out test setup is shown in Figure 5.

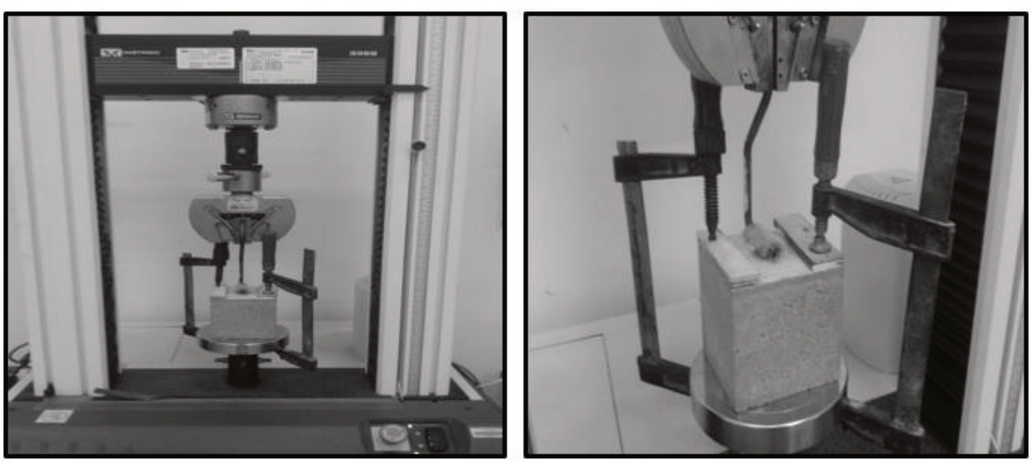

Figure 5. Complete set up of pullout test

RESULT AND DISCUSSION

The strength behaviour of FRC depends on the pull-out behaviour of a single fibre in the concrete matrix. The fibre pull-out test is mostly used in other studies to determine the quality of the concrete matrix around the fibre.

Load-end displacement response

The typical load-end displacement responses of RPET-5, RPET-7.5, and RPET-10 fibres are shown in Figures 6 to 8 (load-displacement) and Table 2. The pull-out load pattern initially increased nearly linearly with the slip at the beginning of the load until it achieved the critical load (linear region).

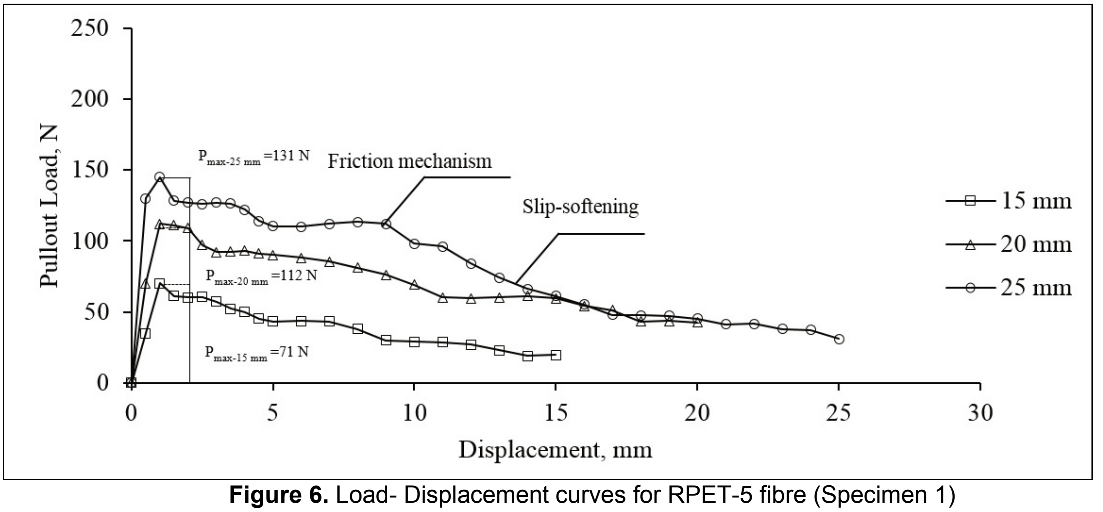

Figure 6. Load- Displacement curves for RPET-5 fibre (Specimen 1)

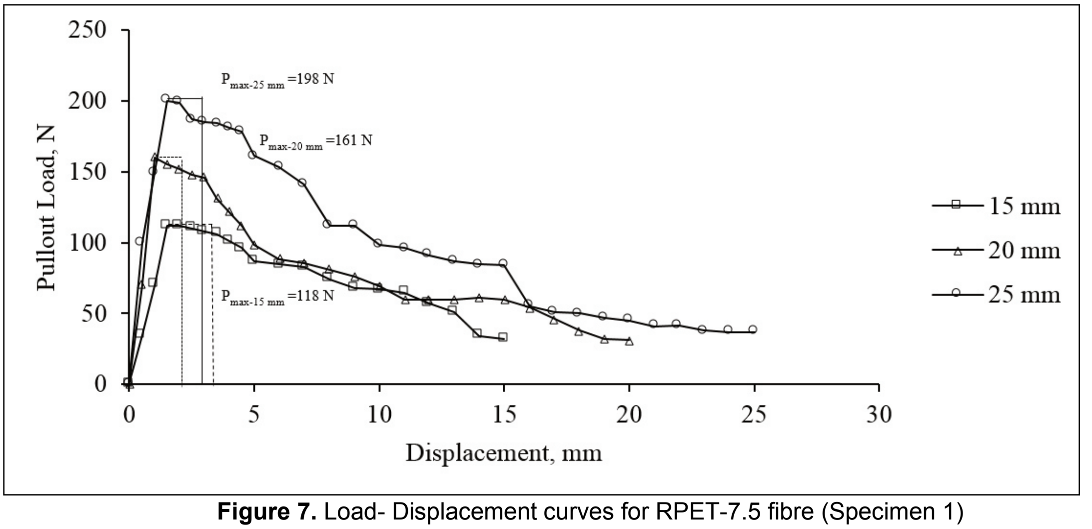

Figure 7. Load- Displacement curves for RPET-7.5 fibre (Specimen 1)

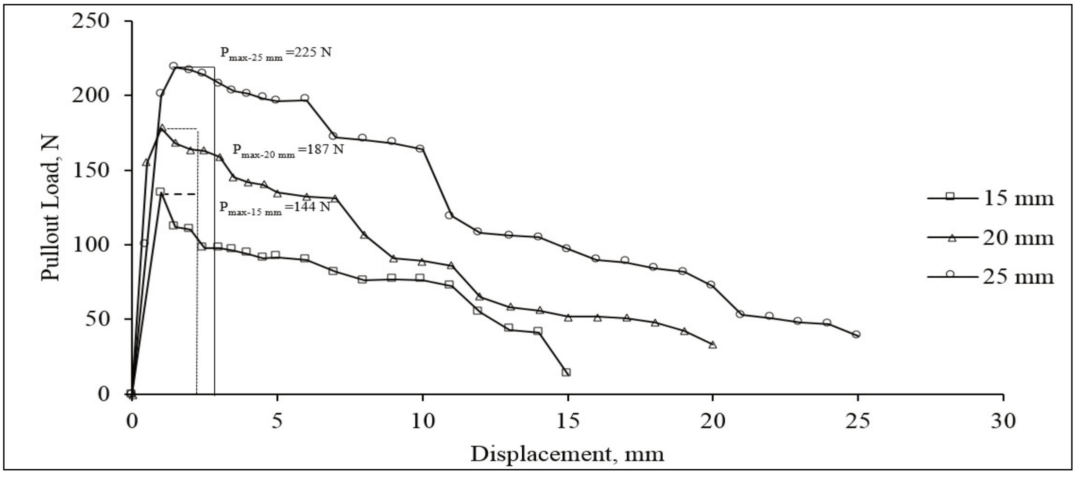

Figure 8. Load- Displacement curves for RPET-10 fibre (Specimen 1)

Table 2. Result of pull-out test for RPET fibre

Type of fibre	Embedment length of fibre, (mm)	Average maximum load, P_{max} (N)
RPET-5	15	75.3 ± 4.380
	20	101.6 ± 2.120
	25	129.8 ± 3.767
RPET-7.5	15	114.8 ± 3.231
	20	150.8 ± 1.879
	25	196.5 ± 2.783
RPET-10	15	153.3 ± 1.890
	20	194.8 ± 2.878
	25	223.4 ± 3.201

The nonlinear region indicates the start of debonding of a fibre from the matrix. The pull-out curves presented a distinct linear initial portion that terminated at a point (P_{max}), in which nonlinear behaviour was exhibited until peak load was reached followed by fibre/matrix debonding and frictional sliding. The initial incline of the fibres pulled from the concrete matrix was excessively steep. The experiment observed that the load decreased gradually after reaching the P_{max} point. The experiment also observed there is no a complete loss of bond, the frictional resistance mechanism has been activated. However, the part of the curve that corresponds to frictional sliding demonstrated an increase in the pull-out load with increasing embedded length. This increase can be attributed to the increase in friction between the fibre and the concrete matrix because of fibre abrasion, which occurs when fibre slides out of the matrix (Choi *et. al.*, 2003 & Singh *et. al.*, 2010). Thus, this finding confirmed that all RPET fibre sizes demonstrated similar patterns in load-displacement, as shown in Figures 6 to 8.

They confirmed that fibres with a large diameter will exhibited improvement in pull-out load energy results compared with fibres with a small diameter (Taher *et. al.*, 2011). A high surface area of fibre (a large diameter) produces high friction and slip hardening energy during the pull-out test. The analysis was continued in present study to determine the behaviour of pull-out fibre by testing the maximum embedded length.

An embedded length of 25 mm indicates maximum pull-out load during the pull-out test. RPET FC exhibited a constant friction and slip-softening effect. Peak pull-out load was achieved after the initial debonding stage. Slip softening started in RPET fibre as the load increased, particularly in RPET-10 fibre. RPET fibre had a constant friction when the curve was linear while slip softening was occurring. The surface area of fibres is the primary advantage in this result. The linear and slip softening behaviour of fibres can be enhanced given that the build-up of the surface shavings of fibres contributes to the present significant load-displacement curve (Redon *et. al.*, 2001).

These findings confirmed that RPET-10 fibre obtained the highest load, followed by RPET-7.5 and RPET-5 fibres. Thus, the size of the embedded area that comes in contact with concrete presented an influence effect on pull-out load of fibre.

Effect of embedded length of fibre on pull-out load

The experiment determined the pull-out behaviour pattern, and the results are provided in Table 3. The maximum pull-out strength values of RPET-5, RPET-7.5, and RPET-10 fibres increased with an increase in the embedded length of fibres.

Table 3 shows that the peak pull-out load increased with an increase in embedded length. This increase can be attributed to the increase in friction between the fibre and the concrete matrix. The embedded length of 20 mm for RPET-5, RPET-7.5, and RPET-10 fibres exhibited increases in pull-out of 34.9%, 31.4%, and 27.1%, respectively, compared with 15 mm embedded length. Meanwhile, the embedded length of 25 mm for RPET-5, RPET-7.5, and RPET-10 fibres presented increases of 72.3%, 71.2%, and 72.2%, respectively, compared with 15 mm embedded length. Nevertheless, these findings showed that the embedded length of 25 mm for RPET-5, RPET-7.5, and RPET-10 fibres demonstrated increases in pull-out load of 27.7%, 30.3%, and 14.7%, respectively, compared with the 20 mm embedded length.

Table 3. Analysis of maximum load from pull-out test

Type of fibre	Embedment length of fibre (mm)	Average maximum single load, P_{max} (N)	Difference percentage					
			Compared to 15 mm, (%)	Compared to 20 mm, (%)	Compared to 25 mm, (%)	Compared to RPET-5, (%)	Compared to RPET-7.5, (%)	Compared to RPET - 10, (%)
RPET-5	15	75.30 ± 4.38	-	-25.9	-42.0	-	-34.4	-50.9
	20	101.60 ± 2.12	34.9	-	-21.7	-	-32.6	-47.8
	25	129.75 ± 3.77	72.3	27.7	-	-	-34.1	41.9
RPET-7.5	15	114.75 ± 3.23	-	-23.9	-41.6	52.4	-	25.2
	20	150.80 ± 1.88	31.4	-	-23.3	48.4	-	22.6
	25	196.50 ± 2.78	71.2	30.3	-	51.4	-	12.0
RPET-10	15	153.30 ± 1.89	-	-21.3	-31.4	103.6	33.6	-
	20	194.80 ± 2.88	27.1	-	-12.8	91.7	29.2	-
	25	223.40 ± 3.20	72.2	14.7	-	72.2	13.7	-

This study confirmed that pull-out load depends on the embedded length of fibre. The fibre-matrix concrete pull-out load is achieved through a combination of friction and mechanical interlocking (Choi *et. al.,* 2003 & Irwan *et. al.*, 2013c). This finding confirmed that an embedded length of 25 mm provided an improvement result compared with that of 15 mm and 20 mm embedded lengths. An increase of embedded length of fibre leads to increase interfacial bond strength that contacted with matrix concrete.

This study found that the fibre has a high pull-out load with concrete as embedded length increases as shown in Figure 9. An observation by Singh *et. al.* (2010), Richardson *et. al.* (2009) and Shannon (2011) studies claimed that an increase in load is achieved by increasing the embedded length of fibre in concrete.

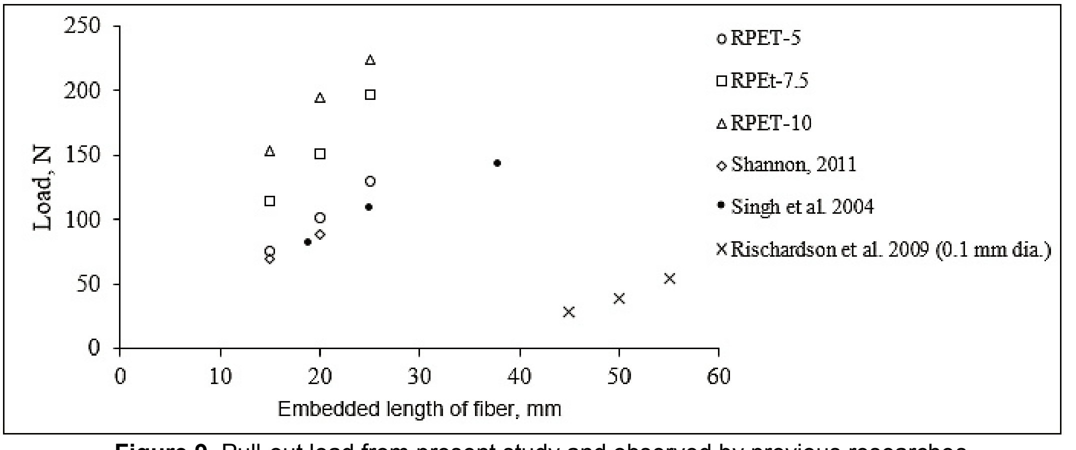

Figure 9. Pull-out load from present study and observed by previous researches

Effect of RPET fibre size on pull-out load

The findings confirmed that the pull-out load at embedded lengths of 15, 20, and 25 mm obtained for RPET-10 fibre is higher when compared with RPET-5 and RPET-7.5 fibres. The experiment indicated that RPET-10 fibre exhibited the highest pull-out load because of higher loads of 103.6% and 33.6% compared with RPET-5 and RPET-7.5 fibres, respectively, at 15 mm embedded length as shown in Table 3. This finding shows a similar pattern for 20 mm and 25 mm embedded lengths. RPET-10 fibre obtained 91.7% and 29.2% increases in pull-out strength compared with RPET-5 and RPET-7.5 fibres, respectively, at 20 mm embedded length. Meanwhile, RPET-10 fibre obtained 77.2% and 13.7% increases in pull-out strength compared with RPET-5 and RPET-7.5 fibres, respectively, at 25 mm embedded length.

Based on the analysis, the surface area connected to concrete is a prior contribution of significant pull-out load results with regard to embedded length. This finding was confirmed, as shown in Figure 10. RPET-10 fibre has a higher surface area connected to the concrete matrix compared with RPET-5 and RPET-7.5 fibres. The result also showed that RPET-10 fibres have surface area contacts with averages of 300 mm^2 to 500 mm^2, which are high compared with those of RPET-5 fibre with averages of only 150 mm^2 to 250 mm^2 in the surface area. Thus, the highest number of surface area significantly contributes to friction energy and bond strength between the fibre and the concrete matrix during the pull-out test (Sammer *et. al.*, 2010 & Shannon *et. al.*, 2011).

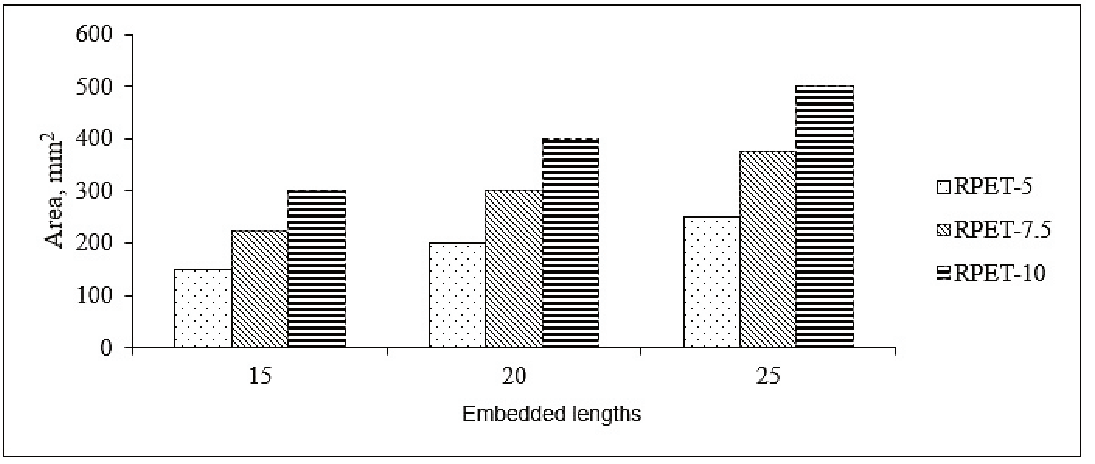

Figure 10. The surface area of RPET fibre in concrete

CONCLUDING REMARKS

The result of the experiment demonstrates that RPET-10 fibre exhibits impressive pull-out strength compared with those of RPET-5 and RPET-7.5 fibres because of the high surface area of fibres. The surface area of the fibres that connect to the concrete matrix offers good frictional resistance. RPET-10 fibre exhibited the highest pull-out load of 103.6% and 33.6% compared with RPET-5 and RPET-7.5 fibres, respectively, at 15 mm embedded length. This finding shows a similar pattern for 20 mm and 25 mm embedded lengths RPET-10 fibre obtained 77.2% to 91.7% and 13.7% to 29.2% increases in pull-out strength compared with RPET-5 and RPET-7.5 fibres, respectively, at 20 to 25 mm embedded lengths.

REFERENCES

Ali M., Xioyang Li, & Nawawi chuow (2013) Experimental investigations on bond strength between coconut fibre and concrete. *Material & Design*, (44): 596-605.

Choi O. C. & Lee C. (2003) Flexural performance of ring type steel fibre reinforced concrete. *Cement and Concrete Research*, 33:841-849.

Faisal, S.K., Irwan, J.M., Othman, N. and Wan Ibrahim M.H. (2016). Flexural toughness of ring-shaped waste bottle fibre concrete. *Matec Web of Conference*. Volume 47, 1, Article number 01002

Foti D. (2011) Preliminary Analysis of Concrete Reinforced with Waste Bottles PET Fibres. *Construction and Building Materials*, 25:1906-1915.

Fraternali A., Ciancia V., Chechile R., Rizzano G (2011) Experimental Study of Thermo-Mechanical Properties of Recycled PET Fibre-Reinforced Concrete. *Composites Structures*, 93:2368-2374.

Frigione M. (2010) Recycling of PET Bottles as Fine Aggregates in Concrete. *Waste Management*. 110(2): 31-35.

Irwan J.M., N. Othman, H.B.Koh, R.M. Asyraf, S.K. Faisal, & M.M.K. Annas, (2013a) The Mechanical Properties of PET Fibre Reinforced Concrete from Recycled Bottle Wastes. *Advanced Materials Research*, 795: 347-351.

Irwan J.M, S.K. Faisal, N. Othman, Wan Ibrahim M.H., & R.M. Asyraf (2013b) Performance of Concrete Using Light Waste PET Fibre. *Advanced Materials Research*, 795:352-355

Irwan J.M, S.K. Faisal, N. Othman, H.B.Koh, A.K. Aeslina, A. Mazni, R.M. Asyraf, & M.M.K. Annas (2013c) Relationship between Compressive, Splitting Tensile and Flexural Strength Of Concrete Containing Granulated Waste Polyethylene Terephthalate (PET) Bottles as Fine Aggregate. *Advanced Materials Research*. 795:356-359

Liao W., Chao S., & Naaman A. (2010) Experience sith self-consolidating high performance fibre reinforced mortar and concrete. *American Concrete Institution*. 274 (6):79-94

Ochi, T., Okubo, S. & Fukui, K. (2007) Development of Recycled PET Fibre and Its Application as Concrete- reinforcing Fibre. *Cement & Concrete Composites*, 29:448-455.

Redon C. & Chermant J. (1999) Damage mechanics applied to concrete reinforced with amorphous cast iron fibres, concrete subjected to compression. *Cement and Concrete Composites*, 21 (3):197-204.

Richardson A.E. & Sean Landless (2009) Synthetic fibres and steel fibres in concrete with regard to bond strength and toughness. *Built Environment Research*, 2 (2) :128-140.

Sammer Hamoush, William Heard, & Brian Zornig (2010) Effect of matrix strength on pull-out behaviour of steel fibre reinforced very-high strength concrete composites. *Construction and Building Materials*, 25(1):39-46

Shannon O'Connell (2011) Development of a new high performance synthetic fibre for concrete reinforcement. Dalhousie University Hailfax, Nova Scotia.

Singh S.K., Jan. (2010). Polypropylene Fibre Reinforced Concrete, an overview. Central Building Research Institute, Roorkee & Honorary Secretary Institute of Engineers. CE&CR, 24(1)

Taher Abu Lebdeh, Sameer Hamoush, William Heard, & Brian Zornig (2011). Effect of matrix strength on pull-out behaviour of steel fibre reinforced very high strength concrete composites. *Construction and Building Materials*. 25:39-46.

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SLENDER CIRCULAR STEEL TUBE (CFST) COLUMNS FILLED WITH SELF-COMPACTING CONCRETE INCORPORATING COAL BOTTOM ASH

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Abstract
This paper presents an experimental study on the behavior of slender, concrete filled steel tube (CFST) columns filled with self-compacting concrete (SCC) incorporating coal bottom ash (CBA), which were tested in compression to failure. Six specimens were tested to investigate the effect of SCC incorporating CBA as an infill. Depth-to-wall thickness ratios of between 28 to 32 were investigated. The ultimate strength results were compared to the current specimens governing the design of CFST columns. The experimental results suggested that the CFST column filled with SCC incorporating CBA gave good performance in terms of strength. The local buckling of the steel tube was delayed by the restraint of the concrete and the strength of the concrete was provided by the confinement effect of the steel tube.

Keywords: *Self-compacting concrete, Concrete-filled steel tube, Buckling, Coal bottom ash*

INTRODUCTION

Self-compacting concrete, commonly abbreviated as SCC, is the latest innovation in concrete technology and can be categorized as a new kind of high performance concrete with excellent deformability and segregation resistance (Su *et. al.,* 2001). It has the advantages of consolidating fully under its own self-weight, as it has certain characteristics typified by filling ability, passing ability and resistance to segregation. With regards to the material composition, the components used in the production of SCC are the same as those used in the production of normal concrete, which are cement, water, aggregates, additives and admixtures (Dehn *et. al.,* 2000). The use of a mineral admixture in SCC helps in governing its mechanical properties (Khatib 2008; Vejmelková *et. al.,* 2011; Yazici, 2008).

The use of a "composite column" normally implies the use of steel and concrete as one form of structure. It is commonly known as a concrete-filled steel tube (CFST) column, which provides composite action between the constituent elements. These composite actions enhance the mechanical behaviour of the column structure as the steel tube provides confinement to the concrete core whilst the concrete provides compressive strength and stiffness. Further explained, the steel tube acts as longitudinal and lateral reinforcement when subjected to compression and developing biaxial stress and hoop tension, which provide confinement pressure to the concrete (Baig *et. al.,* 2006; Hu *et. al.,* 2003). Eventually, the concrete was put under a tri-axial state of stress, which stiffened the steel tube, hence providing stability and strength to the column system.

Numerous research studies have been carried out on normal concrete filled in the CFST columns. Some of the literature was reviewed by Schneider (1998) and a "full" review of the literature was undertaken by Han (2002). In addition, a small number of research studies were carried out on CFST columns with SCC used as the infill material (Ernida *et. al.,* 2014; Jamaluddin *et. al.,* 2013; Muciaccia *et. al.,* 2011). Although the utilization of SCC in the composite structure has begun to capture interest among researchers, the use of SCC incorporating coal bottom ash (CBA) as infill material has yet to be found in the literature. Therefore, this study aims to investigate the behaviour of the CFST column filled with SCC incorporating CBA. A total of six samples were tested under axial force to failure. The parameters for the tests were the diameter-to-thickness (D/t) ratio, length-to-diameter ratio and the type of concrete infill. The buckling load and the failure mode of the samples were analysed and compared with the ultimate strength predicted by Eurocode, EC4.

EXPERIMENTAL PROGRAM

Specimens Specification

Two types of concrete mixture are used: concrete mixture with coal bottom ash (BA0) and concrete mixture with 15% bottom ash replaced with fine aggregate as can be seen in Table 1. The replacement of 15% of CBA used in this study is based on its strength performance as reported in Ernida *et. al.* (2014). In defining the concrete as SCC, some unique tests (slump flow test, slump flow time T500, sieve segregation test) are required in order to check the flowability, filling and passing ability of the fresh concrete. The fresh properties of the concrete mixture are as described in Table 2. In this study, the superplasticizer (SP) is used in the production of SCC in order to ensure that the fresh concrete was able to consolidate under its own self-weight. The SP value is 0.2% from the volume of mortar. As for strength properties, cube size 150 × 150× 150 mm and cylinder Ø150 × 300 mm were used in determining the strength of the concrete. All specimens were cured in the same condition of the CFST specimens. The concrete was designed to achieve a compressive cube strength (f_{cu}) of approximately 40 MPa at 28 days of curing. The cube compressive strength (f_{cu}) and cylinder compressive strength (f'_c) of the infill concrete were determined before the column specimens were tested. For CFST specimens, a total of six SCC filled circular slender columns including two hollow steel tubes were tested. Hot-formed circular hollow sections made up of steel grade S355 were used in the testing program. The mechanical properties of the steel, such as yield stress and elastic modulus, were obtained through tensile coupon testing tests according to BS EN 10002-1:1990. From this test, the average yield stress (f_y) and modulus of elasticity (Es) were 327 MPa and 2.08×10^5 MPa, respectively. The parameter of the specimens and the results of the testing are shown in Table 3. Each of the CFST column specimens was given a unique code to differentiate the specimens from one another. For example, specimens labelled with BA-140H-9 represent a hollow section as H stands for hollow. As for in-filled specimens, the number after 'BA' represents the percentage of the CBA used in the concrete, e.g. BA15 specimens with 15% replacement of CBA. The number 140 and 160 in the label represent the column diameters. All tests were carried out using a universal testing machine of safe working capacity of 2000 kN.

Table 1. The mix proportion for self-compacting concrete

Mixture	Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Sand (kg/m^3)	Coal Bottom ash (kg/m^3)	Water-to-binder ratio (w/p)	Superpasticizer (SP)
BA0	561	593	914	-	0.4	0.2
BA15	561	593	777	100	0.4	0.2

Table 2. The fresh properties of self-compacting concrete

	BA0	BA15
Slump flow diameter (mm)	635	605
Slump flow time T_{500} (s)	2.54	3.23
Segregation Resistance (%)	12.86	11.53

Table 3. Program and results for CFST columns.

No	Specimens ID	Infill type	D (mm)	t(mm)	f'_c (Mpa)	f_y (Mpa)	N_{exp} (kN)
1	BA-140H-19	Hollow	140	4.71			872.8
2	BA-160H-19	Hollow	160	4.79			1089.9
3	BA0-140-19	Without CBA	140	4.71	36.3	380	1550.1
4	BA0-160-19	Without CBA	160	4.81			1927.7
5	BA15-140-19	With CBA	140	4,94	34.2		1501.0
6	BA15-160-19	With CBA	160	4.85			1848.6

Test setup and procedures

A steel plate of 10mm thickness was welded at the bottom of the steel tube to contain the concrete during the casting. Before testing, the uneven surface at the top of the column was filled with high strength mortar in order to ensure that the concrete surface level was the same as the steel tube level. The top of the column was then welded with a steel plate of 10mm thickness in order to ensure that the load was applied simultaneously to the concrete core and the steel tube during testing. All specimens were tested in the Heavy Structure Laboratory at Faculty of Civil Engineering, Universiti Teknologi MARA in Shah Alam. The specimens were tested under concentric axial compression loads. A universal testing machine with a 2000 kN capacity was used. The loads were applied in small increments at a very slow rate (approximately 50-100 kN/min) in order to identify critical information during testing and sufficient data were collected. The strain gauges were installed on the exterior surface of specimens in order to measure the deformations and perimeter expansion of the steel tubes. The linear variable differential transducer (LVDT) were used to measure the elongation and shortening along the working axis. The specimens were subjected to monotonic axial loading at a rate of 0.2 mm/min. This was to ensure that the buckling of the specimens could be carefully observed.

EXPERIMENTAL RESULTS

Result analysis

Six long columns with a length of 1900mm were tested under axial compression to failure. A linear varying displacement transducer (LVDT) and strain gauge were installed in order to analyse the behaviour of the long column under compression. From the test results, there was a significant increase in the ultimate strength of the CFST due to the concrete filling in the hollow section. The specimen filled with SCC without CBA shows the highest strength compared to SCC with CBA and hollow section. From the load-displacement graph in Figure 1, the typical curve can be generally characterized by three processes: elastic stage, elastic-plastic stage and post-peak stage. The elastic-plastic stage in the graph shows that the specimens have high stiffness and low deformation during the initial stage of loading. However, the linear-elastic relationship progressively becomes non-linear as the CFST starts to yield and local buckling is noticeable at the mid-height of the specimens. Furthermore, the slow decrease of the axial load at the post-peak region indicates reasonable ductility performance for the CFST column. The difference between the ultimate strength of the specimens filled with SCC without CBA and SCC with CBA is 5%. Which indicates that SCC with CBA are able to provide stiffness to the steel tube comparable to SCC without CBA. From the graph in Figure 1, it can also be observed that the bearing capacity of the column increased with the diameter. For example, the strength of the BA0-160-19 increased about 20% at the terminated strength when compared to specimens BA0-140-19. As for the specimens with 150mm diameter, note that the axial load applied to the specimens BA0-160-19 and BA15-160-19 was terminated as it almost exceeded the capacity of the testing machines. The load-strain graph of the CFST specimens are depicted in Figure 2. From the load-strain graphs, it can be observed that the specimens behave in a ductile manner. Among all, specimen BA0-140-19 shows better stiffness and confinement compared to BA15-140-19 as the BA0-140-19 was able to undergo relatively high strain compared to BA15-140-19. This suggests that SCC without CBA provided high stiffness to the steel tube compared to SCC with CBA.

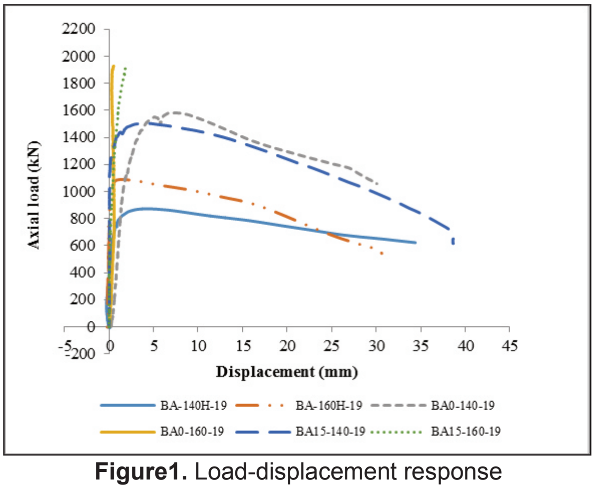

Figure1. Load-displacement response

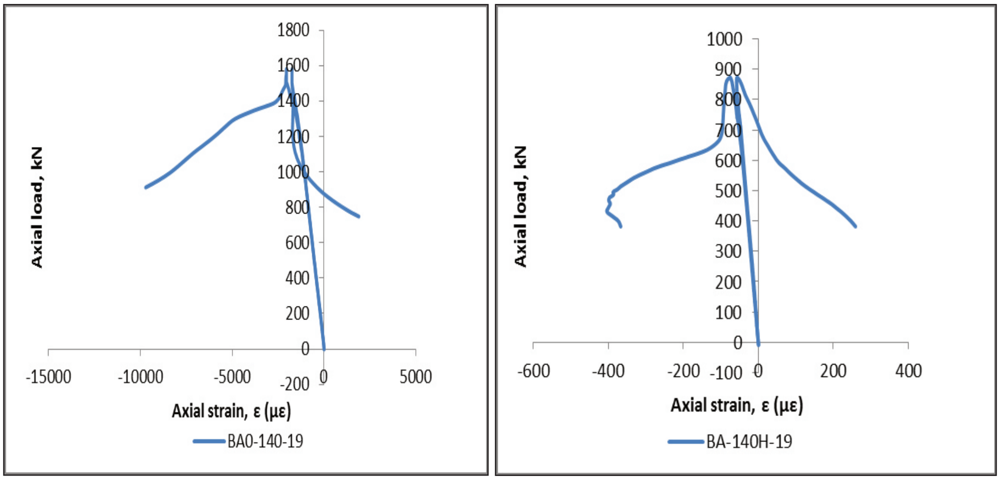

Figure 2. Load- strain response for specimens

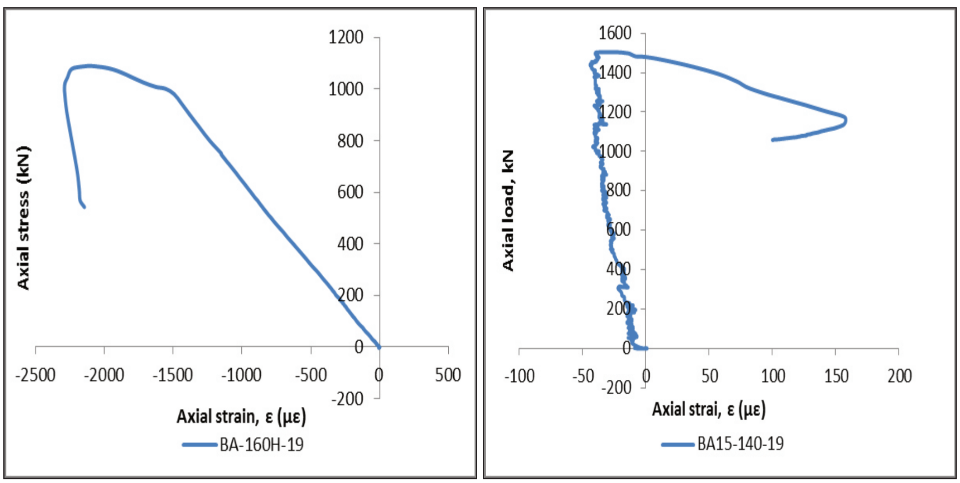

Figure 2. Load- strain response for specimens (continued)

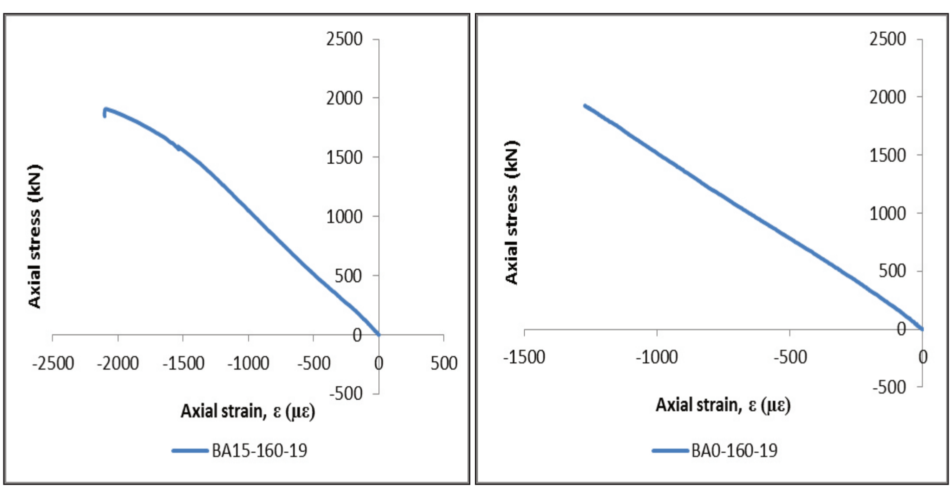

Figure 2. Load- strain response for specimens (continued)

Failure mode

Two typical failures were observed and classified as overall buckling and local buckling. Figure 3 shows the typical failure of the specimens after testing. All specimens failed after reaching the ultimate strength and the overall buckling occurred at the mid-height section for specimens BA-140H-19 and BA15-140-19. The local buckling was observed on specimens BA-160H-19 and BA0-140-19 at the third quarter of the specimen height. As for specimens BA0-140-19 and BA15-140-19, the steel was removed from the specimens after failure and the concrete was found to have taken the shape of the deformed steel tube with tensile crack. As for specimens BA0-160-19 and BA15-160-19, no presence of failure was observed on the surface of the steel tube even when the maximum load of up to 1900kN was applied.

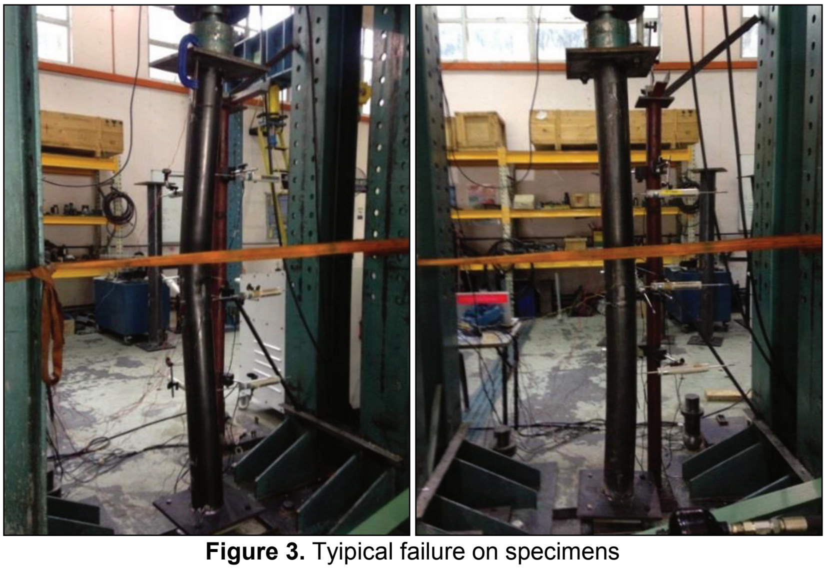

Figure 3. Tyipical failure on specimens

Comparison with Eurocode 4

According to Yu *et. al.* (2007), EC4 gives a reasonable prediction for the ultimate capacities of the CFST specimens compared to other international standards. Furthermore, EC4 covers concrete-filled sections with or without reinforcement and is the only code that treats the effects of long-term loading separately (Giakoumelis and Lam, 2004). In this study, the experimental results were compared with the design rules as specified in EC4 (BS EN 1994-1-1). In EC4, the ultimate strength of the CFST was calculated by adding the resistance of the composite column components as shown in Eq (1):

$$N_{pl,Rd} = A_a . \eta_a . f_y + A_c . f'_c . \left[1 + \eta_c . \frac{t}{d} . \frac{f_y}{f'_c}\right] \quad (1)$$

Where A_a and A_c are the cross-sectional area of the steel tube and concrete and f_y and f'_c are the yield stress of the steel and cylinder strength of the concrete, respectively. The coefficient η_a and η_c represent the steel reduction factor and concrete enhancement coefficient and are calculated as $\eta_a = 0.25(3+2\bar{\lambda}) \leq 1.0$ and $\eta_c = 4.9 - 18.5\bar{\lambda} + 17\bar{\lambda}^2 \geq 0$, respectively. These functions were used for the case where the eccentricity of loading (e) was equal to zero. The function $1+ \eta_c (t/d) (f_y/f_c)$ represents the concrete enhancement factor.

For a circular composite column, if the relative slenderness ($\bar{\lambda}$) were no greater than 0.5 (stockier columns with approximately L/d ≤ 12), the increase in the concrete strength caused by confinement of the steel tube should be taken into account in designing the ultimate capacity of the specimens. The $\bar{\lambda}$ is defined by $\bar{\lambda}=\sqrt{N_{pl,Rk}/N_{cr}}$. The $N_{pl,Rk}$ in this function represents the compressive resistance $N_{pl,Rk} = A_a.f_y + A_c.f'_c$ and the elastic load for the column length, N_{cr} is calculated from $N_{cr} = \pi^2(EI)_{eff} / (K_e.L)^2$ where $(EI)_{eff}$ is the effective elastic flexural stiffness and K_e is the effective length factor.

EC4 takes into account the second order moment, which might be caused by imperfection. Therefore, the reduction factor (χ) was applied to the compressive resistance of the CFST, as given in Eq. (2).

$$N = \chi N_{pl.Rd} \qquad (2)$$

The reduction factor (χ) is calculated from the column curve and is given by $\chi = 1\left(\phi + \sqrt{\phi^2 - \bar{\lambda}^2}\right)$, where $\phi = 0.5(1+\alpha(\bar{\lambda}-0.2)+\bar{\lambda}^2)$. Note that this equation depends on the relative slenderness of the column and χ no greater than 1.

Table 4. Comparison of test results with Eurocode 4

Specimens	Nexp	Npl, Rk	Nexp/N_{EC4}
BA-140H-19	872.8	805.9	1.08
BA0-140-19	1550.1	1420.5	1.09
BA15-140-19	1501.0	1386.0	1.08
BA-160H-19	1089.9	925.3	1.18
BA0-160-19	1927.7	1743.6	1.11
BA15-160-19	1848.6	1697.6	1.09
Standard deviation			0.03
Mean			1.10
COV			0.03

To validate the applicability of the EC4, the experimental results of the CFST columns were compared with the predicted compressive resistance of EC4 as calculated in the design code. Table 4 shows the comparison of the test results with EC4. As predicted the compressive resistance of the column increased with the increase in the column diameter. From the table, the highest compressive resistance was achieved by specimens without CBA. This is probably due to the strength of the concrete without CBA being higher than the concrete with CBA. The confinement effect on the concrete can be observed in the composite column. The values of the specimens with SCC double the value of the hollow section with or without CBA. This suggests that the composite action between the steel and concrete enhances the mechanical behaviour of the column structure.

CONCLUSION

This paper presents the experimental study on the slender CFST columns with SCC incorporating CBA. Six specimens were loaded concentrically to fail. Based on the experimental observation, the following conclusions may be drawn:

- The failure mode of the CFST column was the combination of both the overall and local buckling. The local buckling failure was observed at the third quarter of the column length. There was no sign of failure on specimens BA0-160-19 and BA15-160-19 after the termination.
- The specimens with SCC incorporating CBA show comparable strength development to the specimens with SCC without CBA. The difference between the ultimate strength of both specimens is 5%, which indicates that SCC with CBA is able to provide stiffness to the steel tube comparable to SCC without CBA. The strength of the specimens was observed increased with the increased of the steel tube diameter. The ultimate strength of the specimens obtained from the experimental work was compared with EC4. From the result, EC4 was under-estimating the ultimate strength of the specimens. In general, all specimens behaved in a fairly ductile manner

REFERENCE

Baig, M. N., Fan, J. and Nie, J. (2006) Strength of concrete filled steel tubular columns. *Tsinghua Science and Technology*, 11(6): 657–666.

Dehn, F., Holschemacher, K. and Weiße, D. (2000) Self-Compacting concrete (scc) time development of the material properties and the bond behaviour. *LACER*, 5:115–124.

Ernida, N. A. Z., Haziman, M. I. W., Jamaluddin, N., Kamaruddin, K. and Hamzah, A. F. (2014) The effect of bottom ash on fresh characteristic , compressive strength and water absorption of self-compacting concrete. *Applied Mechanics and Materials*, 660(8):145–151.

Giakoumelis, G. and Lam, D. (2004) Axial capacity of circular concrete-filled tube columns. *Journal of Constructional Steel Research*, 60(7):1049–1068.

Hu, H., Huang, C., Wu, M. and Wu, Y. (2003) Nonlinear Analysis of axially loaded concrete-filled tube columns with confinement effect. *Journal of Structural Engineering*, 129(10):1322–1329.

Jamaluddin, N., Lam, D., Dai, X. H. and Ye, J. (2013) An experimental study on elliptical concrete filled columns under axial compression. *Journal of Constructional Steel Research*, 87: 6–16.

Khatib, J. M. (2008) Performance of self-compacting concrete containing fly ash. *Construction and Building Materials*, 22(9):1963–1971.

Muciaccia, G., Giussani, F., Rosati, G. and Mola, F. (2011) Response of self-compacting concrete filled tubes under eccentric compression. *Journal of Constructional Steel Research*, 67(5): 904–916.

Su, N., Hsu, K. C. and Chai, H.-W. (2001) A simple mix design method for self-compacting concrete. *Cement and Concrete Research*, 31(12):1799–1807.

Vejmelková, E., Keppert, M., Grzeszczyk, S., Skaliński, B. and Černý, R. (2011) Properties of self-compacting concrete mixtures containing metakaolin and blast furnace slag. *Construction and Building Materials*, 25(3):1325–1331.
Yazici, H. (2008) The effect of silica fume and high-volume Class C fly ash on mechanical properties, chloride penetration and freeze–thaw resistance of self-compacting concrete. *Construction and Building Materials*, 22(4):456–462.
Yu, Z., Ding, F. and Cai, C. S. (2007) Experimental behavior of circular concrete-filled steel tube stub columns. *Journal of Constructional Steel Research*, 63:165–174.

GUIDE TO AUTHORS

Aims and Scope:

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

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

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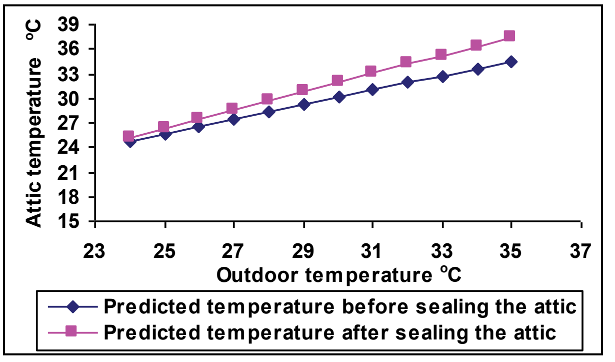

Figure 8. Computed attic temperature with sealed and ventilated attic

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

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

Table Line: 0.5pt.

Table 1. Recommended/Acceptable Physical water quality criteria

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

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

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

Journal

Sze, K. Y. (1994) Simple Semi-Loof Element for Analysing Folded-Plate Structures. *Journal of Engineering Mechanics*, 120(1):120-134.

Books

Skumatz, L. A. (1993) Variable Rate for Municipal Solid Waste: Implementation, Experience, Economics and Legislation. Los Angeles: Reason Foundation, 157 pp.

Thesis

Wong, A. H. H. (1993) *Susceptibility To Soft Rot Decay In Copper-Chrome-Arsenic Treated and Untreated Malaysian Hardwoods*. Ph.D. Thesis, University of Oxford. 341 pp.

Chapter in book

Johan, R. (1999) Fire Management Plan For The Peat Swamp Forest Reserve Of North Selangor and Pahang. In Chin T.Y. and Havmoller, P. (eds) *Sustainable Management of Peat Swamp Forests in Peninsular Malaysia* Vol II: Impacts. Kuala Lumpur: Forestry Department Malaysia, 81-147.

Proceedings

Siti Hawa, H., Yong, C. B. and Wan Hamidon W. B. (2004) Butt Joint In Dry Board As Crack Arrester. *Proceeding of 22nd Conference of ASEAN Federation of Engineering Organisation* (CAFEO 22). Myanmar, 55-64.

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