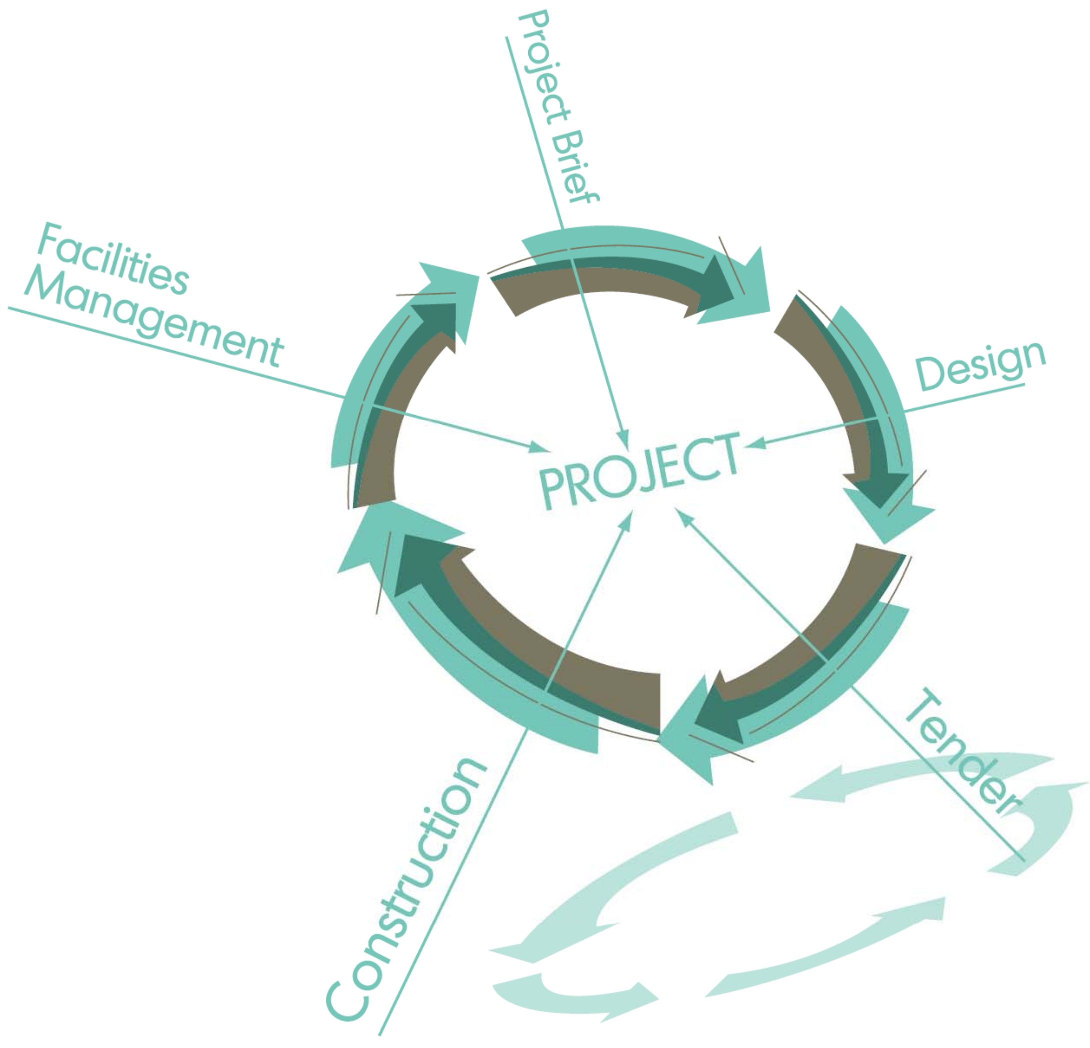
ISSN 1985-3807

MCRJ Volume 10 | No.1 | 2012

Malaysian Construction Research Journal



CREAM
Construction Research Institute of Malaysia

CIDB MALAYSIA

MALAYSIAN CONSTRUCTION RESEARCH JOURNAL (MCRJ)

Volume 10 | No.1 | 2012

The Malaysian Construction Research Journal is indexed in
Scopus Elsevier

ISSN No.: 1985 - 3807

Construction Research Institute of Malaysia (CREAM)
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Editorial Advisory Board

Editorial

Welcome from the Editors

Welcome to the tenth issue of Malaysian Construction Research Journal (MCRJ). The editorial team would like to extend our gratitude to all authors and reviewers for their continuous contributions and valuable comments. It is hope that the readers will find beneficial information from this edition of MCRJ. 6 papers are discussed in this issue.

Byung Gyoo Kang, et. al. investigates the ethical perceptions of designers and contractors in the Malaysian construction industry. 18-major ethical issues have been identified and used in the questionnaire survey. The outcome shows that contractors and designers in Malaysia have similar ethical perceptions despite the differences in their roles and responsibilities in construction projects. Future researches in other countries are recommended to establish a theoretical background of ethical perceptions of construction professionals.

Mohd Yuasrizam Musa, et. al. study on experimental research conducted that focusing on simply supported beam to determine the crack propagations in flexure. From the experimental conducted, analysis showed that addition of steel fibre in conventional reinforced concrete beam increased the ultimate load by 56%, improved the flexural stress by 53% and deflection by 42%, reduced crack opening by 11% and thus inhibiting flexural cracks in beam.

Toong Khuan Chan, et. al. describes the behaviour of semi precast pile caps supported by two piles subjected to axial loading. Objective of this paper is to evaluate the performance of these precast shell pile caps to carry axial loads by comparing the behaviour of these pile caps at ultimate limit state with that of the conventional cast in-situ cap.

Mohd Nasrun Mohd Nawi, et. al. discusses the critical success factors (CSFs) that are pertinent to improving the integration of design and construction activities and summaries the recommendations from industry workshops on the critical success factors towards effective integrated design team delivery in IBS.

Mastura Jaafar, et. al. examines the current JIT practices of IBS manufacturers with respect to transportation and delivery, inventory level, production, client relationship, supplier relationship and also problems faced by them. This research proposed suggestions for new researchers as well as the industry towards the betterment of Malaysian construction industry.

Mohamed Nor Azhari Azman, et. al. introduced a conceptual GIS suitability model by applying six criterion factors i.e. road characteristic, proximity from the new potential development area, population census, proximity from the existing infrastructure, topography and land-use suitability.

Editorial Committee

ETHICAL PERCEPTIONS AND DEMOGRAPHIC FACTORS: A COMPARATIVE STUDY BETWEEN CONTRACTORS AND DESIGNERS IN THE MALAYSIA CONSTRUCTION INDUSTRY

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Abstract
Corporate ethics together with Corporate Social Responsibility (CSR) is becoming a new requirement for a successful business in the 21st century. This trend continues to be strengthened throughout the industry and the construction industry cannot be exceptional. However, for construction ethics management, different approaches are required from other industries due to the project based feature of the industry. In construction projects, designers and contractors are two main stakeholders in respect of the product. This paper investigates the ethical perceptions of designers and contractors in the Malaysian construction industry. 18-major ethical issues have been identified and used in the questionnaire survey. 8-construction companies (contractors) and 8-engineering consulting firms (designers) have been involved in the survey. The ethical issues are ranked based on 'frequency' and 'seriousness' for contractors and designers respectively. In addition the relationship between demographic factors and ethical issues, comparisons between the ethical perceptions of contractors and designers have been analysed through SPSS (Statistical Package for the Social Sciences). The outcome shows that there is no significant difference between contractors and designers in terms of 'seriousness'. For 'frequency' of ethical issues, there seems to be some differences between them. The result also indicates that demographic factors do not influence the ethical perceptions. Overall, contractors and designers in Malaysia have similar ethical perceptions despite the differences in their roles and responsibilities in construction projects. Future researches in other countries are recommended to establish a theoretical background of ethical perceptions of construction professionals.

Keywords*: Construction, Ethics, Contractor, Designer, Demographic*

INTRODUCTION

Ethics in business is becoming a defining issue of our time, affecting corporate profits and credibility, as well as sustainability of global economy. Construction cannot be excluded from this trend. According to the Bribe Payer Index of Transparency International (TI), public works/construction is the business sector most prone to bribery, followed by arms and defence, and oil and gas (Transparency International, 2008). Further, disastrous consequences of unethical behaviours of construction professionals cannot be underestimated as can be seen in the collapse of Sampoong Department Store in Seoul, Korea, 1995 – 501 deaths, 937 injured and 6 missing. (National Emergency Management Agency in Korea, 2011). The main causes of this disaster are incorrect construction, negligence in supervision, excessive structural changes approved by the local government officers who were bribed by the client and main contractor. These causes are definitely related to ethical standards and practice of the construction professionals in the construction project.

The construction industry requires a different approach to ethics management from manufacturing or factory based industries. In manufacturing or factory based industries, mass production methods are common practice and stakeholders are related to business. However, in the construction industry, most projects tend to be one-off and the stakeholders are related to the project. The major stakeholders in construction are the participants of the project, typically clients, designers (architects/ engineers), contractors, sub-contractors, suppliers and end-users. These participants can have different levels of moral development and ethical standards. Therefore, ethical conflicts can easily arise among these participants unless a certain degree of alignment of ethical standards and values is set throughout a project. (Kang et al, 2006a). In Design-Bid-Build (DBB) projects which are traditional and still most common type of contracts, two major stakeholders in actual production of the project are designers and contractors. Here the designers are the representative of the client whereas the contractor is at the bottom of the hierarchy. Therefore their roles and responsibilities are quite different in many aspects, sometimes leading to confrontational situations. Considering the importance of these two stakeholders in construction projects, it is worth investigating the ethical perceptions of these two professionals.

The aim of this research is to investigate the ethical perceptions of contractors and designers in the Malaysia construction industry, thus comparing them to understand the differences and similarities.

The objectives of this research are to:

1. Review and identify current ethical issues in the construction industry.
2. Investigate the differences in ethical perceptions between contractors and designers in the Malaysia construction industry.
3. Investigate the relationship between ethical perceptions and demographic factors among contractors and designers in the Malaysia construction industry.

Malaysia has been chosen as the target country mainly because:

1. Malaysia is a multicultural society whose population is composed of 60% Malay, 30% Chinese and 10% of Indian people and this combination can reflect some of possible international participations in construction projects in Asia region.

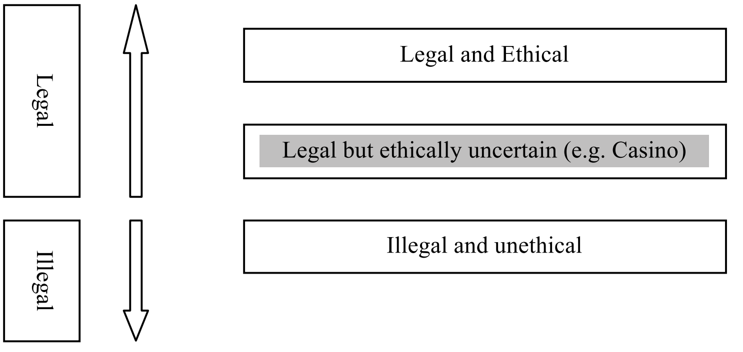
2. As the authors of this research are working in Malaysia, it is relatively easy to acquire accurate data for the research.

LITERATURE REVIEW

Ethical Issues in Construction

Ethics may be defined as ‘philosophical inquiry into the nature and grounds of morality’ (Taylor, 1975 pp 1). Ethics is thus, a branch of philosophy. Frankena (Chapter 1, pp 4-9, 1973) also argued that ethics is moral philosophy or philosophical thinking about morality, moral problems and moral judgements. The term 'morals' is often used by many people to define ethics as it relates to their everyday life or work. Further, 'morals' and 'ethics' are often used interchangeably. However, Sahakian (1974) argued that this practice is not acceptable. According to Sahakian (Chapter 1, pp 6-7, 1974), ethics is the term for the study of morals or moral issues and consists of a theoretical or rational interpretation of moral phenomena. Here, the term 'morals' is not a study or discipline but the standard which individuals should observe in their conduct. In this research, Sahakian's definition is adopted as it gives a clear direction to the research on ethics.

As Ford Pinto case shows, serious consequences might occur if a sole ethical theory is applied to engineering fields (Martin & Schinzinger, 2010, and Harris et al. 2005). The ethics programmes should be based on harmonisation of ethical theories such as end-oriented utilitarianism, mean- oriented deontological theories, virtue ethics etc. (Corvellec and Macheridis, 2010; Helgadóttir, 2008; Kang et al, 2006b). Especially when ethically uncertain issues can be considered legal, this can lead to conflicts between legality and ethicality (Figure 2). These are the areas where most of ethical dilemmas occur. The ethical dilemmas should be dealt very carefully to avoid further conflicts.



(Adapted from Carroll and Buchholtz, 2003)

Figure 2. Ethicalness and Legality

Jackson (2005) conducted a survey on 15 ethical issues for experienced US construction practitioners and identified the ranking of the 15 ethical issues in terms of 'frequency' and 'seriousness'. Fan et al., (2001) argued that quantity surveyors attach great importance to the interest of their clients and employers, and the general public is not considered as an important party when resolving ethical dilemmas. Fan (2009) also found out that when making ethical decisions, construction professionals adopt an egoism approach which prioritises their self-interest and their families' interests higher than the public's interest. A study of UK construction managers' views on ethical perceptions showed that the following were the top five unethical behaviours (Poon, 2004) -Producing falsifying reports, Over-claiming expenses, Having low level of personal honesty, Having deceptive advertisement, Providing trade secrets in order to exchange for personal benefits. At the tendering stage, the ethical issues include improper tendering practices such as withdrawal, bid cutting, cover pricing, compensation of tendering costs (Ray et al., 1999) and collusive tendering behaviour (Zarkada and Skitmore, 2000). Vee and Skitmore (2003) identified unethical conducts in the form of unfair conduct, negligence, conflict of interest, collusive tendering, fraud, confidentiality and propriety breach, bribery and violation of environmental ethics in the construction industry. These studies implied that ethical issues are spread over throughout the lifecycle of construction projects. Thus, the project level approach should be included for effective and efficient ethics management in construction.

Table 1 show the ethical issues in construction which have been identified through the above literature reviews and adopted to be used as the questions in the survey. These issues are comprehensive and detailed enough to represent the ethical issues in the construction industry.

Table 1. Ethical Issues in the Construction Industry

Issue No.	Description
1	**Lack of competence or misinterpretation of competence** (Examples: Operating outside one's area of expertise, operating without a license, misleading information, etc.)
2	**Lack of quality or quality control of work** (Examples: Not satisfying specification, compromising standard, use of low quality material, lack of working manner while performing, etc.)
3	**Lack of protection to public's health, safety and welfare** (Examples: Poor risk management and assessment, neglect worker's safety, hazardous material, etc.)
4	**Lack of protection to the environment** (Examples: Action contributing to water, air, sound, etc., pollution, natural resources depletion, etc.)
5	**Improper bidding practices** (Examples: Bid shopping- disclosing a contractor's bid to another prospective contractor to secure lower bid, Under bid - To make an unnecessarily lower bid, etc.)
6	**Improper Bill of quantities practices (BoQ)** (Examples: Engineer inflates price in BoQ with intention to collude with successful contractor, etc.)
7	**Improper drawings practices** (Examples: Engineer includes unnecessary structure or material in drawing in sharing the excess cost with abettor, etc.)
8	**Improper political or society involvement, conflict of interest** (Examples: Involvement in politic for personal and company's interest, fraud, performing construction services for others' financial, political and personal interest, etc.)
9	**Misrepresentation of financial status or records** (Examples: Misleading lending institution, bank, client, etc.)
10	**Misrepresentation of completed work or value of work** (Examples: Adjusting schedule of value, work percentage completed, etc.)
1	**Abuse of company resources** (Examples: Use of company's telephone, vehicles, facilities, etc, for self-beneficiary, etc.)
12	**Abuse of client resources** (Examples: Over billing for time and material, excessive charges, etc.)
13	**Favouritism, discrimination and harassment** (Examples: Bias treatment in favour of race, sex and religion in performing construction practice, sexual harassment, etc.)
14	**Mishandle sensitive information** (Examples: Revealing or obtaining confidential information such as bid and price, violation of privacy, etc.)
15	**Failure to practice whistle-blowing** (Examples: Failure to inform any wrongdoing occurring in workplace, no protection given to whistle-blower, etc.)
16	**Bribery and corruption** (Examples: Making or receiving illegal payment in a form of money or gifts in exchange for favour or influence, etc.)

17	**Alcohol and drug abuses** (Examples: Consumption of alcohol and drug while on duty, consumption of alcohol and drug off duty which could affect performance while on duty, possession of alcohol and drug at workplace, etc.)
18	**Workplace violence** (Examples: Bringing or using weapon at workplace, causing commotion at workplace, extortion, etc.)

RESEARCH METHODLOLOGY

Figure 1 shows the methodology and logic of this research. Similar surveys were conducted successfully in USA, UK and South Korea before this research (Jackson, 2005, Kang 2009). In addition, as ethical perceptions are very sensitive matters, face to face interviews are not an appropriate method. This fact also gives a justification to use the quantitative approach – questionnaire surveys.

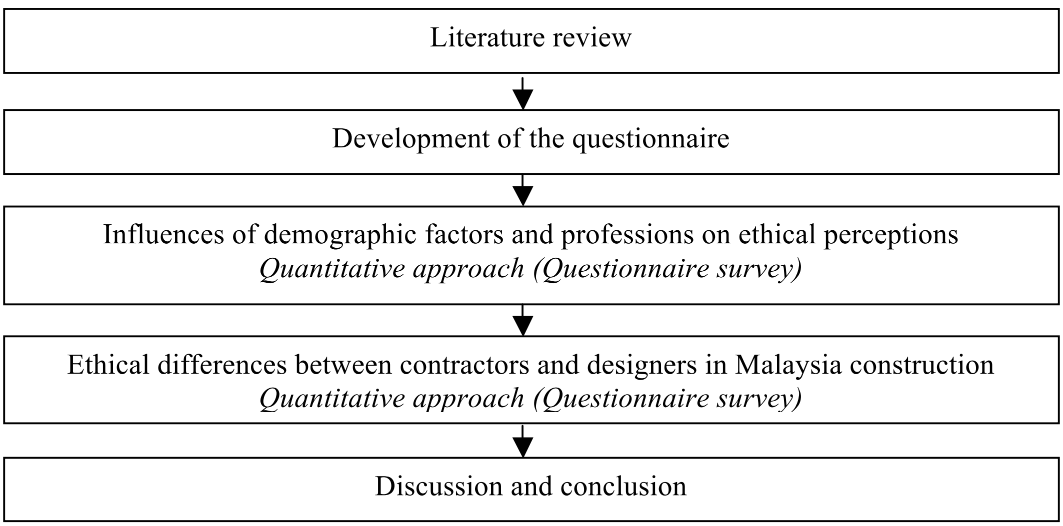


Figure 1. Flowchart of the Logic of the Research

FINDINGS AND DISCUSSION

The Survey Undertaken

The participants involved in the survey are people who work for either construction companies (contractors) or consulting engineering firms (designers) in Malaysia. Regardless of their positions in the company, all workers were eligible to answer the questionnaire. Anonymity of the survey participants and their companies was assured to avoid any negative reputations of the company or bias responses from the participants.

Preliminary selections of companies were;

i. Browsing contractor's companies in Construction Industry Development Board (CIDB) Malaysia Official Portal's directories for local contractor;

ii. Browsing engineering consultant's firm in The Association of Consulting Engineers Malaysia's directory of members; and
iii. Through search and recommendations for companies in Kuala Lumpur and Selangor.

Further selections were made from the list of preliminary selection to ensure that the selected companies' best represent contractors and engineering consultants. Criteria for the second selection were;

i. Amount and size of completed projects;
ii. Awards/achievements received; and
iii. Company websites (all reputable companies have their own websites)

The cheaper and faster method of sending out questionnaires is the use of email. But the response rates can be very low. Therefore questionnaires were distributed to selected companies by hand. 150 questionnaires were distributed to eight companies, each for construction companies and consulting engineers firms. All selected companies were informed in advance by phone call of the intention to carry out survey in their companies. A cover letter was presented when handing in the questionnaire to ease the procedure. The receiver of questionnaire (either receptionist or representative of the company) was briefed on the details of the questionnaire survey. Questionnaires were collected once it was completed, normally one week or two weeks later.

Questionnaires are divided into two parts. First part contains 18 ethical issues with responses using Likert Scale of 1 to 5. Every issue has two Likert scales, one for seriousness of the issue and the other for frequency of issue. For the Likert scale of seriousness, 1 indicates 'not serious at all', 2 indicates 'fairly serious', 3 indicates 'serious', 4 indicates 'very serious' and 5 indicates 'extremely serious'. Subsequently, for the Likert scale of frequency, 1 indicates 'never', 2 indicates 'rarely', 3 indicates 'sometimes', 4 indicates 'often' and 5 indicates 'very often'. Second part of the questionnaire contains 6 questions. The questions require the participants to fill in their demographic information such as gender, age, working experience, education level, the existence of company codes of ethics and the effectiveness of the codes of ethics.

Results and Analysis of the Survey

Table 2 shows the response rates from contractors and designers. The response rates are quite good as the questionnaires were directly handed out to/ collected from the survey participants. The statistical analyses have been conducted using the Statistical Package for the Social Sciences, SPSS. Due to the nature of the data – not normally distributed and not equally variant-, non-parametric tests are adopted instead of parametric tests (Field, 2009).

Table 2. Response Rates of Questionnaires for Contractors and Designers

	Contractors	Designers	Total
Sent	150	150	300
Received	69	95	164
Response Rates in %	**46%**	**63%**	**55%**

Significance Level

The preset significance level in this analysis is 0.05, which is the typical level to decide whether the null hypothesis should be rejected or not. (Chapter 6, Morgan et al, 2004 and Chapter 4, Kerr et al, 2002). So, if p<=0.05, then the null hypothesis of no difference or no relationship would be rejected as it is highly unlikely due to chance.

Differences of ethical perception within a demographic factor

Table 3 summarises the demographic factors used in the survey. The demographic information is categorised into six factors and subdivided into several groups. For example, ‘age’ has been divided into six sub-groups from ‘20 and below’ to ’61 and above’. All six demographic factors have been analysed by Kruskal-Wallis (K-W) test. These analyses identified ethical differences among each sub-group within the same demographic factors –e.g. whether differences in age range can influence the ethical perceptions.

Table 3. Ranges of Demographic Factors

Gender	Age (Years)	Working Experience	Education	Code of Ethics’ Existence in Organisation	Effectiveness of Code of Ethics
Male	20 and below	Below 5 years	SPM/ O level	Yes	Yes
Female	20-30	6-10 years	STPM/A level	No	No
	31-40	11-15 years	College diploma		
	41-50	16-20 years	University’s bachelor degree		
	51-60	Above 20 years	Master’s degree		
	61 and above		PhD		

The Kruskal-Wallis (K-W) test compares the mean ranks within a demographic factor. If the test statistics shows statistical significance (p<=0.05), then it can be interpreted that there is an overall difference among the range groups in the chosen demographic factor. On the other hand, if the test statistics shows no statistical significance (p.>0.05), then the overall difference is highly unlikely. The K-W test, in this research, has provided a tool to investigate the differences in ethical perceptions among the ranges of a demographic factor. Table 4 summarises the outcome for Kruskal-Wallis test for all the demographic factors. It can be seen that only frequency of ‘Effectiveness of Code of Ethics’ within the contractors’ groups has significant difference when tested at 0.05 (shaded in table 4) – one issue out of twenty four. Therefore, there is virtually no difference in ethical perceptions of the participants in relation to the demographic factors. Consequently, the demographic factors do not influence the ethical perceptions of contractors and designers.

Table 4. Output for Kruskal-Wallis Test

	Contractors		Designers	
Demographic factors	Seriousness	Frequency	Seriousness	Frequency
Gender	H*(1)=0.001 P=0.971	H(1)=0.045 P=0.833	H(1)=1.632 P=0.201	H(1)=0.053 P=0.819
Age	H(4)=1.791 P=0.774	H(4)=3.567 P=0.468	H(3)=6.951 P=0.073	H(3)=3.749 P=0.290
Working Experience	H(4)=1.582 P=0.812	H(4)=3.623 P=0.459	H(4)=4.292 P=0.368	H(4)=2.594 P=0.628
Education	H(4)=3.722 P=0.445	H(4)=4.964 P=0.291	H(3)=1.424 P=0.700	H(3)=1.092 P=0.779
Code of Ethics' Existence in organisation	H(2)=2.054 P=0.358	H(2)=1.145 P=0.564	H(2)=3.356 P=0.187	H(2)=0.705 P=0.703
Effectiveness of Code of Ethics	H(2)=0.946 P=0.623	H(2)=7.426 P=0.024	H(2)=0.349 P=0.840	H(2)=0.561 P=0.756

**H: Test statistic for Kruskal-Wallis test*

Correlations between ethical perception and demographic factors

To reconfirm the findings from Kruskal-Wallis test and investigate whether there are statistically significant relations between mean of seriousness and frequency and the demographic factors, the Spearman correlations were computed. Table 5 summarises the outcomes of Spearman correlation between mean of seriousness and frequency and the demographic factors. Applying significance level of p=0.05, only designers' mean of seriousness in 'age' factor is significantly correlated (shaded in Table 5) again only one issue out of twelve. This shows that ethical perceptions of the participants in relation to the demographic factors are not different among them. This reconfirms that demographic factors do not exert influences on the ethical perceptions of contractors and designers.

Table 5. Results of Spearman Correlation between Mean of Seriousness and Frequency and Demographic Factors

Demographic factors	Contractors		Designers	
	Mean of Seriousness	Mean of Frequency	Mean of Seriousness	Mean of Frequency
Age	γ_s*(69)=0.023 P=0.848	γ_s(69)=-0.084 P=0.493	γ_s(95)=-0.218** P=0.034	γ_s(95)=-0.153 P=0.138
Working Experience	γ_s(69)=-0.085 P=0.486	γ_s(69)=-0.104 P=0.394	γ_s(95)=-0.201 P=0.051	γ_s(95)=-0.137 P=0.186
Education	γ_s(69)=0.078 P=0.524	γ_s(69)=0.210 P=0.083	γ_s(95)=-0.103 P=0.359	γ_s(95)=-0.086 P=0.444

**Spearman's Correlation coefficient*
***Correlation is significant at the 0.05 level (2-tailed)*
(Gender, existence and effectiveness of code of ethics are excluded as the ranges are independent from each other –i.e. 'male' vs. 'female' and 'yes' vs. 'no')

Ethical perception of contractors and designers

Table 6 and 7 show 'mean, standard deviation, rank' of the issues in terms of seriousness and frequency from contractors and designers. For example, the differences of ethical perception on 'Q1: lack of competence or misinterpretation of competence' is 16^{th} seriousness issue and

7th frequent issue among the contractors. The most serious ethical issue from contractors is 'bribery and corruption' and from designers it is again 'bribery and corruption'. The most frequent ethical issue for contractors is 'abuse of company resources and from designers it is' lack of protection to the environment'.

Table 6. Seriousness, Frequency and Importance of Ethical Issues (Contractors)

Ethical Issues	**Seriousness**			**Frequency**			**Importance**	
	Mean	Stdev*	Rank	Mean	Stdev	Rank	Value	Rank
Bribery and corruption	3.942	1.110	1	3.101	1.202	6	12.226	**1**
Lack of protection to the environment	3.681	1.078	6	3.319	1.022	2	12.217	**2**
Improper political or society involvement, conflict of interest	3.826	0.999	2	3.159	1.120	4	12.088	**3**
Abuse of company resources	3.522	1.066	12	3.377	1.214	1	11.892	**4**
Lack of quality or quality control of work	3.652	1.012	8	3.232	0.860	3	11.803	**5**
Failure to practice whistle-blowing	3.652	0.888	7	3.058	1.149	8	11.168	**6**
Lack of protection to public's health, safety and welfare	3.710	1.139	5	2.986	0.993	9	11.077	**7**
Improper bidding practices	3.638	0.907	10	2.928	1.048	11	10.649	**8**
Abuse of client resources	3.725	1.013	4	2.855	1.019	13	10.634	**9**
Lack of competence or misinterpretation of competence	3.420	0.976	16	3.058	0.856	7	10.459	**10**
Mishandle sensitive information	3.551	1.092	11	2.870	1.028	12	10.189	**11**
Improper bill of quantities practices (BoQ)	3.449	1.051	14	2.928	0.913	10	10.098	**12**
Misrepresentation of completed work or value of work	3.217	0.838	18	3.116	0.814	5	10.025	**13**
Misrepresentation of financial status or records	3.435	0.962	15	2.725	0.922	15	9.359	**14**
Favouritism, discrimination and harassment	3.449	1.022	13	2.710	1.126	16	9.348	**15**
Improper drawings practices	3.333	0.965	17	2.754	0.881	14	9.179	**16**
Alcohol and drug abuses	3.652	1.359	9	2.507	0.949	17	9.157	**17**
Workplace violence	3.754	1.355	3	2.377	0.956	18	8.922	**18**
Average of Mean	3.589			2.948			10.583	
Stdev of Mean	0.182			0.266			1.136	

The importance values in Table 6 and Table 7 are obtained by multiplying mean of seriousness and mean of frequency in each issue. Both contractors and designers view 'bribery and corruption' and' lack of protection to the environment' to be the two most important ethical issues. If average mean of all the issues are taken into account, contractors and designers ethical perceptions are quite similar (difference of 0.216=3.589-3.373 for seriousness and 0.234=2.948-2.714 for frequency).

Table 7. Seriousness, Frequency and Importance of Ethical Issues (Designers)

Ethical Issues	**Seriousness**			**Frequency**			**Importance**	
	Mean	Stdev*	Rank	Mean	Stdev	Rank	Value	Rank
Bribery and corruption	3.937	1.156	1	3.189	1.416	3	12.556	**2**
Lack of protection to the environment	3.747	1.010	2	3.442	1.028	1	12.899	**1**
Improper political or society involvement, conflict of interest	3.516	1.237	5	2.905	1.238	7	10.214	**6**
Abuse of company resources	3.011	1.067	18	3.063	1.119	5	9.222	**9**
Lack of quality or quality control of work	3.611	1.075	4	3.253	0.922	2	11.744	**3**
Failure to practice whistle-blowing	3.400	1.115	7	2.726	0.994	11	9.269	**8**
Lack of protection to public's health, safety and welfare	3.737	1.084	3	3.116	0.999	4	11.643	**4**
Improper bidding practices	3.442	1.182	6	3.032	1.153	6	10.435	**5**
Abuse of client resources	3.126	1.094	16	2.737	1.023	10	8.556	**10**
Lack of competence or misinterpretation of competence	3.379	1.187	8	2.832	0.781	8	9.568	**7**
Mishandle sensitive information	3.232	1.340	12	2.358	0.944	14	7.620	**14**
Improper bill of quantities practices (BoQ)	3.211	1.262	13	2.579	1.017	12	8.280	**13**
Misrepresentation of completed work or value of work	3.042	1.041	17	2.779	0.936	9	8.454	**11**
Misrepresentation of financial status or records	3.147	1.229	15	2.316	0.926	15	7.289	**15**
Favouritism, discrimination and harassment	3.347	1.270	9	2.505	1.061	13	8.386	**12**
Improper drawings practices	3.179	1.353	14	2.200	0.974	16	6.994	**16**
Alcohol and drug abuses	3.347	1.486	10	1.947	0.972	17	6.519	**17**
Workplace violence	3.305	1.544	11	1.874	0.970	18	6.193	**18**
Average of Mean	3.373			2.714			9.213	
Stdev of Mean	0.256			0.447			2.026	

The Mann-Whitney (M-W) test is used to statistically compare the differences between contractors and designers, as the M-W test is developed to compare two different conditions. The comparisons have been made in frequency and seriousness of the ethical issues. From table 8, it can be seen that only question 11 and 12 (shaded in Table 8) produce significant difference between contractors and designers in term of seriousness when tested at 0.05. However in terms of frequency, there are seven issues with differences between contractors and designers (shaded in Table 9). In general, it can be concluded that the ethical perceptions between contractors and designers are quite similar in spite of the differences in their roles and responsibilities in construction projects.

Table 8. Output for Mann-Whitney Test (Seriousness)

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Q1	3241.000	7801.000	-0.126	0.900
Q2	3216.500	7776.500	-0.211	0.833
Q3	3257.000	7817.000	-0.071	0.943
Q4	3199.000	5614.000	-0.273	0.785
Q5	2970.000	7530.000	-1.064	0.287
Q6	2943.000	7503.000	-1.150	0.250
Q7	3124.500	7684.500	-0.525	0.600
Q8	2848.000	7408.000	-1.484	0.138
Q9	2851.500	7411.500	-1.470	0.142
Q10	2989.000	7549.000	-1.008	0.313
Q11	2485.500	7045.500	-2.732	0.006
Q12	2305.500	6865.500	-3.354	0.001
Q13	3208.000	7768.000	-0.239	0.811
Q14	2863.500	7423.500	-1.417	0.156
Q15	2908.500	7468.500	-1.284	0.199
Q16	3256.000	5671.000	-0.075	0.940
Q17	2897.000	7457.000	-1.307	0.191
Q18	2755.000	7315.000	-1.804	0.071
Mean of Seriousness	2832.000	7392.000	-1.485	0.138

Table 9. Output for Mann-Whitney Test (Frequency)

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Q1	2836.000	7396.000	-1.611	0.107
Q2	3136.500	5551.500	-.498	0.619
Q3	3030.500	5445.500	-.862	0.388
Q4	2974.000	5389.000	-1.057	0.291
Q5	3072.500	5487.500	-.708	0.479
Q6	2668.500	7228.500	-2.134	0.033
Q7	2167.500	6727.500	-3.899	0.000

Q8	2897.500	7457.500	-1.303	0.192
Q9	2535.000	7095.000	-2.599	0.009
Q10	2635.500	7195.500	-2.294	0.022
Q11	2851.000	7411.000	-1.465	0.143
Q12	3078.500	7638.500	-.692	0.489
Q13	2909.000	7469.000	-1.276	0.202
Q14	2431.500	6991.500	-2.961	0.003
Q15	2786.000	7346.000	-1.731	0.083
Q16	3124.000	5539.000	-.523	0.601
Q17	2191.000	6751.000	-3.802	0.000
Q18	2266.000	6826.000	-3.562	0.000
Mean of frequency	2650.500	7210.500	-2.090	0.037

Discussion

The findings of this research indicates that demographic factors such as gender, age, working experience, education, existence/ effectiveness of code of ethics do not influence the ethical perceptions among contractors and designers in the Malaysia construction industry. To check the consistency of the findings with current trends and studies, literatures on the influences of demographic factors in business ethics have been reviewed. Table 10 presents the findings on relevant studies of demographic factors in relation to ethics and business ethics in Journal of Business Ethics (JBE). JBE has been selected as the main publication of this literature review. JBE is the leading academic journal in business ethics. The focus on JBE also secures the consistency in analysing the findings and trends on studies of demographic factors in business ethics. The majority of the findings indicate that in respect of demographic factors, the outcomes are not consistent. Therefore the influences of demographic factors are very low. However the only demographic factor which shows consistency is nationality i.e. when more than two nations are compared. This can be in line with Kang (2009)'s research in that the most influencing factor for the ethical perceptions of contractors and designers can be nationality not the demographic factors. Kang (2009) compared UK construction and Korea construction, subdividing them into contractors and designers as is in this research. For the 2nd stage of this research, Singapore and/or Indonesia can be considered for the comparison with Malaysia.

Table 10. Empirical Studies of Demographic Factors in Relation to Ethics in JBE

Author(s)	Year	Survey subjects	Findings
Mujitaba et al	**2011**	**448 citizens, managers and employees in Iran**	**Education and work experience make a difference in the moral maturity of respondents**
Sweeney et al	**2010**	**441 Ireland and 114 U.S. pre-manager level auditors**	**Country (nationality) has a significant impact on auditors' ethical evaluation and intention. company size, work experience, age not significant**
Peterson et al	**2010**	**6300 business students attending 120 colleges and universities in 36 countries**	**Statistically significant differences were found between the business-related ethicality of American survey participants and that the non-American survey participants (different nationalities). However the magnitudes of the differences were not substantial. Further research required for generalisation.**

Nilsson	2008	528 private investors	Women and better-educated investors were more likely to invest a greater proportion of their investment portfolio in Socially Responsible Investment.
Park et al	2008	284 South Korean, 230 Turkish, and 245 U.K. university students	For different ways of possible whistle blowing, significant variations related to nationality and culture were found.
Kisamore et al	2007	217 business students	Age was significantly related to misconduct contemplations. Gender was not.
Arnold et al	2006	294 employees in accounting firms from 8 Western European countries	Nationality was related to ethical perceptions. Gender and position in company were not.
Lopez et al	2005	353 business students	Business education and gender were related to ethical perceptions. Age was not.
Forte	2004	214 managers of Fortune 500 firms	Age and position in company were related to moral reasoning. Gender, education level and work experience, were not.
Valentine and Rittenburg	2004	222 business professionals in US and Spain	Nationality was related to teleological (consequential) evaluation. American individuals had higher teleological (consequential) evaluation.

CONCLUSION

This research has investigated the ethical perceptions of contractors and designers in the Malaysia construction industry, analysing 18-ethical issues in terms of 'seriousness' and 'frequency' and 6-demographic factors of the survey participants. The main findings of this research together with the rankings of ethical issues (Tables 6 & 7) are summarised below.

1) Kruskal-Wallis (K-W) tests have shown that there is virtually no significant difference within the sub-groups of the demographic factors in terms of seriousness and frequency of ethical issues from both contractors and designers. –e.g. differences in age range (sub-group) do not influence ethical perceptions of contractors and designers.
2) Spearman correlation tests have reconfirmed the findings from K-W tests that there is practically no significant correlation between demographic factors and seriousness and frequency of the ethical issues from both contractors and designers again.
3) Mann-Whitney tests have shown that overall there are no significant difference between the perceptions of contractors and designers on the seriousness of ethical issues, though the frequency of ethical issues tends to have some differences between contractors and designers.

The SPSS analysis has shown that there is in general no difference in the way contractors and designers perceive ethical issues in the Malaysia construction industry, despite their different roles and responsibilities in construction projects. In case of seriousness, only two issues out of eighteen are statistically different. For frequency issues they showed some differences. Moreover, the analysis confirms that demographic factors such as gender, age, education, experience, existence of code of ethics and effectiveness of code of ethics do not influence the ethical perceptions among contractors and designers in Malaysia.

The ranks of ethical issues in terms of seriousness and frequency can be used to help establish codes of ethics, ethics training programmes and ethical decision making systems for construction and engineering companies in Malaysia. In this research, the geographical boundary is limited to Malaysia. This research can be expanded to other countries in Asia in order to identify the ethical perceptions of construction professionals together with ranks of the issues and compare the similarities and differences among different countries. This will make a good contribution to reduce ethical conflicts when various stakeholders with different national and cultural backgrounds work together in international construction projects. As the second stage of investigation on the relationships between demographic factors and ethical perceptions, personal traits such as Locus of Control (LOC) and Defining Issues Test (DTI), and positions in an organisation and the size and type of the organisation will be good areas of research.

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EFFECT OF STEEL FIBRES IN INHIBITING FLEXURAL CRACKS IN BEAM

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Abstract
Concrete is widely used as it is cheap and versatile construction material as compared to other material. Tension in concrete beam causes cracks formation. In this study, the introduction of the steel fibre in reinforced concrete beam at tension zone has been proposed in inhibiting the flexural cracks. This experimental research was conducted focusing on simply supported beam to determine the crack propagations in flexure. The mix includes 1.0% steel fibre. This dosage was selected for this study as an optimum concrete strength (f_{cu}) was achievable and economical when compared to other dosage. Three sets of beams with size of 150 mm x 250 mm x 1000 mm were tested under flexure to determine the serviceability and ultimate flexural strength. A set of two beams was cast full with 1.0% steel fibre (SFRC), another set of two beams with 1.0% steel fibre placed at the tension zone of the beam and the last set of two beams as control sample. For SFRC (tension zone) beam the steel fibre is limited into the tension zone to investigate the effectiveness of the steel fibre usage. The analysis showed that addition of steel fibre in conventional reinforced concrete beam increased the ultimate load by 56%, improved the flexural stress by 53% and deflection by 42%, reduced crack opening by 11% and thus inhibiting flexural cracks in beam.

Keywords: *Steel fibre, fibre, flexural cracks, beam, reinforced concrete beam, steel fibre reinforced concrete beam*

INTRODUCTION

Cracking occurred when stresses in the concrete exceed the concrete strength and it is a major problem for concrete structure usually in terms of site application, resistance to loading and general lack of durability. This study is focused on to determine the effect of steel fibre in reinforced concrete beam by analysing and comparing the crack propagations and flexural strengths of the reinforced concrete (RC) beam and steel fibre reinforced concrete (SFRC) beam. Members that are subjected to the bending forces generally exhibit a series of distributed flexural cracks, even at working load. These cracks are less disrupting and harmless unless the width become too excessive, in which appearance and durability will anguish as the reinforcement are exposed to corrosion. This study is based on experimental work involving compression test of concrete cube that contain of 1.0% volume of steel fibre, tensile test and bending test of reinforcement bar that was used in the reinforced concrete beam and lastly, flexural test of RC beam, SFRC beam and SFRC (tension zone) beam.

FINDINGS FROM PREVIOUS RESEARCH

According to study of Altun et al (2006), bending experiments on beams conclude that both the ultimate loads and the flexural toughness of reinforced-concrete beams produced with concrete classes of C20 and C30 with steel fibres at a dosage of 1.25% increase appreciably as compared to the plain RC beams. They also found that SFRC beams having steel fibres at a dosage about 1.25% should be favoured or even should be common practice, because firstly the crack formation, crack size, and crack propagation in beams against bending moments are appreciably better, secondly the ultimate bending-moment-carrying capacity is a little better, and thirdly and most importantly the toughness is much higher than those of the RC beams having the same conventional reinforcement but no steel fibres. However in this study a dosage of 1.0% steel fibres was chosen because according to Norharyati (2010), concrete cube with dosage of 1.0% steel fibre give the highest compression strength compared to 0.6%, 0.8% and 1.25% of steel fibre addition and as such is expected that the bending behaviour will be in similar trends to findings of Altun et al (2006).

Lim and Oh (1999) had carried out experimental and theoretical investigation on the shear of steel fibre reinforced concrete beams and they found that the addition of steel fibres increases the compressive strength, flexural strength and tensile splitting strength and the increase is greatest in tensile splitting strength. Steel fibres can greatly enhance the tensile properties of concrete and improve resistance to cracking. They also found that the mode of failure changed from shear to flexure when the volume fraction of steel fibres used exceeds a certain amount, namely about 1% in this study. This means that the addition of fibre reinforcement increases shear capacity greatly.

In 2011, Ibrahim and Che Bakar studied on effects of mechanical properties on industrialised steel fibres addition to normal weight concrete. From their experimental works on the properties of compression, they determined that specimen with 0.5% steel fibres give the lower compressive strength compared with plain concrete and as steel fibres increases between 0.75% and 1.25%, it shows constant increased in the compression strength. Moreover, they determined that splitting tensile and flexural strengths show SFRC with steel fibres dosages of 0.5% and 0.75% are merely ineffective because there is not much improvement on the mechanical properties and the Modulus of Elasticity as compared with plain concrete. Meanwhile, SFRC with 1.00% and 1.25% steel fibres resulted in the increase of the splitting tensile strength and flexural strength. However, there is not much improvement in strength for SFs dosage between 1.00% and 1.25%.

According to research done by Holschemacher et al (2009) entitled effect of steel fibres on mechanical properties of industrialised steel fibres addition to normal weight concrete, the SFRC has increased extensibility and tensile strength under flexural loading. The fibres hold the matrix together even after extensive cracking. It yields pronounced post-cracking ductility, compared to ordinary concrete. Transformation from a brittle to ductile type of material increases the energy absorption characteristics of steel fibre reinforced concrete and its ability to withstand repeatedly applied, shock or impact loading.

Bencardino et al (2009) have reviewed experimental evaluation of fibre reinforced concrete fracture properties. They stated that the behaviour of the ordinary concrete specimens was almost linear-elastic up to the peak load, followed by a slight descending branch up to failure, then the complete separation of specimens into two parts occurred. On the contrary, fibre reinforced concrete specimens showed a tri-linear variation with an extensive cracking process between first crack load and peak load that clearly differentiated them from the plain concrete (PC) specimens. In their research, the SFRC specimens showed peak flexural loads of about two to three times that of the PC at 1% and 2% fibre volumes, respectively. The SFRC specimens had residual loads of 70–90% of their peak loads at a deflection of 3 mm. The loss in load capacity was gradual especially at the 2% fibre volume content.

METHODOLOGY

The investigation is focused on the effectiveness of using steel fibre in the concrete beam in order to reduce the crack propagation within it. Structural member were designed using f_{cu} of 30 N/mm^2. The concrete mixing contained of Ordinary Portland Cement (OPC), water, normal coarse aggregate and sand. The compliance material tests involved is slump test, casting and curing, concrete cube compression test, steel reinforcement tensile test and steel reinforcement bending test. Subsequently, beams were subjected to three points bending in ensuring ultimate moment occurring under the point load in maximising flexural cracks.

Materials Compliance Testing

Materials compliance tests were conducted accordingly for concrete and steel reinforcement. BS 1881 and MS 7.1 specify the use of concrete cubes for determining compressive strength using 100 mm x 100 mm x 100 mm cubes for quality control purposes. The compression test was conducted in order to determine the compressive strength (crushing strength) of concrete test cube according to BS 1881: Part 4: or MS 7.1: Part 1: 1971 for 7 days, 14 days and 28 days comprises of plain concrete as control sample and concrete containing of 25 kg/m^3 steel fibre.

Reinforcement tensile test is used to measure the stress that builds up in the materials as its length is being pulled by moving crossheads. Meanwhile, for reinforcement bending test, BS 4466: 1997 specified bend test to determine any transverse rupture on the metal during bending. For this research, reinforcement bar grade 250 N/mm^2 uses bar of 6 mm as shear links and reinforcement bar grade 460 N/mm^2 uses bar of 10 mm as top and bottom steel.

Preparation of Beam Specimens

All beams were design according to BS8110-4:1997 using steel reinforcement with yield strength of f_y = 460N/mm^2. The beams were cast after all the material compliance tests were done and met the requirements. The plain RC beams and SFRC beams were cast as the usual procedure. However, in the SFRC (tension zone) beams, the pouring was done in stages. The steel fibres concrete mix was first poured into the formwork to the height of 125 mm complying with the tension zone position of the beam and then allowed to set before topping up with the plain concrete mix. The set time is short enough as not to allow formation of separation between the two mixes but appropriate to let the steel fibre remain in the tension zone only.

Flexural Test of Concrete Beam

Flexural tests are conducted on the simply supported RC beams, SFRC beams and SFRC (tension zone) beams. They were loaded at mid span. The resulting bending moments induce compressive stresses at the top and tensile stress at the bottom of the beam. Crack propagations were monitored and measured. Strain gauges of 120 Ω and 5 mm length were bonded onto the longitudinal steel bar at mid span of the steel cage, two on the tensile bars and another two on the compression bars. The tests were carried out by imposing displacement rate of 0.01 mm/

sec using Universal Testing Machine with maximum load 250 kN. The load versus deflection graph, crack pattern and width, length of crack and cracking load, configuration of failure and defect in sample due to design and testing has been included in this report. Figure 2.1 and Figure 2.2 shows the schematic diagram of the beam sample and the three points bending test experimental set up for the simply supported beam respectively.

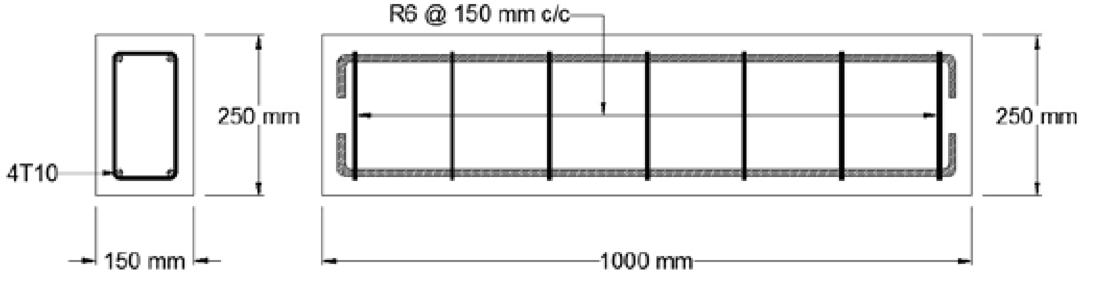

Figure 2.1. Schematic Diagram of Beam Samples

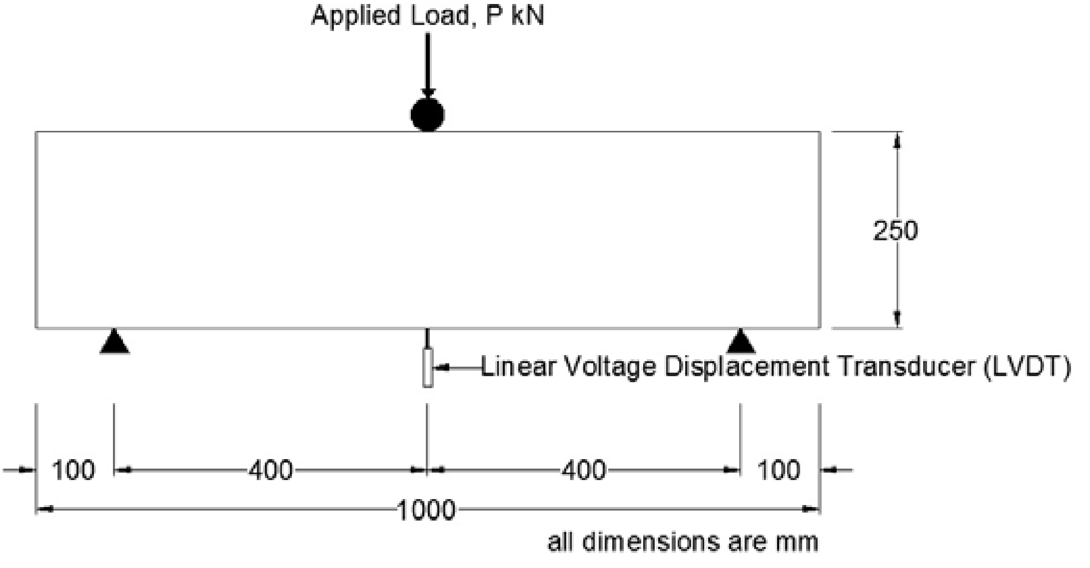

Figure 2.2. Three Points Bending Test Experimental Set Up for Simply Supported Beam.

RESULTS AND DISCUSSIONS

Steel fibres helped to improve mechanical properties of concrete by decreasing the permeability of the cracks, making concrete more ductile, improving its durability appreciably and increasing the strength of the concrete. The experiments were expected to show that incorporating fibres into concrete matrix improved the crack due to increase in tensile strength of mix.

Compressive Strength

Figure 3.1 shows the result of compressive strength of the control samples and concrete with 1% steel fibre. The characteristic strength for both batch designs is 30 N/mm^2 and the water cement ratio is 0.5. The concrete with steel fibre is stiffer than control sample making it less workable as steel fibre additions introducing more surface area absorbing the water. If water in the concrete with fibre is increase, the slump will increase and workability will be good but the strength of the concrete will decrease. According to research by Chang and Chai (1995), increasing the surface area of fibres per unit volume, the slump value decreases rapidly and the workability of the SFRC is worse. Therefore the water content has to increase adequately or a water-reducing agent used when the surface area of fibres per unit volume more than about 0.6 cm^2/cm^3. For this experiment, the f_{cu} obtained for plain concrete (PC) and steel fibre concrete (SFC) is 12% and 35% increase from the design value respectively. According to the weight and volume of the concrete cubes, the density of plain concrete and steel fibre concrete is 2451 kg/m^3 and 2466 kg/m^3. The different of density between plain concrete and steel fibre concrete is only 0.61%.

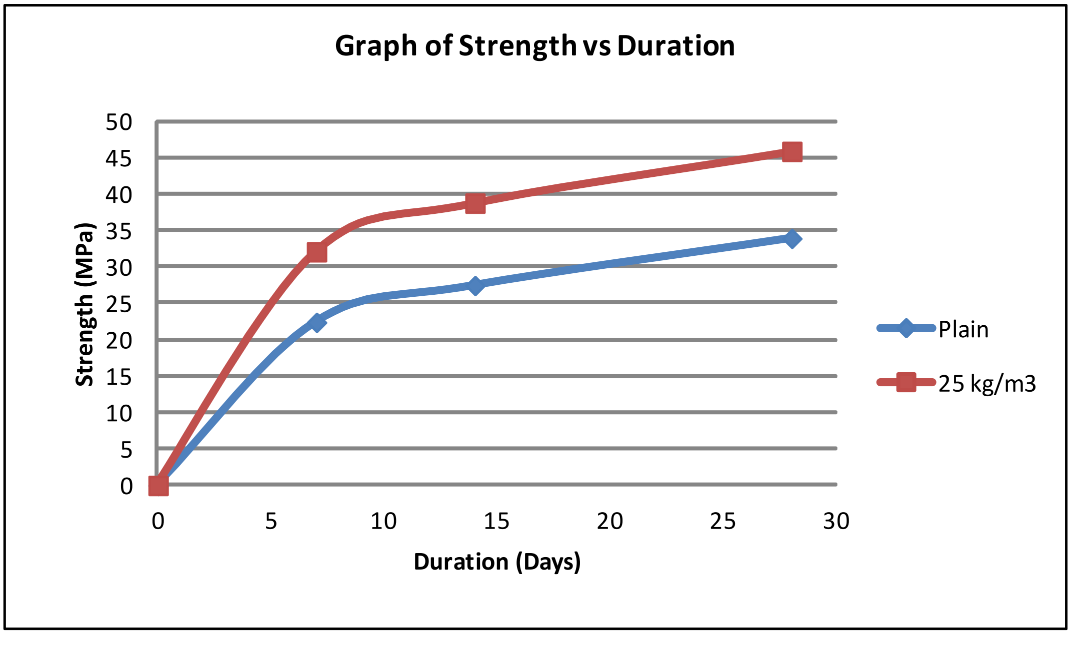

Figure 3.1. Graph of Compressive Strength Versus Duration

Ultimate Flexural Load and Deflection Plots

Figure 3.2 shows the graph of comparison of load versus deflection for all simply supported beams which is RC, SFRC and SFRC (tension zone) beams when subjected to static loading. All beams behave linearly during service until yield. Table 4.1 shows the applied load at first crack, yield and ultimate along with its respective deflection during the experiment for all beams. The flexural behaviour of fibre-reinforced concrete, even when the fibre content by volume and the cross-sectional dimensions are the same, differs considerably between the case where the Young's modulus of the fibre is higher than that of the matrix and the case where it is lower (Kobayashi & Cho, 1982).

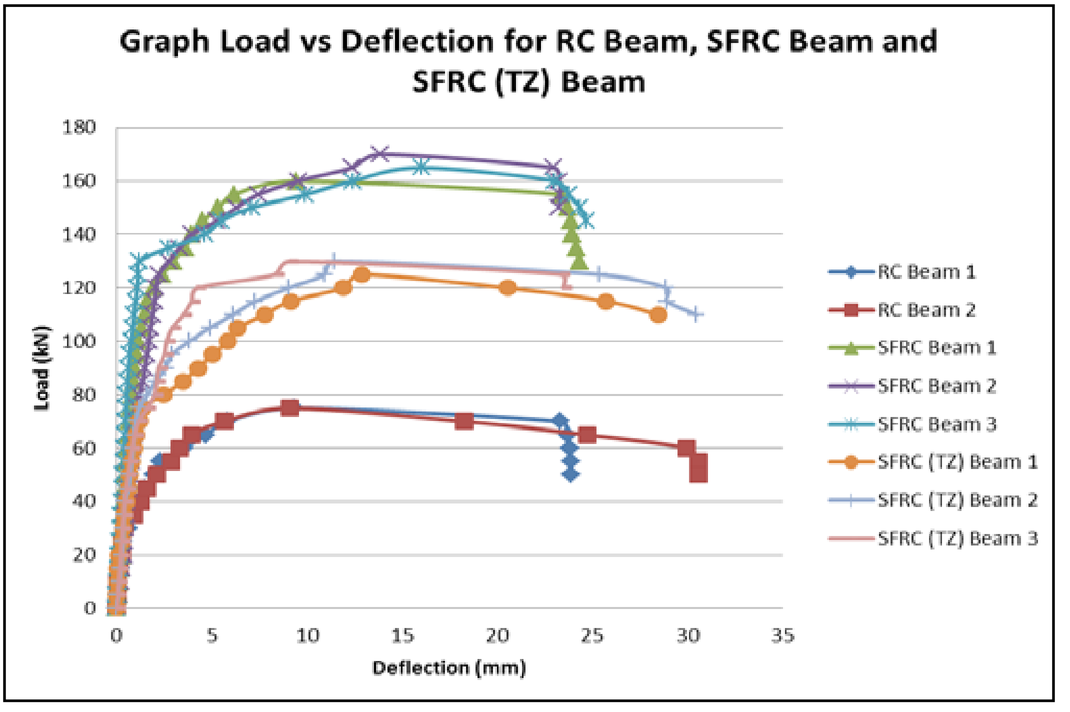

Figure 3.2. Relationship between Applied Load and Deflection in RC and SFRC (TZ) Beam

Table 3.1. Loads and Deflections

Sample	P_{crack} (kN)	δ at P_{crack} (mm)	P_{yield} (kN)	δ at P_{yield} (mm)	P_{ult} (kN)	δ at P_{ult} (mm)	P_{ult}/P_{yield}	P_{theory} (kN)	P_{ult}/P_{theory}
RC Beam 1	30	0.59	40	0.74	75	9.33	1.88	90.98	0.82
RC Beam 2	30	0.41	30	0.41	75	9.11	2.50	90.98	0.82
SFRC (TZ) Beam 1	55	0.78	75	1.37	125	12.88	1.67	108.05	1.16
SFRC (TZ) Beam 2	60	0.85	75	1.18	130	11.44	1.80	108.05	1.20
SFRC (TZ) Beam 3	60	0.81	70	1.15	130	9.12	1.86	108.05	1.20
SFRC Beam 1	70	0.67	120	1.93	160	9.44	1.33	125.14	1.28
SFRC Beam 2	65	0.93	125	2.22	170	13.88	1.36	125.14	1.36
SFRC Beam 3	75	0.49	130	1.20	165	16.01	1.27	125.14	1.32

Based on the experimental result, the crack load for SFRC (tension zone) beam and SFRC beam is improved by 50% and 60% from crack load on RC beam, respectively. Similar trend is seen in yield loads which are 47% and 69% higher than yield load on RC beam. As for the ultimate loads, SFRC (tension zone) improved the carrying capacity appreciably by 42%, meanwhile the SFRC beam improved by 56%. Full SFRC beam can sustain 24% greater applied load than the SFRC (tension zone). The ratio of ultimate load over yield load showed that the SFRC (tension zone) beam reduced by 26% and SFRC beam reduced by 46% from RC beam and reduced by 27% from SFRC (tension zone) beam. When compared between SFRC beam and SFRC (tension zone) beam, it could be seen that SFRC beam can sustain greater applied load than SFRC (tension beam) but the crack load and maximum deflection is not much different.

The SFRC (tension zone) beam and SFRC beam can sustain the maximum deflection under the ultimate load with 28% and 42% respectively increased from maximum deflection on RC beam. In comparing with theoretical deflection, the maximum deflection of RC beam 1 and 2 indicates 50% and 51% respectively decreased from the theoretical deflection value 18.76 mm. While, the maximum deflection of SFRC (tension zone) beam 1,2 and 3 indicates 31%, 39% and 51% decrements respectively and the maximum deflection of SFRC beam 1, 2 and 3 decreased 50%, 26% and 15% respectively. It is concluded that SFRC beam sustained deflection appreciably well compared to RC beam and both SFRC (tension zone) beam and SFRC beam can sustain almost similar maximum deflection under its maximum applied load.

For all three RC, SFRC and SFRC (tension zone) beams, the load started to decrease when the applied load reach the maximum strength and wider cracks were observed underneath the beams. The deflections magnitudes indicated by these three beams represent the appreciative function of the steel fibre in significantly controlling the deflection. Addition of steel fibre control deflection with lesser magnitude than normal RC beam. It shows that steel fibre-reinforcement enhances both tensile strength and fracture energy so that it can improve the flexural strength to a much extent for normal concrete beam behaviour performance. In terms of strength, SFRC (tension zone) beam can resist more load than RC beam even though only half of the beam contains steel fibres. Based on the concrete density, the SFRC beam which had higher concrete density can resist more flexural load compare to RC beam which had a lower concrete density.

Stress versus Strain

Figures 3.3, 3.4, 3.5 and 3.6 show the relationship between stress and strain of simply supported beam for strain gauges 1, 2, 3 and 4 respectively where initially the stress and strain behaves almost linearly until the concrete achieve the maximum stress. When maximum stress was reached, the stress decreased correlating to the increase of strain leading towards breakage. At this point, the beam experience strength degradation and reinforcement bars started to bend and beam tend to fail with severe rupture. The theory of bending for reinforced concrete assumes that the concrete will crack in the region of tensile strain and that, after cracking, all the tension is carried by the reinforcement (Mosley et. al, 1999). Strain gauges 1 and 2 were located on surface of tensile reinforcement bars while strain gauges 3 and 4 were located on surface of compression reinforcement bars. SFRC beam withstood greatest stress compared to RC beam and SFRC (tension zone) beam because it can sustain the highest applied load and deflection. On the other hand, the strain value recorded for SFRC (tension zone) beam and SFRC beam is much lower than the strain value for RC beam at the ultimate strength point. This represents that the amount of deformation of SFRC (tension zone) beam and SFRC beam body due to an applied force is less compare to RC beam.

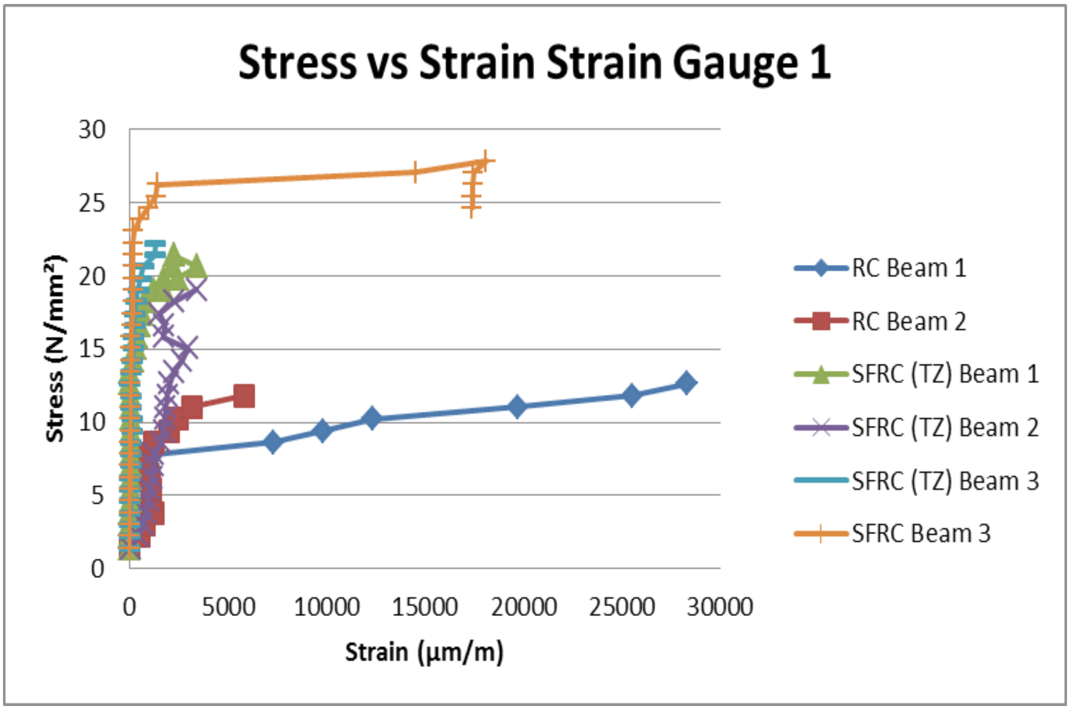

Figure 3.3. Graph Stress versus Strain Strain Gauge 1

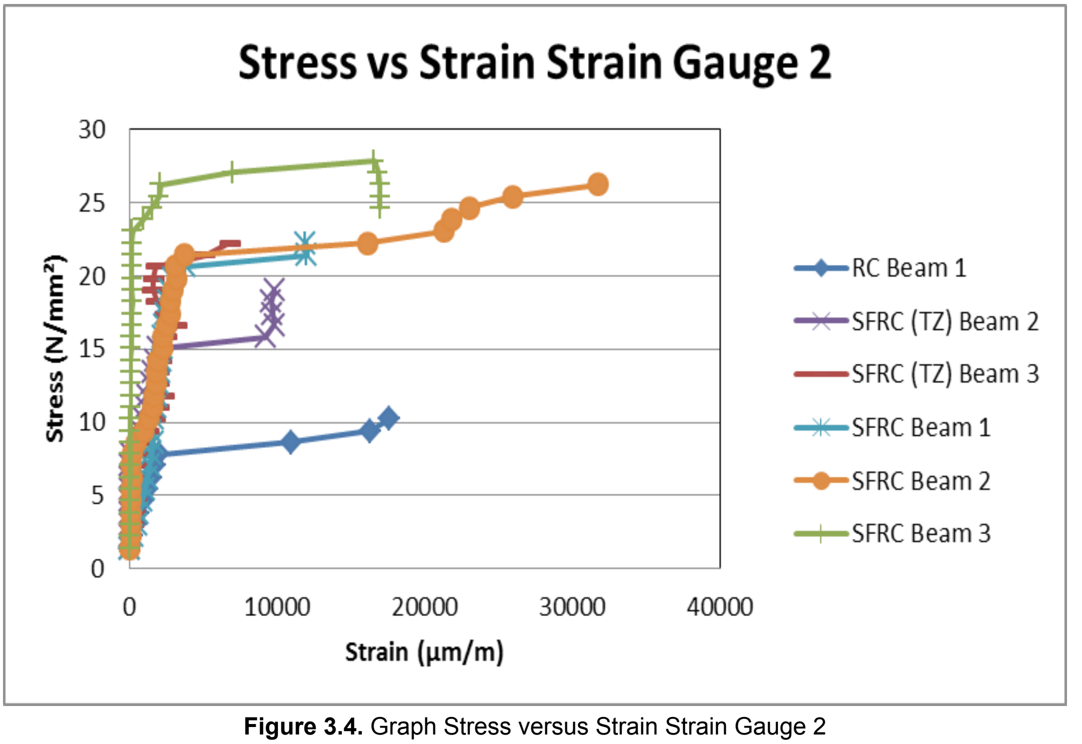

Figure 3.4. Graph Stress versus Strain Strain Gauge 2

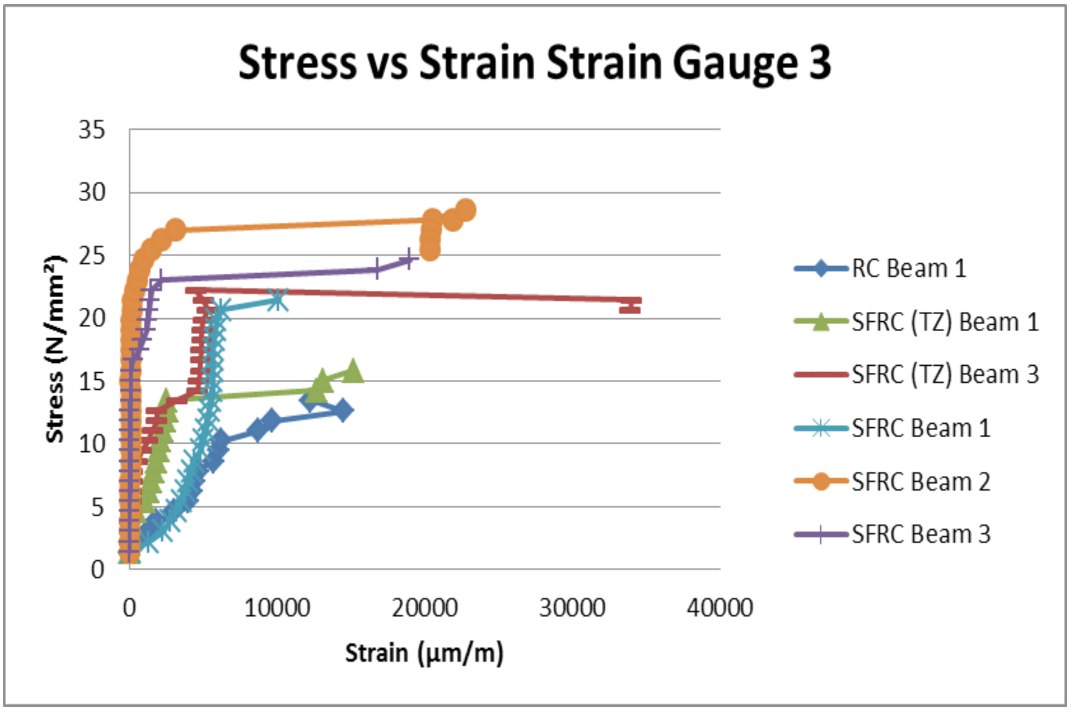

Figure 3.5. Graph Stress versus Strain Strain Gauge 3

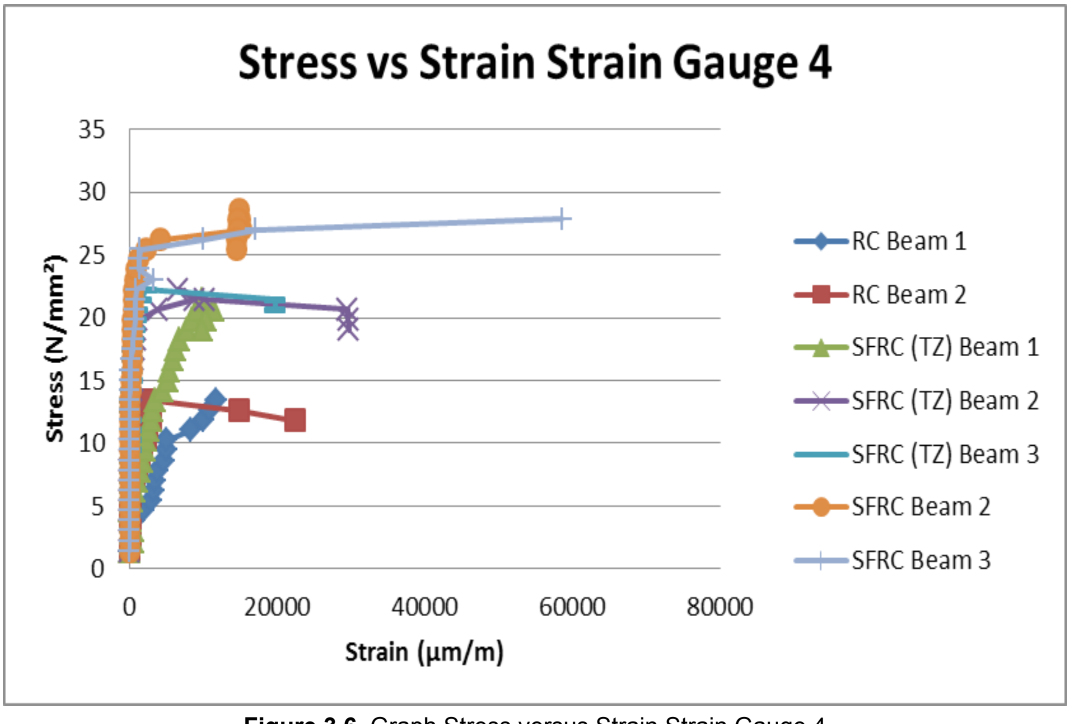

Figure 3.6. Graph Stress versus Strain Strain Gauge 4

As can be observed from the three points bending test, the flexural stress for both RC beams is 13.43 N/mm^2. Meanwhile, the flexural stress for SFRC (tension zone) beam 1, 2 and

3 is 21.43 N/mm^2, 22.23 N/mm^2 and 22.23 N/mm^2 respectively and for SFRC beam 1, 2 and 3 are 27.03 N/mm^2, 28.63 N/mm^2 and 27.83 N/mm^2 respectively. The flexural stress of SFRC (tension zone) beam 1 and 2 is 37%, 40% and 40% respectively higher than flexural stress on RC beam, while SFRC beam 1, 2 and 3 is 50%, 53% and 52% higher than flexural stress on RC beam, respectively. Based on the three point bending test result, it can be noted that the presence of the steel fibre in conventional reinforced concrete beam can improve the energy absorption capacity, thus allowed the reduction of deformation in brittle material particularly in concrete. While the compressive strength of steel fibre concrete cube increase 26% than compressive strength of plain concrete cube, the flexural stress of SFRC beam improve 53% than flexural stress of RC beam.

The bending modulus of the RC beam 1 is 32.32 kN/mm^2. On the other hand, the bending modulus for the SFRC (tension zone) beam 1, SFRC (tension zone) beam 2 and SFRC (tension zone) beam 3 is 72.73 kN/mm^2, 82.09 kN/mm^2 and 80.00 kN/mm^2 respectively. The bending modulus of the SFRC beam 2 and SFRC beam 3 is 48.48 kN/mm^2 and 48.19 kN/mm^2. Bending modulus for RC beam 2 and SFRC beam 1 is unavailable due to strain gauge faulty. Bending modulus of SFRC (tension zone) beam 1, 2 and 3 is 55.56%, 60.63% and 59.60% higher than RC beam, respectively. Meanwhile, the bending modulus of SFRC beam 2 and SFRC beam 3 is 33.33 % and 32.93% higher than the bending modulus on RC beam. The theoretical modulus of elasticity of concrete is 26 kN/mm^2. The bending modulus of RC beam is 19.55% higher than theoretical modulus of elasticity of concrete. Meanwhile, the bending modulus of SFRC (tension zone) beam 1, 2 and is 64.25%, 68.33% and 67.50% respectively higher than theoretical modulus of elasticity and the bending modulus of SFRC beam 2 and SFRC beam 3 is 46.37% and 46.05% higher than theoretical modulus of elasticity. RC beam with additional of 1.0% steel fibres increased the modulus of elasticity of the concrete.

Crack Patterns

Crack pattern and crack length is important parameter that requires observation and measurement during the experimental work for this research. The experimental results show that incorporating steel fibres into concrete matrix of beam improve the crack and deformation characteristic due to increase in strength. Besides, the random distribution of the steel fibre in reinforced concrete beam reduced the characterization of the damage process because it mentioned that dispersion in concrete modified the cracks propagation by slowing the crack initiation. The observation and measurement for length of crack and crack opening occurred in both beams during testing is stated in Table 3.2.

Table 3.2. Measurement Result for Crack Length and Crack Opening for RC, SFRC (tension zone) and SFRC Beam

Sample	P_{crack} (kN)	Maximum length of crack (mm)	Maximum crack opening (mm)	Theoretical crack opening (mm)	Type of crack in beam failure
RC Beam 1	30	230	25	0.29	Flexure
RC Beam 2	30	318	30	0.29	Flexure
SFRC (TZ) Beam 1	55	295	18	0.29	Flexure
SFRC (TZ) Beam 2	60	280	21	0.29	Flexure
SFRC (TZ) Beam 3	60	252	23	0.29	Flexure
SFRC Beam 1	70	440	15	0.29	Flexure
SFRC Beam 2	65	330	24	0.29	Flexure
SFRC Beam 3	75	260	27	0.29	Flexure

Table 3.2 shows the experimental result gathered based on the measurement of cracking imposed on the surface of the reinforced concrete beam. In the RC beam, the extensive crack formations are seen on the tension surface. On the other hand, the SFRC (tension zone) beam showed 8% and 30% significant reduction in the formation of the crack length and crack opening respectively compared to RC beam. The SFRC beam showed 38% increment in crack length and 11% reduction in crack opening compared to the RC beam. The SFRC (tension zone) can sustain 50% load more than RC beam before the beams started to crack. Meanwhile, the SFRC beam can sustain load 60% more than RC beam and 20% more than SFRC (tension zone) beam before the beams started to crack. The SFRC beam can sustain higher load and reduce more crack than RC beam. But, the crack load and crack pattern on SFRC (tension zone) is almost similar to SFRC beam even though the beam can sustain less maximum load compared to SFRC beam.

Figures 3.7 to 3.14 show the close-up view of cracks patterns for all beams samples after testing. From the side view of the beams, it is proven that the load capacity of RC beam contain 1.0% steel fibres was always higher compared to RC beam without steel fibres because from the side view of RC beams, the cracks can be seen propagating closer to mid span of the beam and formed significantly a wider visible crack opening of 25 mm for RC beam 1 and 30 mm for RC beam 2. On the other hand, for SFRC (tension zone) beam, it was indicated that only single crack opening measured 18 mm for SFRC (tension zone) beam 1, 21 mm for SFRC (tension zone) beam 2 and 23 mm for SFRC (tension zone) beam 3 imposed in beam surface together with several hairline cracks formed without undergoing structures failure. While, for SFRC beam, it was also indicated that only single crack opening displacement measured 15 mm, 24 mm and 27 mm for SFRC beam 1, SFRC beam 2 and SFRC beam 3 respectively imposed in beam surface together with several hairline cracks. The crack failure of all the beams can be classified as flexure crack because the crack is in the mid third span.

As been mentioned before, the theoretical calculation for the crack width according to BS 8110: Part 2: 1985 indicated the theoretical crack width value is between 0.19 mm to 0.29 mm. It is smaller compared to experimental result. However, it is worth to note that the formula was designed to give a width with acceptable value, thus and occasional crack slightly larger and exceeded than the predicted width should not be considered as cause for concern. The maximum crack opening for RC beam 1 and 2 is 98.8% and 99.0% wider than theoretical maximum crack opening value respectively. While for SFRC (tension zone) beam

1, 2 and 3, the maximum crack width is 98.4%, 98.6% and 98.7% respectively wider than theoretical maximum crack value and 40.0%, 30.0% and 23.3% respectively smaller than maximum crack width on RC beam. Meanwhile, for SFRC beam 1, 2 and 3, the maximum crack opening is 98.1%, 98.8% and 98.9% respectively wider than theoretical maximum crack value and 50.0%, 20.0% and 10.0% smaller than maximum crack opening on RC beam. The contribution of steel fibres in RC beam improves the strength of the concrete beam and also reduces the crack width.

The steel fibres improved the brittleness of concrete to ductile by bridging the concrete matrix when load applied to it, thus reduce the propagation of cracking in beam (Norharyati, 2010). The proof come from the experimental work that have been mentioned that crack length in RC beam is wider than in the SFRC (tension zone) beams and SFRC beams. In addition, the steel fibres that randomly distributed in concrete beam form a better bonding between the fibres and matrix resulted in reducing the hairline cracks for further development into wider cracks. The experimental observation proved that steel fibres in the concrete beam act as crack arrester and give a good performance in controlling crack propagation at the tension zone together remarkable to increase the tensile strength in reinforced concrete beam.

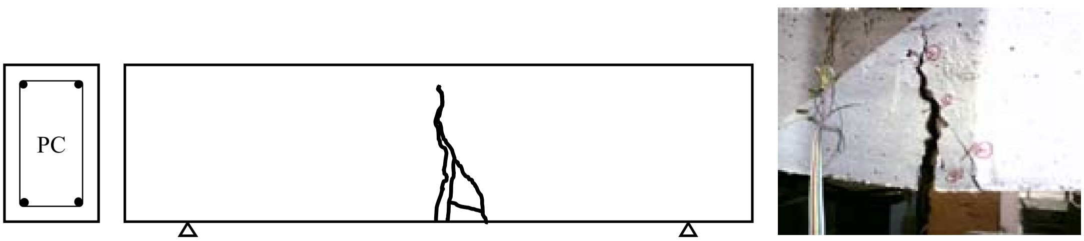

Figure 3.7. Cracks Pattern on RC Beam 1

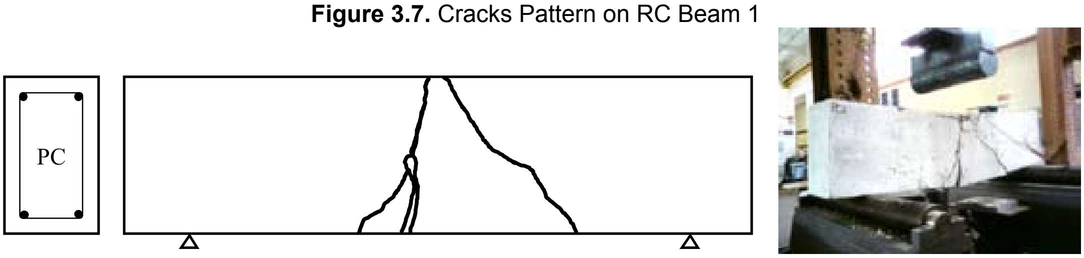

Figure 3.8. Cracks Pattern on RC Beam 2

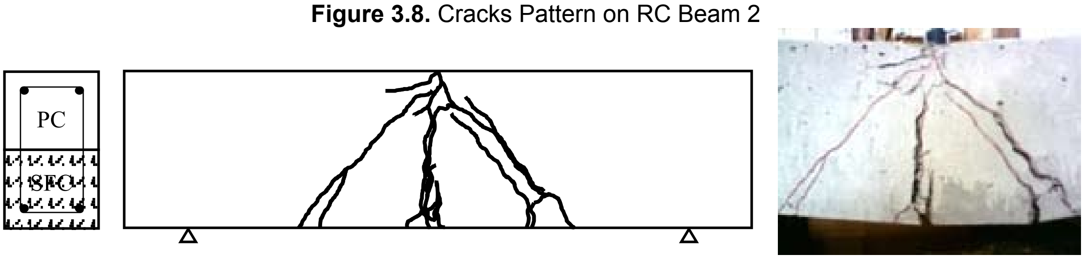

Figure 3.9. Cracks Pattern on SFRC (TZ) Beam 1

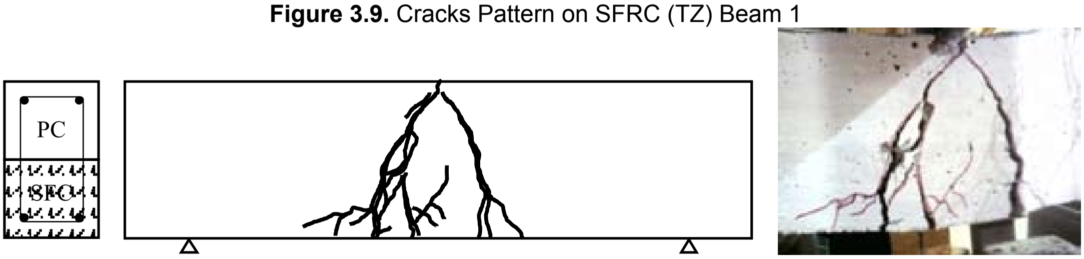

Figure 3.10. Cracks Pattern on SFRC (TZ) Beam 2

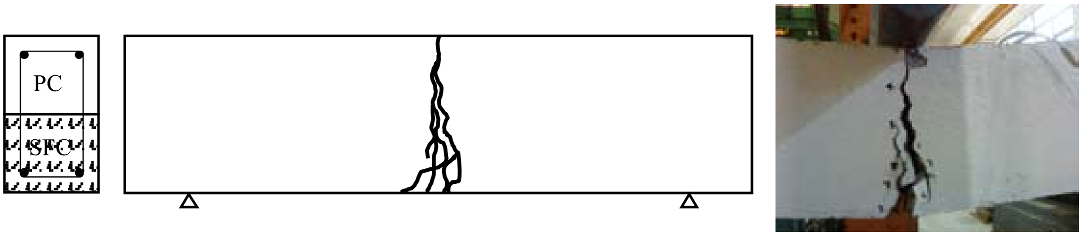

Figure 3.11. Cracks Pattern on SFRC (TZ) Beam 3

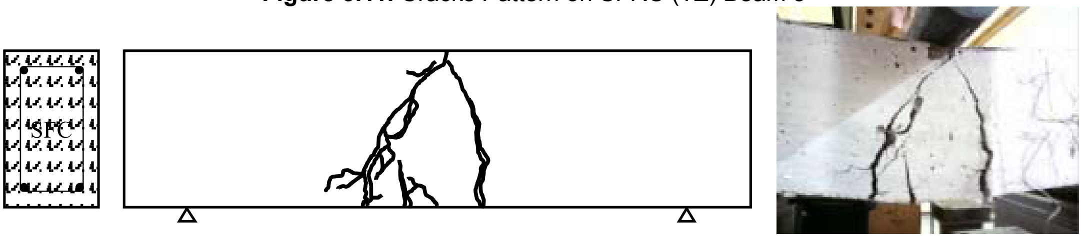

Figure 3.12. Cracks Pattern on SFRC Beam 1

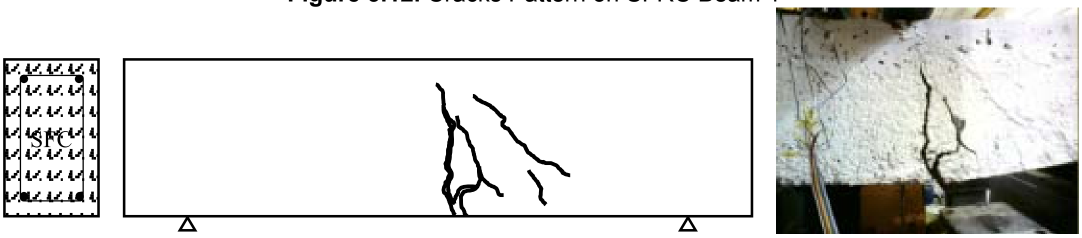

Figure 3.13. Cracks Pattern on SFRC Beam 2

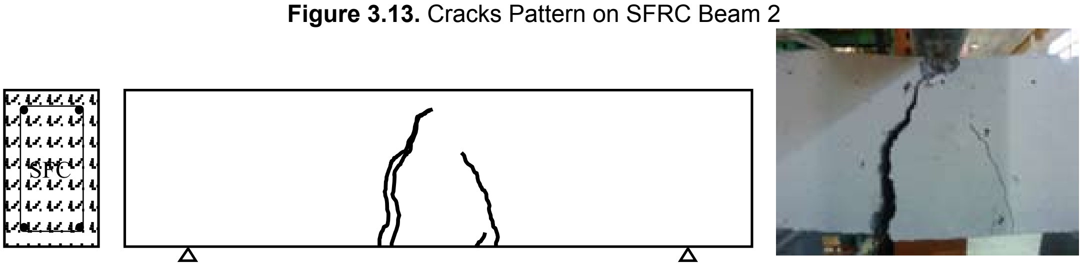

Figure 3.14. Cracks Pattern on SFRC Beam 3

CONCLUSION

Based on this research study, it can be concluded that when the reinforced concrete beam subjected to flexural load, the addition of 1.0% steel fibre in reinforced concrete beam has increased the ultimate load, improved deflection and reduced crack. The SFRC (tension zone) beam can sustain the maximum load of 42% more than maximum load on RC beam with the maximum deflection under the maximum load of 28% more than maximum deflection on RC beam under its maximum load. The SFRC (tension zone) beam showed 8% and 30% significant reduction in the formation of the crack length and crack opening respectively in compared to the plain RC beam. On the other hand, SFRC beam can sustain the maximum load of 56% more than maximum load on RC beam and 24% more than maximum load on SFRC (tension zone) beam with the maximum deflection under the maximum load of 42 % more than maximum deflection on RC beam under its maximum load and 20% more than maximum deflection on SFRC (tension zone) beam under its ultimate load. Meanwhile, the SFRC beam showed 38% increment and 11% reduction in the formation of the crack length and crack opening respectively comparing to the RC beam.

The crack load for SFRC (tension zone) beam is increased 50% from crack load for plain RC beam. But, the SFRC beam is increased by 60% from crack load on RC beam and also increased by 20% from crack load on SFRC (tension zone) beam. It can be concluded that the addition of steel fibre in conventional reinforced concrete beam reduced the crack opening and the steel fibre is act as crack arrester by holding the concrete matrix together and also provide the good performance in absorption of the energy. Meanwhile, in term of stress and strain relationship, the SFRC beam prove that the presence of steel fibre in concrete matrix can provide better performance in carrying high stress compare to SFRC (tension zone) beam and RC beam. The presence of steel fibre in reinforced concrete beam also improved the flexural stress compared to conventional RC beam and SFRC (tension zone) beam. Meanwhile, the bending modulus of RC beam is 32.32 kN/mm^2. While, the bending modulus of SFRC (tension zone) beam 1, 2 and 3 is 72.73 kN/mm^2, 82.09 kN/mm^2, and 80.00 kN/mm^2 respectively. Then, the bending modulus of SFRC beam 2 and 3 is 48.48 kN/mm^2 and 48.19 kN/mm^2.

In conclusion, the incorporation of steel fibre in conventional concrete beam has a major influence on the compressive strength, flexural strength, fracture energy and ductility thus inhibit the crack propagation of the reinforced concrete beam.

ACKNOWLEDGEMENT

Authors would like to acknowledge the Faculty of Civil Engineering Universiti Teknologi MARA (UiTM) Shah Alam for providing all testing facilities.

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ULTIMATE LIMIT STATE BEHAVIOUR OF PRECAST SHELL PILECAPS

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Abstract
This paper describes the behaviour of semi precast pile caps supported by two piles subjected to axial loading. A semi precast pile cap consists of a precast shell which is initially cast with all the steel reinforcements for the cap. This shell is then placed over the prepared piles and the inside of the pile cap is subsequently filled with fresh concrete to complete the construction process. The objective of this paper is to evaluate the performance of these precast shell pile caps to carry axial loads by comparing the behaviour of these pile caps at ultimate limit state with that of the conventional cast in-situ cap. The ultimate load carrying capacity, mode of failure and crack pattern was investigated. The results indicate that these precast shell pile caps behave in a similar manner as the conventional cast in-situ caps and can be designed using either flexural design procedures or the strut-and-tie design models.

Keywords: *Pile caps: Piles; Strut-and-Tie Model; Precast Shell*

INTRODUCTION

Pile caps are primarily used to transfer loads from columns to a group of piles through a deep reinforced concrete block. Chan and Poh (2000) previously proposed the precast shell method of construction for sites with poor soil conditions. In addition, precast components offer many potential advantages over site casting of concrete including improved quality and workmanship, and increased site productivity. Existing methods of incorporating precast systems in foundation construction includes a pilot implementation of a fully precast pile cap (Tay and Aw, 2002) and prefabricated precast concrete panels for lift shafts (HDB, 2008) in Singapore. It was reported that these precast systems resulted in increases in site construction productivity between 50 to 60% and achieved cost savings over the conventional cast in-situ methods.

The proposed precast concrete shell shown in Figure 1 shall serve as a permanent form into which fresh concrete is placed to complete the construction of the pile cap. The concrete shell, which is complete with all the required steel reinforcements for structural capacity, shall be cast separately and placed directly on the cut piles. Once the shell is aligned and column starter bars added, the shell can be filled with fresh concrete. Thus, no extensive ground preparation or external form is required. With this semi precast system, exposure of the excavation to the risk of flooding and failure of its sides is significantly reduced. Evidently this precast shell is not able to cater for piles driven with large deviations from its intended positions or for pile groups with additional piles. Site conditions may dictate that a larger shell is required to allow for deviations in pile position.

This study will attempt to investigate the behaviour of the precast shell reinforced concrete pile cap as compared to a conventional homogenous pile cap in view of its load carrying capacity, modes of failure and cracking characteristics. These three parameters are examined to determine if the precast shell caps perform as well as the conventional pile caps at the ultimate limit state.

If this precast shell is to be adopted for commercial use, existing design methods will have to be validated for the design of these elements. Current design procedures for pile caps include the beam approach similar to that used for beams or slabs where the element is designed for flexure based on the maximum bending moment at the column face, and designed for shear which determines the depth of the section to provide the necessary shear resistance. Alternatively, since the pile cap is usually short and deep as compared to a beam or slab, the stresses developed within the pile cap are complex and may be more accurately described by the strut-and-tie model (STM).A full discussion of these methods of analyses may be found in Teh (2005).

PREVIOUS TESTS ON PILE CAPS

There is a limited number of previous experimental work on pile caps reported in the literature. Adebar etal. (1990) tested eleven full-scale pile cap specimens to examine failure modes, the effect of arrangement of steel reinforcements and to evaluate the STM method of analysis in predicting failure loads. Although early design codes (ACI, 1983) treat pile caps similarly to two-way slabs, the behaviour of deep pile caps was observed to be significantly different. Firstly, the measured tension in the reinforcements did not vary linearly from maximum at mid-span to zero at the piles but still carried up to 75% of the maximum tension. The failure was always in a shear mode although some specimens were predicted to fail in flexure. The specimen with lower flexural capacity exhibited yielding of the longitudinal reinforcement and followed by a punching shear failure. The failure of the pile caps occurred after a compression strut split longitudinally due to the transverse tension caused by spreading of the compressive stresses – the compressive stress pattern is commonly referred to as bottle-shaped. It was reported that the strut-and-tie model more accurately represented the structural behaviour and failure mode of deep pile caps. Siao (1993) refined the compression strut in his paper on shear behaviour in deep beams and extended the application of the compression strut to the case of a three-dimensional pile cap with four piles.

Adebar and Zhou (1996) compared the results from a large number of tests on pile caps to show that the then ACI Building Code(ACI 1983)which indicated that the critical section for one-way shear was considered at the face of the column, was excessively conservative for pile caps. It was suggested that the maximum load that can be applied to very deep pile caps is always limited by the bearing stress at either the bases of the column or the top of the piles, and that the maximum bearing stress is a more appropriate indicator of shear strength. The more critical of the general shear design procedure or the maximum bearing stress limit governs the design. Their experimental results indicated that pile caps were basically large blocks of plain concrete that cannot undergo significant flexural deformations without triggering brittle shear failures and that flexural design shall be achieved using strut-and-tie models.

Recently Brown and Bayrak (2008) examined the 2004 revision of the ACI 318 Building Code (ACI 2004) in relation to the use of the STM for the design of deep beams. Their analysis of a database of 596 tests indicated that the STM recommendations did not produce the necessary levels of safety. As a result new efficiency factors for the compression struts were proposed to increase the safety to the required levels.

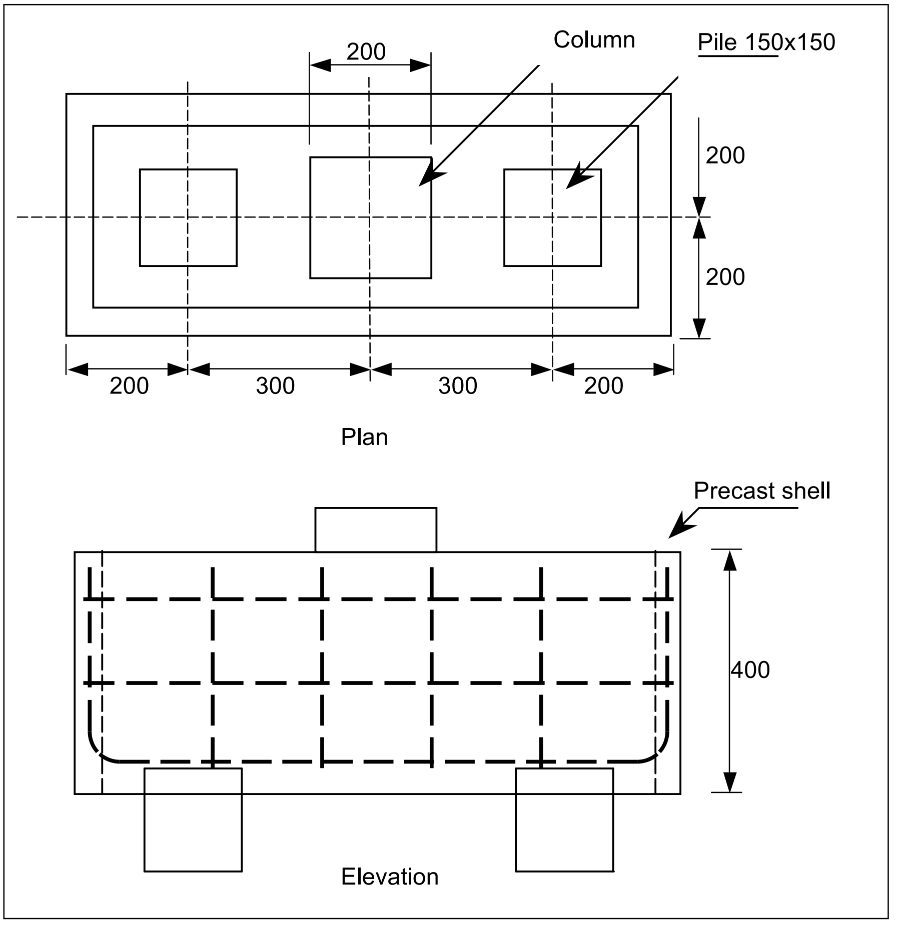

Figure 1. Precast Pile Cap Shell before Filling with Concrete
(Column Starter Bars and Pile Reinforcements have been Omitted for clarity)

MATERIALS AND METHODS

Twelve pile cap units for a two-pile group were fabricated in two series. The first series, M-1 to MV-5, of 1000x400x400mm (length x breadth x height) with a shell thickness of 70mm were designed to fail in flexure. One specimen, M-0 was a conventional cast in situ pile cap without the shell. The steel reinforcement configurations were varied to provide a predicted failure load range of between 600kN to 1,200kN. A second series of five specimens, V-1 to V5, were designed to fail in shear, with V-0 being a conventional cast in situ pile-cap of 1000x400x300mm. Five specimens were precast with varying pile cap depths. Two 150x150x5mm rectangular hollow sections filled with concrete were utilised to represent the piles. The specimens were fabricated to within 5mm tolerance for all dimensions including the positioning of the piles. The precast shells were allowed to cure for at least three days before filling with fresh concrete to complete the construction of the pile cap. The details of the specimens are reported in Table 1. The yield stress of the T16 and T20 steel reinforcements was 518 MPa and 539 MPa, respectively. A full description of the specimens has been reported by Teh (2005).

A 1500kN capacity testing frame was used to apply the vertical load onto each test specimen. A 200x200x20mm thick steel plate was cast into the top of the specimen as a loading plate. The two pile stubs were supported on steel plates on rollers to simulate simply supports as shown schematically in Figure 2.

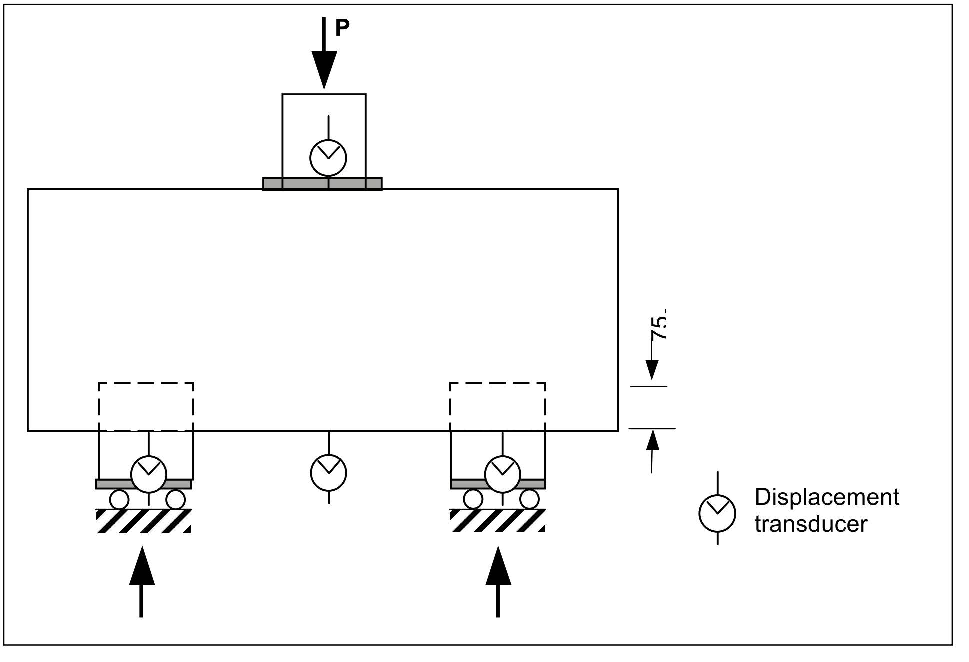

Figure 2. Load Arrangement and Location of Displacement Transducers

RESULTS AND ANALYSIS

The observed load-deflection relationships for the two series of specimens are shown in Figure 3. The pile cap failure loads and failure modes are tabulated in Table 2. Figures 4 and 5 show the crack patterns on one side of the pile cap together with a super-imposed sketch of the struts, ties and nodal zones for the STM.

Precast Shell versus Conventional Pile Cap

The load-displacement behaviour of the homogenous (M-0)versus precast (M-3) specimens indicate that both the specimens have similar stiffness but the homogenous specimen exhibited a continued load carrying capacity beyond the maximum point. Figure 4 shows the crack pattern of the homogenous specimen V-0 at failure. There were two flexural cracks which initiated at the bottom face at a load of 294kN and extended upwards but stopped short of the compression struts. At a load of 528kN, a new diagonal crack suddenly appeared on the right side and quickly extended up to the loading plate by 559kN. A second diagonal crack appeared on the left side at 781kN and extended at 864kN. This specimen failed at a maximum load of 924kN. The diagonal cracks widened considerably with additional movement of the loading jack indicating shear failure. In comparison, the precast specimen V-3 initiated the first crack at a load of 218kN, and exhibited two short flexural cracks in the tension zone at 469kN. At a load of 495kN, a new diagonal crack appeared at the left side. Two additional diagonal cracks appeared at the right side at 718kN and 731kN, respectively, indicating splitting of the compression strut at these loads. The load at which the first crack appeared for the precast specimen of 218kN was lower than the 294kN for the homogenous specimen.

Table 1. Details of Test Specimens

Specimen	l x b x h (mm)	Steel	Concrete (f_{cu})(MPa)	Beam Method, P_1 (kN) Flexure	Shear	Strut-and-tie Model (kN) ACI, P_2	Siao, P_3
V-0	1000 x 400 x 300	6T20	12.4	1046.9	**502.7**	170.7 (S)	707.5 (S)
V-1	1000 x 400 x 200	6T20	13.0	560.0	**264.8**	83.0 (S)	421.7 (S)
V-2	1000 x 400 x 250	6T20	16.6	803.5	**430.4**	190.6 (S)	648.2 (S)
V-3	1000 x 400 x 300	6T20	14.2	1046.9	**519.4**	209.3 (S)	758.4 (S)
V-4	1000 x 400 x 350	6T20	13.1	1290.4	**614.1**	196.9 (S)	879.1 (S)
V-5	1000 x 400 x 400	6T20	16.2	1533.9	**811.0**	233.3 (S)	1145.1 (S)
M-0	1000 x 400 x 400	4T16	14.1	**707.0**	761.3	255.0 (S)	972.0 (T)
M-1	1000 x 400 x 400	3T16	10.0	**524.4**	642.1	185.5 (S)	729.0 (T)
M-2	1000 x 400 x 400	2T20	12.8	**564.1**	722.4	247.8 (S)	790.2 (T)
M-3	1000 x 400 x 400	4T16	18.6	**741.6**	874.6	297.0 (S)	972.0 (T)
M-4	1000 x 400 x 400	3T20	17.6	**832.3**	844.9	352.1 (S)	1185.3 (T)
M-5	1000 x 400 x 400	4T20	13.1	1022.6	**730.9**	218.8 (S)	1032.0 (S)

The sequence of crack formation of Specimen M-0 is illustrated in Figure 5. The first cracks to form were flexural cracks at mid-span at 305kN, which propagated up the tension zone. Up to a load of 665kN there were only three flexural cracks. At a load of 761kN, a new diagonal crack appeared at the right side followed by a new crack on the left side at 786kN. These two diagonal cracks formed independently of any previously existing crack indicating compression strut failure at these diagonals. A similarly sized and reinforced precast shell specimen M-3 showed its first crack at 388kN and only two flexural cracks up to 764kN. One diagonal crack appeared at the right side at a load of 896kN and at the left side at 992kN after which the specimen could not carry any additional load. A comparison of specimens M-3 and M-0 showed that the precast specimen carried a greater load of 992kN (1.4% higher) compared to the 978kN of the homogenous specimen. The load at the first crack for the precast specimen at 388kN was 27% higher than the 305kN for the homogenous specimen.

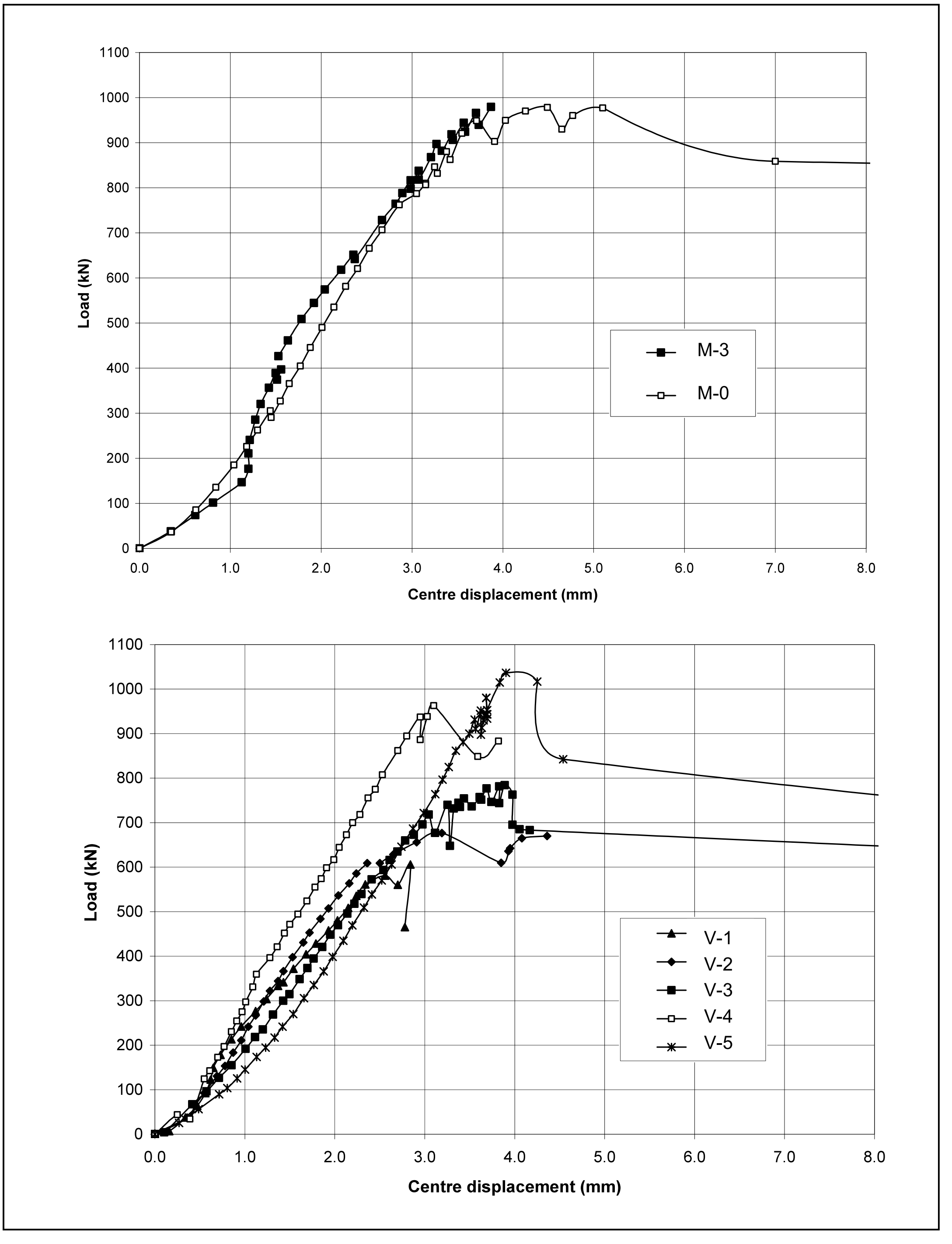

Figure 3. Load vs Deflection Plot for the M- and V-Series Specimens

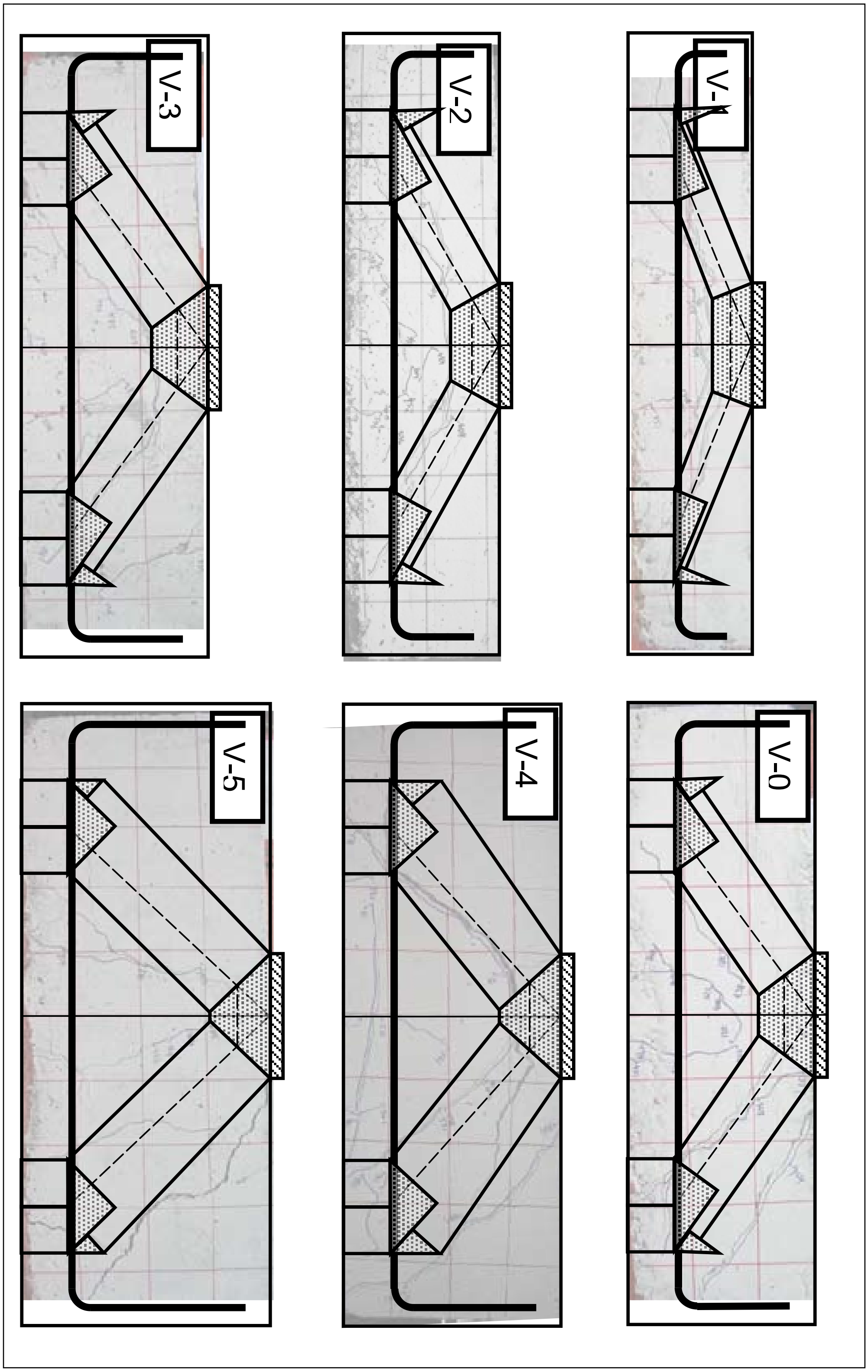

Figure 4. Series-V Specimens Showing Crack Patterns

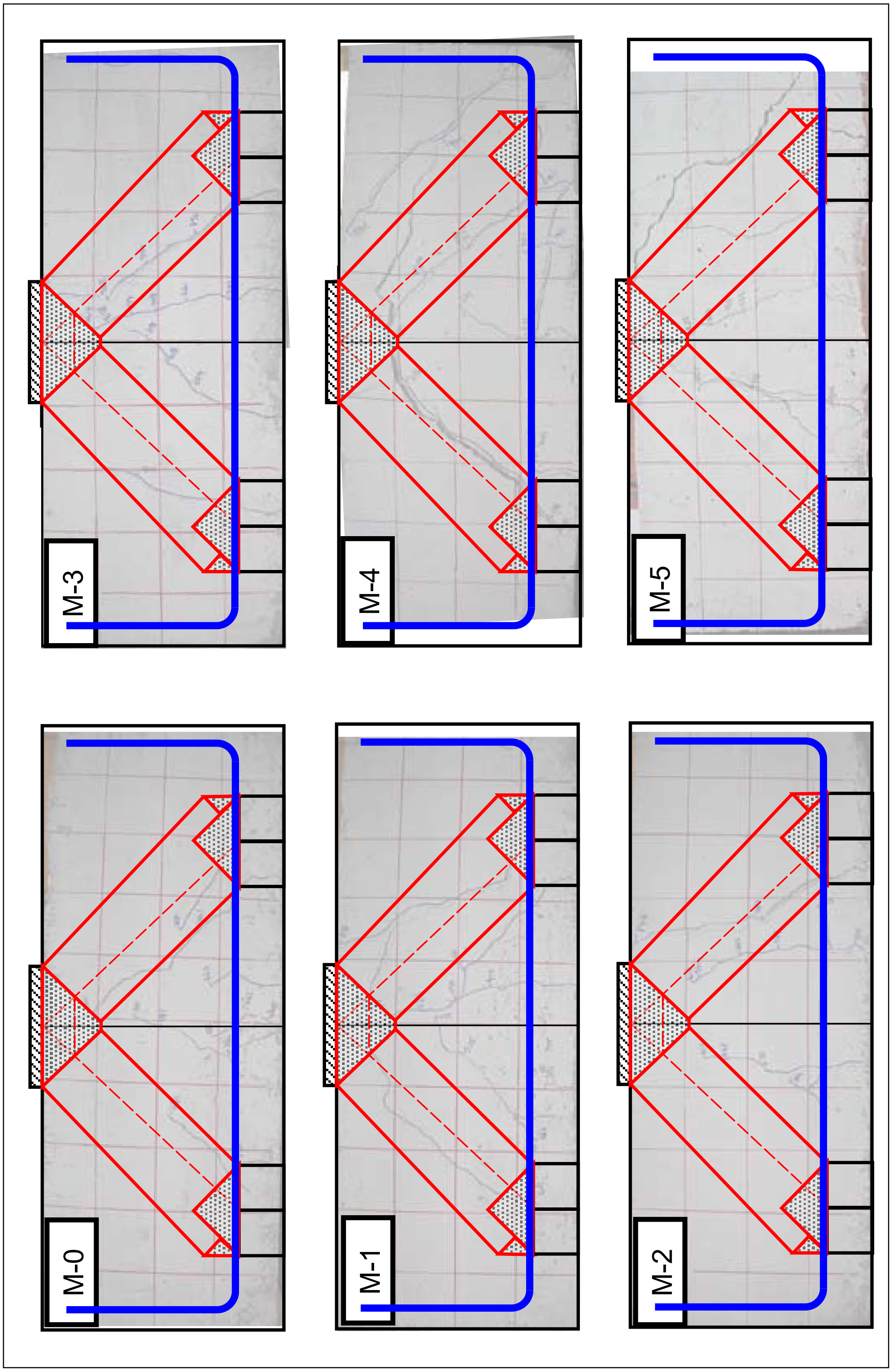

Figure 5. Series-M Specimens Showing Crack Patterns

Maximum Loads and Failure Modes

The observed load-deflection relationship at the point of load application for the M- and V-series is shown in Figure 3. All five specimens in the V-series exhibited increasing stiffness with increase of the depth of the specimens from 200mm for V-1 to 400mm for V-5. These specimens continued to deform after reaching the maximum load but with a rapidly reducing capacity indicating limited ductile behaviour. The failure mode of all these six specimens of the V-series was clearly in shear with large shear cracks appearing at the diagonal between the load point and the supports as shown in Figure 4. All the V-series specimens failed with a clear shear cone.

COMPARISON OF STRENGTHS AND FAILURE MODES

Table 2 presents a comparison of the calculated capacities and measured strengths for each of the 12 specimens. The actual failure loads for the V-series and M-series specimens were all significantly higher than the predicted shear capacities based on the maximum shear strength of beam sections. The mean strength ratio (P_{test}/P_1) is 1.66 for the V-series and 1.36 for the M-series with coefficients of variations of 19% and 9%, respectively. The overall load ratio for all twelve specimens is 1.51 with a coefficient of variation of 18%. The predicted shear strength increased linearly with increasing effective depth of the pile cap section and this trend was observed in the V-series tests. The predicted flexural strength also increased linearly with increasing quantities of steel reinforcements and this was similarly demonstrated in the M-series tests. All the measured failure loads were greater than the calculated strengths which suggest that both the flexure and shear design equations in ACI 318-05 were conservative for these pile cap specimens.

Table 2. Comparison of Predicted and Observed Maximum Loads

Specimen	Beam Method, P_1 (kN)		Predicted	Test Load	Load Ratio (Test / Predicted)		
	Flexure	Shear	Mode	P_{test} (kN)	P_{test}/P_1	P_{test}/P_2	P_{test}/P_3
V-0	1046.9	**502.7**	Shear	**924**	1.84	5.41	1.31
V-1	560.0	**264.8**	Shear	**581**	2.19	7.00	1.38
V-2	803.5	**430.4**	Shear	**670**	1.56	3.52	1.03
V-3	1046.9	**519.4**	Shear	**781**	1.50	3.73	1.03
V-4	1290.4	**614.1**	Shear	**963**	1.57	4.89	1.10
V-5	1533.9	**811.0**	Shear	**1036**	1.28	4.44	0.90
				V-series mean	**1.66**	**4.83**	**1.12**
				COV	**19%**	**26%**	**16%**
M-0	**707.0**	761.3	Flexure	**978**	1.38	3.84	1.01
M-1	**524.4**	642.1	Flexure	**736**	1.40	4.04	1.01
M-2	**564.1**	722.4	Flexure	**848**	1.50	3.42	1.07
M-3	**741.6**	874.6	Flexure	**992**	1.34	3.34	1.02
M-4	**832.3**	844.9	Flexure	**951**	1.14	2.70	0.80
M-5	1022.6	**730.9**	Shear	**1007**	1.38	4.60	0.98
				M-series mean	**1.36**	**3.66**	**0.98**
				COV	**9%**	**18%**	**10%**
				Overall mean	**1.51**	**4.24**	**1.05**
				COV	**18%**	**27%**	**15%**

The overall load ratio for the ACI prediction was 4.24 with a large coefficient of variation of 27%. Based on these observations, the recommendations in Appendix A of the ACI 318-05 may be considered more appropriate for deep beams as opposed to pile caps as most of the data for the STM were derived from tests on deep beams. The proposed formulations from Siao (1993) have resulted in a much better prediction of strut capacity and failure mode with average load ratios of 1.12 and 0.98 for the V-series and M-series, respectively. The analysis also accurately predicted the yielding of the steel reinforcements for the specimens which were expected to fail in the tension tie. The overall load ratio was 1.05 with a coefficient of variation of only 15% - the lowest variation in all three models.

Based on these observations and findings, the performance of the precast pile cap may be considered to be similar to that of a conventional cast-in-place pile cap. More importantly, the crack patterns and failure modes for both these specimens were similar and the precast specimen did not exhibit any adverse behaviour. A comparison with the predicted failure loads using beam analysis for flexure and shear capacities has shown that a beam analysis of this two-pile cap is conservative. A similar comparison using the strut-and-tie model showed very good correlation with the approach proposed by Siao (1993) but would require additional safety factors to be included to achieve the necessary factors of safety for design applications. The formulations of the ACI 318-05 were found to be excessively conservative for these precast pile caps.

DESIGN RECOMMENDATIONS FOR PRECAST SHELL PILE CAPS

The precast shell pile caps shall be analysed using either the beam action together with design recommendations for flexure and shear, or the strut-and-tie model. The design following beam action shall be based on the full cross-sectional properties assuming full interaction between the precast shell and the in-fill concrete. Based on the results of the load tests on the twelve specimens, an efficiency factor of 0.75 for the compression strut may be applied to the recommendations by Siao(1993) to ensure that less than 5% of the test data have ultimate strengths less than the nominal capacities for pile caps designed using the strut-and-tie method.

CONCLUSIONS

The results of two series of tests on the precast shell pile caps designed to validate both the flexure and shear failure modes have indicated that the performance of these specimens are consistent with conventional cast-in-place homogenous pile caps. Increasing the depth of the pile cap increases the shear strength of the section. An increase in the percentage of main longitudinal reinforcement increases the flexural capacity. The performance of these pile caps having a shear span to depth ratios between 2.6 and 0.95 are more accurately described by the strut-and-tie model proposed by Siao(1993) with a mean load ratio of 1.05 and a coefficient of variation of 15%. The STM recommendation in Appendix A of the ACI Building Code was excessively conservative. Designing the pile cap with beam action provided a mean load ratio of 1.51 and a coefficient of variation of 18%. The recommended method for predicting the failure loads of these pile caps is the STM method proposed by Siao(1993). The ultimate capacity, failure mode and crack pattern of the precast shell pile caps under axial load was observed to be similar to the homogenous cast-in-place pile caps.

ACKNOWLEDGEMENTS

The experimental work was performed in the Heavy Structures Laboratory of the Department of Civil Engineering at the University of Malaya, Kuala Lumpur. Financial support from the Construction Industry Development Board (CIDB) Malaysia and the Malaysia University of Science and Technology (MUST) is gratefully acknowledged.

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CRITICAL SUCCESS FACTORS FOR IMPROVING TEAM INTEGRATION IN INDUSTRIALISED BUILDING SYSTEM (IBS) CONSTRUCTION PROJECTS: THE MALAYSIAN CASE

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Abstract:
Industrialised Building System (IBS) is defined as a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal additional site work. The Malaysian construction industry has been urged to change from using a conventional method to IBS to attain better construction quality and productivity, reduce risks related to occupational safety and health, alleviate issues for skilled workers and dependency on manual foreign labour, and achieve the ultimate goal of reducing the overall cost of construction. The use of IBS has been made compulsory in the construction of public buildings and the adoption was supported by the government through programmes, incentives and encouragement policies stipulated under the IBS Roadmap 2003-2010. Despite acknowledging its benefits, the construction industry is still not rapidly embracing IBS. This is mainly due to its traditional and conservative nature where anything new or different, faces implementation barriers. Investigation by some researchers identified that one of the main barriers of IBS implementation in the Malaysian construction industry is related to poor integration among stakeholders involved during the design stage. A number of reports challenged the construction industry to create a fully integrated process capable of delivering predictable results to clients through processes and team integration. Responding to the challenge, this research hopes to counter this problem and help towards the betterment of the IBS Malaysian construction industry using an integrated design team delivery approach. Therefore, this paper discusses the critical success factors (CSFs) that are pertinent to improving the integration of design and construction activities and summaries the recommendations from industry workshops on the critical success factors towards effective integrated design team delivery.

Keywords: *Industrialised Building System (IBS), Integration, Integrated Practiced, Critical Success Factor (CSFs).*

INTRODUCTION

The main aim of this paper is to identify and discuss all the critical success factors (CSFs) that are pertinent to improving the integration of design and construction activities, thus aiding communication and co-ordination among stakeholders involved during the design stage of Malaysian IBS projects. Accordingly, this study required the researcher to understand, explore, and elicit opinions and perceptions based on those experienced by Malaysian construction practitioners which was governed by the qualitative inquiry of 'what' (to explore the context of a number of variables associated with effective integrated design team delivery in IBS projects) and 'how' questions (to investigate in-depth information and explanation of the data to be collected – CSFs).

In order to identify the CSFs for effective integrated design team delivery in the Malaysian IBS projects, this paper began by reviewing literature that related to the Malaysian construction industry. Literature reveals some confusion as to which frameworks should be used in order to solve the problem of fragmentation in the construction industry. Most of the frameworks are developed to address a multitude of problems, but often fail to address all of the issues, such as, lack of integration and therefore, do not fit the purpose of this research. In the Malaysian construction industry, it is difficult to select the best framework for addressing all the problems, such as lack of integration among IBS stakeholders involved during the design stage of a project. This is because explanations of frameworks vary and there are differences in characteristics, advantages and disadvantages which, obviously, cause confusion in term of selecting the most appropriate framework. Therefore, this paper intended to highlight the CSFs that exist within these frameworks and develop a set of guidelines which can be used to create effective integrated design team for Malaysian IBS projects. The process involved a comprehensive literature review of secondary sources of data including reports, principles, tools and guidelines that particularly relate to team integration such as Integrated Project Delivery (IPD), Partnering, Supply Chain Management (SCM), Concurrent Engineering (CE), Design and Build procurement etc.

Unfortunately, the findings from previous studies and tangible examples of 'full' integration, especially in the Malaysian construction industry, are limited. Therefore, this research generated an industry workshop (Workshop 1) among Malaysian IBS practitioners in order to gather information related to integration in the Malaysian construction industry, specifically within the design teams of IBS projects. This technique was chosen as the mode of data collection because of the capability to obtain data based on multidisciplinary Malaysian IBS stakeholders' perspectives (experienced based) for developing and validating the framework of CSFs for effective integrated design team delivery in Malaysian IBS projects.

In general, this research structure begins by setting the backdrop to the growth of the Malaysian construction industry and continues by highlighting the current challenges facing the Malaysian IBS construction projects. It further discusses and recommending the need of transformation process from traditional design approach towards integrated design practice as a methodology to enhance the implementation of IBS technology into Malaysian construction projects. Various issues pertaining to 'the traditional design and construction process' such as, fragmentation approach including some limitations that related to design process will be explored. The explanations also include the justification of the decisions that have been made in the selection of the appropriate research methodology. The paper culminates in the identification of all the relevant CSFs that based on the primary findings gathered via the industry workshop (Workshop 1) for the development of effective integrated design team delivery framework in Malaysian IBS projects. The outcomes of this paper endeavours to identify the key factors for effective integrated teams in order to establish the need for an integrated design team framework to be developed for overcoming the lack of IBS implementation in Malaysian construction industry. Detail explanation of this research process will be highlighted in the following section.

THE NEED FOR AN INTEGRATED DESIGN TEAM DELIVERY

The traditional construction delivery process is associated with problems of fragmentation, including the isolation of professionals, lack of co-ordination between design and construction, and, as it is carried out in a sequential manner, to time delays (Abadi, 2005; Masterman, 2002; Dainty *et al.*, 2001; Egan, 1998; and Anumba *et al.*, 1997), poor communication, and conflicts and misunderstanding between design consultants and contractors (Blacud *et al.*, 2009; Love and Sohal, 2002; Kamara *et al.*, 2000; Ofori, 2000; Gunasekaran and Love, 1997 & 1998). In view of these problems, many industry-led reports (Bourn, 2001; Egan, 1998; Egan, 2002; Latham, 1994; Strategic Forum for Construction, 2003) have all called on the industry to change its traditional modus operandi and improve performance through increased collaboration. Recent follow-up reports such as the UKCG (2009) and Egan (2002), challenged the construction industry to create a fully integrated service capable of delivering predictable results to clients through processes and team integration. Integrated team practice appears to be a significant strategy that may solve the issue of lack of integration in the traditional construction process. This approach for example, could bring together various skills and knowledge and remove the traditional barriers to effective and efficient delivery of a project (Baiden *et al.*, 2006; Achieving Excellence in Construction, 2003; Akintoye, 1994; Fleming and Koppelman, 1996).

A detailed explanation of the growth required for improving construction project delivery processes to offer integrated practices has been highlighted in the previous section. For example, there are many different frameworks, tools, strategies or approaches available in the current construction industry to enhance integration of the design and construction process such as through integrated procurement (such as Design and Build, Constructing Management), Concurrent Engineering, Lean Construction, Supply Chain Management, Constructability (or Buildability) and partnering. Most of the researches undertaken in the area of integrated teams are based on promoting the benefits of integrated frameworks such as; implementation of Concurrent Engineering (CE) in design-build project (Anumba and Evbuomwan, 1996), procurement for CE (Bowron, 2002), framework for improving integration team project delivery (Baiden, 2006), and development of a supply chain management model for construction (Love *et al.*, 2004). In addition, tangible examples of full integration in the industry are also limited (Vincent and Kirkpatrick, 1995; Vyse, 2001). Previous researchers (such as Egan, 1998; Latham, 1994; and Akintoye, 2000) suggest that this level of integration is still lacking in the construction process, particularly during the design process. Even though there have been many related studies concentrated on this area and attempts have been made to improve construction design team integration such as, early involvement of contractors (Song *et al.*, 2006), maintaining long-term relationships with supply chain members (Buzell and Ortmeyer, 1995), and working cooperatively without boundaries among the various organisation members (Baiden *et al.*, 2006), they do not specifically focus on the critical success factors needed to promote integrated project teams for design delivery especially in IBS construction projects.

As a response to that challenge, and consistent with needs of the construction industry, this research reviewed all the CSFs necessary for effective integrated project teams for IBS projects in the Malaysian construction industry.

RESEARCH METHOD

As discussed above, to determine the CSFs for effective integrated design team delivery in Malaysian IBS projects, multiple approaches have been employed in order to ensure that the data is gathered comprehensively and accurately. The approach included a literature review and an industry workshop. The literature review gathered data and information directly from web sites, libraries, books, articles and other printed material sourced from international and national journals, proceedings and bulletins. As the aim of this research was to obtain data from a multidisciplinary IBS stakeholders' perspective an industry workshop was particularly suitable as the principal technique to gather and validate all the critical success factors for integrated design teams. Many researchers (Nawi *et al.,* 2011; Abukhzam, 2011; Finch, 2010; Nawi and Lee, 2010) believed that this technique is the most appropriate and effective way of obtaining information, insight, experience and knowledge from a large group of industry players in the shortest period of time. Another reason for the selection of this technique is to draw upon respondents' experiences and reactions in a way that would not be feasible using other methods, for example observation, one-to-one interviewing, or questionnaire surveys (non-verbal survey). During the data collection stage, the industry workshop (referred to as Workshop 1) involved organised discussion within a selected group of individuals from different backgrounds (i.e. designers, contractors, manufacturers etc.) to gain in depth information about their views and reactions to the topic. As stated by (Robson, 2004 cited from Abukhzam, 2011), the workshop is considered to be 'a highly efficient technique for qualitative data collection since the amount and range of data is increased by collecting it from several people at the same time'.

In this research, the first series of workshops (Workshop 1) was organised to gather primary data and information directly from participants employed in the construction industry. As highlighted by Abukhzam (2011), the secondary data from the literature review needed to be combined with the primary data from the workshop in order to ensure that it is comprehensive, up-to-date and appropriate for the precise needs of this study. Accordingly, a workshop was conducted on 16th December 2010 in the meeting room of the IBS Centre in Kuala Lumpur which was organised and supported by the Construction Industry Development Board (CIDB); the Construction Research Institute of Malaysia (CREAM); the IBS Centre; and the University of Salford, UK. The IBS centre provided the facilities for the five hours of the workshop meeting session. It was attended by multidisciplinary IBS practitioners, consisted of several sessions and activities such as group discussions, plenary feedbacks, syntheses and general (or open) discussions. Several criteria were used for the selection of the workshops participants. Firstly, the participants had to have had at least 5 years working experience involving several completed local IBS projects. This criterion excluded inexperienced practitioners involved in the Malaysian construction projects from workshop participation and ensured that the participants selected had the competency, particularly in the work discipline area, to discuss all the issues during the entire workshop session. Based on the selection criteria, 60 respondents were identified as suitable and invitation letters were sent to them two weeks prior to the date of the workshop. However, due to circumstances of time availability, only 15 people accepted the invitation and subsequently attended the workshop.

For the purpose of this study, the primary data from Workshop 1 was combined with secondary data based on the literature review in order to ensure that it is comprehensive, up-to-date and appropriate for the precise needs of the study (refer Figure 1). The importance of the critical success factors to IBS projects was validated by multidisciplinary Malaysian IBS experts using the same technique as well as the same respondents from Workshop 1 for the validation stage. The eventual outcome and findings from the validation process revealed the CSFs that are the most and least important to enhance the implementation of IBS in Malaysian construction projects. The following sub-sections will discuss the triangulation process of the findings from both the literature review and Workshop 1.

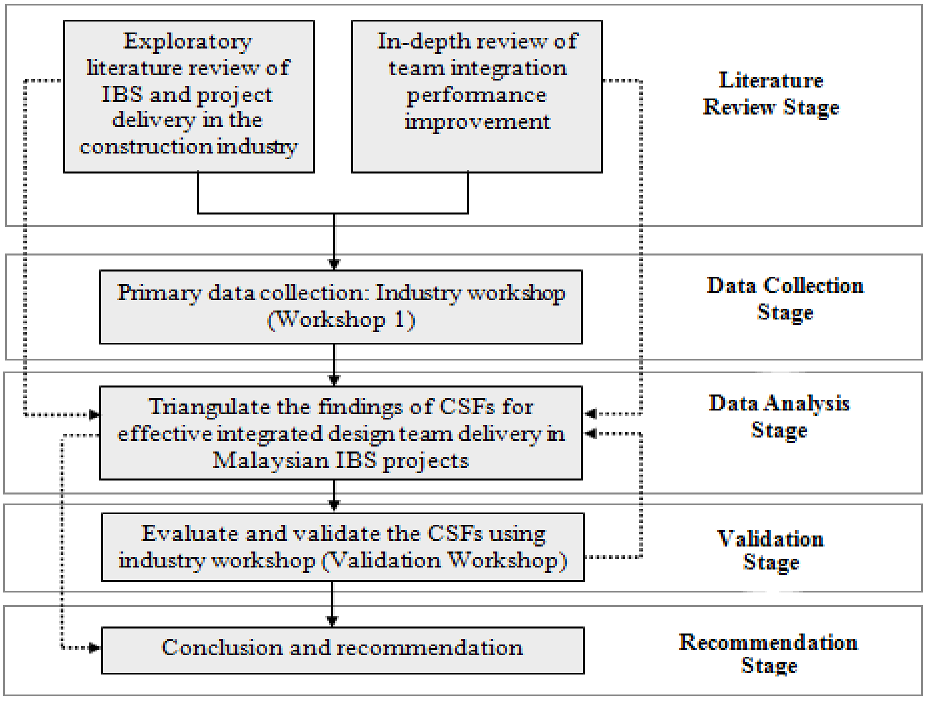

Figure 1. Flow Diagram of Methodological Framework

CRITICAL SUCCESS FACTORS FOR EFFECTIVE INTEGRATED DESIGN TEAM DELIVERY

According to the literature review and industry workshop, nine (9) factors were identified as critical for an integrated IBS project. All the critical success factors for effective integrated design team delivery are summarised in Table 1 below followed by a detailed explanation of each factor.

Table 1. Cross-Referencing Critical Success Factors based on the Triangulation of Findings from the Literature Review and From the Workshop 1.

	Critical Success Factors	Literature	Workshop 1
1	Personal Working Attitude	√	√
2	Team Base Accountability	√	√
3	Team Organisation	√	√
4	Management of Leadership	√	√
5	Transparent Communication Process	√	√
6	Policy	√	√
7	Procurement & Contract	√	√
8	Operational	√	√
9	Appropriate Technology	√	√

Personal Working Attitude

Personal working attitude in this study means a hypothetical construct that represents an individual's degree of like or dislike for work. This factor has been identified as one of the critical factors for achieving a fully integrated team on a construction project (Liddell, 2010; Koutsikouri, 2008; Seligman, 2002; Johansson, 2002; Amabile, 1997). Previous researchers relate this factor to psycho-social dynamics such as motivation, positive *can do it* attitude, high commitment, flexibility and openness to learning (or willingness to change) for continuous working improvement (Koutsikouri, 2008; Holland *et al.*, 2000; Jassawalla and Sashittal, 1998). Furthermore, there is a strong relationship between integrated team effectiveness and team members' perceptions of the task (Younker, 2010; Denison *et al.*, 1996). For example, "doing what you love" or having/creating a sense of challenge in work routine creates a powerful motivator of group performance. Fundamentally, team groups need intrinsically meaningful tasks in order to perform well (Brickner *et al.*, 1986). The participants of the Workshop 1 recognised that this factor was significantly associated with successful integrated design team delivery in Malaysian IBS projects. According to them, the younger generation is more highly motivated to learn and adopt any innovation as new knowledge. The participants also claimed that the Malaysian construction industry was slow to accept any new technology, such as IBS, but most of the younger practitioners were found to be more amenable to attending technical or management training courses/ workshops, especially those related to information technology.

Team Base Accountability

Numerous authors (IPD, 2007; Abdelhamid, 2007; Bowron, 2002; Holland *et al.*, 2000; Jassawalla and Sashittal, 1998; Love and Gunasekaran, 1998; Rowlinson, 1999; Anumba & Evbuomwan, 1997; Ayers *et al.*, 1997) highlighted the fact that team accountability has a significant influence on the effectiveness of team integration. In the scope of this study, team accountability is defined as 'all team players who are responsible for the progress and performance of the project' (Cooper, 1995). To become an effective integrated team, all the members must feel a 'sense of ownership,' clearly understand their roles and be responsible for the project from beginning to end (IPD, 2007; Abdelhamid, 2007; Holland, 2000). Previous authors (Donough, 2000; Mohammad, 1999; Hershock *et al.*, 1994) described 'a sense of ownership' as a feeling of being able to make a difference and wanting to do so. Basically, this sense goes beyond a team member's responsibility or routine duty. It is more about commitment, in that a team member begins to tie their identity to a project's outcome, putting in extra effort to ensure its success (Donough, 2000; Jassawalla and Sashittal, 1998; Evbuomwan and Anumba, 1998). As emphasised by Ayers et al., (1997), team-based accountability is a necessary counter balance to empowerment, and helps to prevent excessively cost relational norms which have a negative impact on new product success. However, although the findings from the workshop confirmed that team accountability was a key factor to the success of integrated design team delivery in Malaysian IBS projects, the discussion of this factor was limited to its relationship to roles and scope of work. For example, the participants explained that top and senior management actions, such as the clarification of the scope of the work and the generation of strategy, had been recognised as important components for overcoming potential redundancies.

Team Organisation

Organisation structure has consistently been related to the effectiveness of an integrated team (Garza *et al.*, 2009; BuildOffsite, 2008; Koutsikouri, 2008; Baiden *et al.*, 2006; Pan *et al.*, 2005; Love *et al.*, 2004; Holland *et al.*, 2000; Evbuomwan and Anumba, 1998; Love and Gunasekaran, 1998). Fundamentally, the nature and composition of the construction team makes the issue of leadership very important (Baiden, 2003). This is because the practice of the construction industry is to bring together a number of different departments and functional units with unique identities at the beginning of a project (construction period) to assume a new identity. This creates an integrated environment where all the functional expertise required for the project is brought together to act as a single entity focusing on issues rather than individuals (Garza *et al.*, 2009; Baiden, 2006; Kahn, 1996). During the workshop, this CSF was recognised by the participants as having a major impact on the success of integrated project teams in Malaysian IBS projects. The workshop participants elaborated that a prerequisite criteria for the successful delivery of a project included the need for an experienced or established project manager to manage the team, the importance of the transparency of the team selection process, and an explanation of how the skills, knowledge and experience of many people can be mutually advantageous within a conducive work environment.

Management of Leadership

Leadership has consistently been related to the effectiveness of an organisational group or work team (Baiden, 2006). This is because leadership ensures that the vision and strategy required to align the culture and values of the organisation are communicated effectively to all members. This factor focuses more on people rather than processes to create a direct affect on project performance. For example, the characteristics and capabilities of the team leader's skill and vision are very important in order to create changes that are required for progress (Jassawalla and Sashittal, 1998; Denison *et al.*, 1996). At the same time, top management and all senior managers from the various functions must be supportive, acting as executive sponsors and maintaining commitment to the project (Khang and Moe, 2008; Turner and Muller, 2007; Belassi and Tuker, 1996). Giving empowerment such as 'autonomy,' 'authority' or 'power' such as decision-making authority or responsibility for the team is part of the top management's support towards fully integrated teams (Holland *et al.*, 2000). Furthermore, the leadership must, therefore, understand the dynamics of the team such as the development stages, cohesiveness and conflict (Baiden, 2006). Providing good education or training and incentives such as team based rewards and recognition are among the components that leaders can use in order to increase the level of employees' motivation to increase their performance (Appelbaum, 2007; Parker, 2003; Holland *et al.*, 2000). Findings from the workshop illustrated that this factor is recognised as a part of the continuous improvement process in the organisation of a project through the involvement of top level management and their contribution to the success of integrated design team delivery for Malaysian IBS projects. In general, the discussion was related to the element of education and training as a crucial sub-factor towards effective integrated teams.

Transparent Communication Process

Transparent communication is extremely important in creating an atmosphere for successful project and team effectiveness (Koutsikouri, 2008; IPD, 2007; Anumba *et al.*, 2002; and Bowron, 2002; Hoegl and Gemuenden 2001; Holland *et al.*, 2000; Pinto and Slevin, 1987). Transparency refers to the commitment of open, frequent and real communication at all levels in the integrated design team organisation. This communication process provides tangible opportunities and a channel for all members of the team to be directly involved, and to have a direct input into the project goals, changes in policies and procedures and status reports, etc. (Smith, 2006). This process is significantly related to a good informal working environment that will, indirectly, enhance the level of trust, respect and understanding among project team members (Baiden *et al.*, 2006; Strategic forum for construction, 2003; Holland *et al.*, 2000; Edmondson, 1999). This transparent communication will create a good collaborative working environment aiding resolution of disagreements without confrontation among team members on a project (Hoegl and Gemuenden, 2001). In contrast to the literature review, even the participants agreed that this CSF significantly contributed towards effective integrated team however, the findings of the workshop did not describe this factor in detail especially that related to definition, roles and strategy for the successful of implementation. The participants, however, focused more on the methodology for improving communication by highlighting the advantages of having good relationships both through formal and informal communication, and also with regards to the difficulty that exists from miscommunication. For example, they advocated that meetings (such as weekly meetings) are an appropriate medium for the team members to air problems to avoid confrontation or miscommunication, especially on site.

Policy

The construction industry is bounded by governmental policies and regulations (Nifa and Ahmed, 2010). Government policy have been noted as one of the key influences in promoting a new technique or products in the construction industry, simply because the government is one of the biggest client in any construction industry (Nifa and Ahmed, 2010). Normally, such policies will affect the delivery of a construction project either in term of process or team structure. In the UK construction industry for example, a team working concept (such as partnering) gained its popularity with support from government policies and recommendations. The importance of policies in achieving successful integrated teams can be reflected in the findings of previous studies such as UKCG (2009); Baiden (2006); Egan (2002); Holland *et* *al.*, (2000). In can be summarised that the construction industry has been challenged to create a fully integrated service capable of delivering predictable results to clients through processes and team integration. This factor is supported by the findings from the workshop, which confirmed that Malaysian Government policy was the critical factor that heavily influenced the promotion of new techniques or products especially in the construction sector. In addition, the findings from the workshop showed that it is the norm for a company or agency to update their policy in order to make sure it aligns with government policy especially related to IBS implementation in order to avoid any issues such as redundancies or delays in the delivery of the project.

Procurement & Contract

Construction teams have traditionally been formed along professional and functional lines and have unfortunately remained separate thus making the ‘team’ industry, ‘teams’ industry (Baiden, 2006). The impact of this practice indirectly influences the delivery of a project. Currently, for example, most of the processes in Malaysian IBS projects are done separately or in sequence instead of in parallel. As highlighted earlier, this practice has many points for potential conflict where each participant may try to pass on the risk to others within the project. Many reports (such as Egan, 2002; Egan, 1998; Latham, 1994) advocated replacing traditional practices within the construction industry with collaborative working approaches. This has resulted in calls for the integration of the entire supply chain with traditional project delivery practices (Bourn, 2001). This process, which includes procurement, covers development across the processes from briefing to construction; relationships between parties involved in the process; and apportion of risk between the parties involved in the process (Bowron, 2002). This factor was supported by the findings from the workshop and proved to be critical, playing an important role in integrated design team delivery. As well as indentifying benefits to practices, the findings of the workshop also identified some difficulties that arise during the transformation of the design process from traditional practices to IBS. For example, the participants explained that the traditional contract and procurement route directly contributes to the problem of lack of integration and coordination between design, structure and M&E works during the traditional design and construction process. Therefore, some proposals were suggested by the workshop participants in order to improve the current delivery of IBS practice for integrated team practice. For example, the participants agreed with the findings of the literature review which found that a two stage tendering process must be implemented urgently in IBS projects in the Malaysian construction industry especially to improve the selection of credible contractors for delivery of the project.

Operational

Previous authors (Stapley, 2006; Baiden *et al.*, 2006; Love *et al.*, 2004; Strategic forum for construction, 2003; Bromley *et al.*, 2003; Anumba *et al.*, 2002; Austin *et al.*, 2002; Holland, 2000; Pinto *et al.*, 1993) highlighted that this factor is required to enhance fully integrated teams in a project. Operational in this study means pertaining to a process or series of actions to create a collaborative work environment for achieving a successfully integrated team. This factor includes components related to integrating people and processes such as interactive space, team co-location, non operational boundaries, intensive planning, working concurrently, and a collaborative, co-operative climate supportive of teamwork. These components are very important because once the organisation becomes a fully integrated team this will, indirectly, improve team culture and attitude among professional disciplines (Austin *et al.*, 2002; Moore and Dainty, 1999). For example, this approach can create an environment where individual opinions and preferences are acceptable and not considered as threats. Dennellon (1993) points out that the teams who have integrated successfully will have made a conscious effort to develop a collaborative culture and creatively utilise the potential of every participant to deliver a project. Findings from the workshop supported the literature findings and confirmed that this CSF plays an important role in shaping the organisational structure of an integrated team. The workshop participants highlighted that the issue of production and construction should be incorporated earlier, during the design stage, in order to ensure the project runs smoothly and error-free during construction. According to them, an integrated and concurrent approach in design, production and construction in IBS project delivery will significantly improve the time and cost of the project for the client.

Appropriate Technology

Several authors cite the vital importance of appropriate technology when shaping an organisation's structure to create successfully integrated teams (Koutsikouri, 2008; IDP, 2007; Anumba *et al.*, 2002; Durst and Kabel, 2001). This study revealed that technology plays an important role as a medium or appropriate mechanism for co-ordinating activities, enhancing interaction and sharing knowledge within a project team (Koutsikouri, 2008; Mohammed *et al.*, 2004; Stough *et al.*, 2000; Holland *et al.*, 2000). Technology also needs to support team communication in order to coordinate detailed design and construction methods, cost, and schedules in a project (Mohammed *et al.,* 2004). For example, due to physical, temporal and departmental constraints face-to-face communication and physical self-managed teaming are not always feasible, and in this area technology can act as a channel of communication among team members to help them to integrate their activities and keep the whole team supplied with up-to-date design information (Holland *et al.*, 2000). Currently, there are many technology applications or tools used in the construction market such as groupware system (i.e. Building Information Modeling - BIM), Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), material database, and decision support software that will significantly aid communication and coordination between parties towards successfully integrated project team (Kamar *et al.*, 2010; Anumba & Evbuomwan, 1997; and CIDB, 2003). The findings from the workshop confirmed that using appropriate technology has a strong influence on effective integrated design team delivery in Malaysian IBS projects. The workshops participants described that visualisation technology is of significant importance in improving coordination during the IBS installation process. The participants further explained that, typically, a CD manual of installation provided by IBS manufacturers is used by the contractors as a guideline for the installation process. According to them, it clearly shows that choosing an appropriate technology is prerequisite for improving communication and integration among project teams on Malaysian IBS projects.

SUMMARY OF RECOMMENDATIONS DERIVED FROM THE VALIDATION WORKSHOP

As highlighted in section (3.0), the second workshop (Validation Workshop) was conducted in order to validate all the critical success factors that had been identified from the literature review and the first workshop (Workshop 1). The selection process for the participants for the validation workshop followed the same criteria as was employed in Workshop 1, so as to provide continuity of discussion in the research. In addition, the participants were selected to represent different divisions of a project organisation (company) such as planning, design, construction, and manufacturing in order to generate a wide range of opinions during the workshop. The results and recommendations from the Validation Workshop are expected to help the Malaysian construction industry to enhance the level of IBS implementation in the future. Furthermore, the findings will be used by policy makers and IBS promoters to pave the way forward in establishing new policies for IBS and to guide the promotional activities for improving team integration in Malaysian IBS projects.

Based on the findings from the industry workshop (Workshop 1), it was confirmed that all the CSFs obtained from the literature review are necessary to improve the current IBS design process to achieve effective and efficient delivery of a project. Accordingly, the second industry workshop (Validation Workshop) was conducted in order to reconfirm and obtain feedback from the perspective of multidisciplinary IBS practitioners with regard to the robustness and applicability of the CSFs to be applied in Malaysian IBS projects. Additionally, the participants of the Validation Workshop were asked to proritise the CSFs based on their level of importance to a project. Establishing the priority of the CSFs early in a project is essential for guiding IBS stakeholders in the selection of the most suitable/appropriate framework/approach or to develop new policies/guidelines for improving team integration to achieve a successful project outcome in Malaysian IBS projects. During the process of this research, various issues were uncovered and highlighted, which led to the following recommendations for improvement of team integration. Table 2 below shows the ranking and summaries of all the recommendations discussed during the Validation Workshop.

Table 2. Summary of Evaluation and Recommendations from the Validation Workshop

Rank	CSFs	Level of importance to the project (as discussed and agreed by participants)
1	**Policy**	The participants agreed that this CSF is most importance to allow the team to work in an integrated and collaborative manner. Typically, the decision making process depends on policy, such as the vision or mission of senior management. Therefore, a strategy or approach for the delivery of a project is based on direction from the top level of management. For example, the Malaysian Government's support of IBS implementation clearly shows how powerful top level direction is in influencing the industry to shift from conventional to IBS in comprehensively. It is apparent from the statement by participant P10 (C&S Engineer); ***'Treasury Circular 7/2008 is a good example of the Government's instruction in order to boost IBS implementation in the Malaysian construction industry. This endorsement has shown how serious the government is about applying IBS, especially in public projects'***

2	**Procurement & Contract**	The majority of the participants agreed that this factor is a vital element for integrated design team delivery. Even though there are some initiatives to overcome the 'over the wall' syndrome, such as the introduction of integrated forms of procurement (i.e., Design and Build, Constructing Management and other variants) this has not resulted in fully merged teams of multi-professionals. However, they strongly agreed that the significance of this factor is still relevant. According to them, detailed agreements or documenting contracts is required to understand the distinctive roles and responsibilities among the main stakeholders involved in a project. At the same time this factor can prevent conflicts where roles and responsibilities overlap and which may cause problems to collaborative working. An example showing how participants agreed with this approach was: ***'During the initial stage, we would call all project members such as consultants, contractors and sub-contractors in order to confirm their scope of work, and at the same time explain the type of project delivery approach that we want to apply in the project' – Participant P9 (Planning Manager)***
3	**Team Organisation**	The majority of the participants agreed that an integrative organisation structure needs a team lead by a senior manager or designer to achieve a high performance. The participants explained that the characteristics and capabilities of the team leader in terms of team leader skills and vision (to create and articulate a holistic vision of the product concept) are among the critical contributors to team effectiveness. Furthermore, utilization of collective skills and expertise through the concept of early involvement of key players is recognised and can contribute to the success of integrated design team delivery. Participant P3 (Construction Manager) stated that: ***'Based on the work experienced while under client, contractor, consultant, and manufacturer, I realized that early involvement of construction expertise during the design stage is vital to reduce design defects and reworks during the construction process'***
4	**Personal Working Attitude**	Workshop participants also agreed that motivation is very important to team integration because demotivated team members slow down the progress of work leading to delays in the project or non-completion within the given period of time. According to them, a highly motivated team ensures that jobs are done quickly and efficiently and that team members feel proud of the work completed. This approach will, indirectly, create a team which is more productive, content, happy, and interested in overall project success. As affirmed by participant P6 (Principle/ Contract Manager): ***'A few of our engineers are new but they are very committed and willing to learn new knowledge, especially that which is related to technology or design software. As senior staff, we are also happy to teach and share our knowledge and skill to others'***
5	**Team Base Accountability**	All the participants felt that team members must feel a 'sense of ownership' for the team to become an effective integrated group. This means employees who feel 'included' as part of a team and part of a work family (integrated team), will be more productive and more efficient. Typically, they are encouraged to make extra efforts that are outside their responsibilities or duties as members of the team, becoming fully committed to a project's outcome, thus putting in extra effort to ensure its success. The representative for group P7 (Head Deputy Director) noted that; ***'Every employer or client hopes to have employees or project teams that are run by individuals with a sense of ownership of their place on the project or in the organisation. However, to achieve this aim a project team needs more tolerance between top and lower ranks of staff'.***

6	**Management of Leadership**	The workshop participants concurred that this factor is vital in establishing integrated design teams. The justifications for this are related to the nature and amount of support the team receives from the project's senior management. The participants further explained that supporting the team by providing sufficient resources (financial, manpower, time, etc.), commitment and encouragement is crucial for achieving fully integrated practices. In addition, a commitment by senior management to provide rewards, education and training schemes for team members is a significant measure in this approach. This is clearly shown by the statement made by participant P5 (Area Manager): ***'The leader or top level of management must give considerable control or freedom to the team to explore, discuss, and challenge ideas and make their own decisions on what strategies or technologies to pursue, problems to solve, and tasks to undertake rather than giving the instruction and taking the responsibility for himself or herself'***
7	**Transparent Communication**	The participants agreed that this factor is extremely important in creating an atmosphere for successful project and team effectiveness. They agreed that transparent communication should refer to gathering and sharing information and knowledge and to assure follow-up activities among team members. According to them, the real process of communication is not only about passing paper (information) from one point to another, but is also about getting the right information to the right person at the right time. Normally, the most effective medium for improving communication is through regular meetings (such as consultant/site meeting etc.). As explained by one of the participants (P1), the best method of communication is through short, weekly meetings to ensure that the entire team is kept up to speed. He further explained that these meetings must be attended by all members involved with the project with no exceptions and that all the outcomes from the meeting should be documented. In order to ensure that all parties involved in the project are kept informed the information should be available and easily accessible by all members of the team. The impression was supported by participant P2 (BIM Manager), stated that: ***'Normally, we will use weekly meetings to solve our problems. Meetings are an appropriate medium for everybody to declare their problems and it is very effective for avoiding confrontation or miscommunication among members on the site. However, all the members must be well prepared before attending the meeting, otherwise the meeting will end unsatisfactorily'***
8	**Appropriate Technology**	The workshop's participants agreed that this factor is highly important for the success of the integrated design team. However, 40% of the participants still argued that this factor could be classed as enabler to fully integrated design teams, rather than a critical success factor. As stated by the participant P11 (Innovation Manager); ***'Information technology (IT) is more suitable as a support tool (enabler) for improving the IBS design and construction process. It means project team integration can still be achieved without these tools'*** The majority (60%) of the participants however, still believed that this factor has to be regarded as a critical factor for the success of teams in future construction projects. According to them, technology must be implemented together with people and processes as an integrative mechanism for the successful development of an integrated team. For example, due to physical, temporal and departmental constraints, face-to-face conversations and physical self-managed teams are not always feasible, and therefore, telecommunication technology will act as a medium or appropriate mechanism to co-ordinate activity, enhance interaction and knowledge sharing within a project team.

9	**Operational**	Almost all the participants agreed that this factor is less important on a project. The arguments focused on the culture and current practices in the Malaysian construction industry which is still not ready to embrace fully integrated teams. For example, the majority of the participant disagreed with the argument for non-operational boundaries such as unrestricted access to private spaces and free information access and distribution that can contribute to the success of integrated design team. This is because the level of trust and loyalty among practitioners in the current construction project are still very low and thus distrustful. Therefore, it is difficult for practitioners, unknown to each other, to work together and share their information during a project. Furthermore, the participants argued that there is no practicality in multidisciplinary and multifunctional teams being sited in a single location for the duration of the project, the reason being that most employees are paid to work on more than one project at time. However, the participants agreed that some of the factor's elements such as concurrent work processes are significant and applicable to the success of an integrated team. The arguments placed more emphasis on 'overlapping problem-solving' between upstream (product design) and downstream (manufacturing process) functions of a project. As stated by participant P4 (Operation Manager): ***'We always think about transportation issues during the design phase to avoid problems such as delays that usually happen during the transportation or delivery process. All the information is discussed with the design team either during consultant meetings or by directly attending the consultants office'***

CONCLUSION

Problems associated with fragmentation in the traditional construction process, such as isolation of professionals, lack of co-ordination between design and construction, and the sequential manner of its processes, has impacted on construction performance leading to a lack of integration, wastage, low productivity and efficiency. Team integration is perceived as paramount. Numerous tools have emerged in recent years to improve the lack of integration such as; relational contracting, procurement, partnering, constructability, supply chain management or concurrent engineering. Discussions about improving team integration are concentrated on the characteristics, advantages and disadvantages of the available frameworks leading to confusion among the practitioners when trying to select the most appropriate frameworks for a project organisation. Therefore, factors that exist to strengthen the frameworks namely; the 'critical success factor for integrated effective team' must be clearly identified. CSFs are very important as a reference or guideline in advance of selecting the most suitable or appropriate framework for achieving successful integrated design team. As discussed above, this research aims to garner information related to integration in the Malaysian construction industry, specifically within the design team of IBS projects. The triangulation findings of secondary (literature based) and primary (industry workshop based) data have been merged and then validated as an initiative for improving team integration in Malaysian IBS projects. It is expected that the proritised CSFs (from Validation process) will guide Malaysian IBS practitioners when selecting the most suitable/appropriate framework/ approach or to develop a new policy/ guideline for improving team integration and achieving successful project outcome in Malaysian IBS projects.

ACKNOWLEDGEMENT

We would like to acknowledge the Construction Industry Development Board (CIDB); the Construction Research Institute of Malaysia (CREAM); the IBS Centre, and the University of Salford, UK for their help contribution to the organisation of the successful workshops.

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J.I.T. PRACTICES FROM THE PERSPECTIVES OF MALAYSIAN IBS MANUFACTURERS

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Abstract
IBS manufacturers are playing an important role in enhancing the efficiency of the supply chain by ensuring successful JIT delivery. This research examines the current JIT practices of IBS manufacturers with respect to transportation and delivery, inventory level, production, client relationship, supplier relationship and also problems faced by them. Questionnaire survey approach was used for data collection. This study involved as many as 54 manufacturers of various IBS components in Malaysia with only 15 responses. The results showed that IBS manufacturers were currently practicing JIT practices which include JIT delivery, JIT inventory and JIT production. For JIT delivery, the manufacturers always provide on-time deliveries and feasibility to make frequent deliveries in small lot sizes. To support JIT inventory, the respondents provide sufficient storage capacity for holding and handling the stocks. Besides that, provision of demand schedules from the contractors was chosen as the main factor to support JIT production. Since the use of IBS is emerging in the industry, this research proposed suggestions for new researchers as well as the industry towards the betterment of Malaysian construction industry.

Keywords: *Supply Chain Management, Just-in-time philosophy, Industrialised Building System.*

INTRODUCTION

Malaysian construction sector is facing pressure to reduce the dependency on foreign labour and the need to build more infrastructures to support the nation's development. Due to the inability of traditional construction system to deal with the enormous demand, the alternative solution is by using IBS. IBS is a construction process that utilises techniques, products, components or building systems which involve prefabricated components and on-site installation with minimal additional site works (Seeley, 1996 and CIDB, 2003). The components are manufactured at factories on or off site, transported and then assembled into a structure with minimum work. IBS Roadmap 2003 – 2010 plan has been formulated by CIDB as a reference for all parties in implementing all programs towards the modernization and competitiveness of the Malaysia construction sector.

The aggressive attention of using IBS technology in Malaysian construction industry started under the 9th Malaysia Plan. Many mega projects in Malaysia have been constructed using IBS such as the Petronas Twin Towers, Putrajaya, KL Sentral and KLIA. IBS can be produced in few different components for example in Malaysia, CIDB has classified IBS into five main groups which include Precast Concrete Framing, Panel and Box Systems, Steel Formwork Systems, Steel Framing Systems, Prefabricated Timber Framing Systems and Block Work Systems. The main advantage of using IBS is the shift of huge amount of work offsite which results in less site labour, materials and wastage. This practice helps to contribute to a safer and more organized construction site, and reduce the completion time of construction (CIDB, 2009). Having the building components produced in the factory, it is the role of manufacturers to produce JIT deliveries of pre-fabricated materials. Having to implement the supply chain practices, JIT is one of the techniques that fit the IBS production, requirement and implementation.

JIT is a philosophy originating from Japan's manufacturing sector. Schonberger (1990) describes the JIT manufacturing system as to produce and deliver finished goods just-in-time to be sold, subassemblies just-in-time to be assembled into finished goods, fabricated parts just-in-time to go into subassemblies, and purchased materials just-in-time to be transformed into fabricated parts. Cheng and Podolsky (1993), on the other hand, emphasize on having the right items of the right quality and quantity in the right place and at the right time.

JIT helps to smooth the production process through efficient handling of materials that is by providing the right materials, in the right quantities and quality, just in time for production (Low & Chan, 1997). Because JIT is apparently time-sensitive, all components must be delivered and received promptly. Its disciplined approach improves overall productivity and eliminates waste (Voss, 1987). It stimulates workers to identify and resolve problems and operational weaknesses which hinder organisational effectiveness and efficiency (Schonberger, 1982 and Hall, 1983). Overall, the JIT concept suggests that building materials will be brought to their location for final installation and be installed immediately upon arrival; without incurring any delay.

However, industry players are uncommitted to transform from conventional method to IBS technology. From a survey conducted by CIDB Malaysia, the usage level of IBS in the local construction industry stands at only 15% (CIDB, 2009). A recent study in 2006, published in IBS Roadmap Review, shows that only 10% of completed projects used more than 70% of IBS components (Kamar et al., 2009). They quote that the low labour cost in this country and being complacent with the current level of productivity, quality and safety are always said to be the main causes of the industry's failure to reform. Exploring on why industry players are not ready for IBS, Low & Choong, (2001a) identified the influence factors such as poor coordination and management of activities, inadequate space for storage and traffic congestion at the worksite may impede smooth deliveries and receipt of materials causing additional expenses to be incurred. Apart from that, precast components delivered late to site results in delays in the construction progress. At times, the precast components delivered to the site are not in the right quantity or the right type. Thus, the manufacturer has to redeliver the components to the site, causing waste of time and money. On the other hand, there are some cases whereby the delivery is too early. The space at the site is limited, therefore causing congestion at the site. There is also a high probability that damages may happen to the precast components if there is no proper storage area for them. All these problems occur due to improper management of the manufacturer who does not have a detailed scheduling system. Besides that, IBS manufacturers require the use of transport vehicles such as trailers and lorry cranes for hoisting their products. It is therefore important to minimize handling by good management of logistics (Low & Choong, 2001a).

Hence, it is necessary for IBS manufacturers to ensure proper SCM practices especially in logistics management by applying JIT philosophy at worksites to help raise productivity levels to contractors and clients, as well as to improve the production process through efficient handling of materials. JIT helps to reduce inventory level, storage space, factory overheads, production costs and rectification works, and it leads to improvement in quality and productivity (Low & Mok, 1999).

Previous JIT studies in the construction industry have been done on the application of JIT philosophy in construction (Low & Mok, 1999; Harrison, 1992; Low & Choong, 2001a; Low & Choong, 2001b), and the productivity of JIT practices (Lim & Low, 1992; Tatum, 2010). Studies on IBS were done by CIDB (2009) and Kamar et al., (2009). The important role of JIT in IBS in Malaysia was discussed by Abdullah & Egbu (2010) and Kamar et al., (2009) in their respective papers. However, there is still room for research in IBS where the empirical evidence is very scarce. Since IBS constitutes a large proportion of building components, the efficient services provided by IBS manufacturers will greatly influence the construction progress. Moving a step further, this paper seeks to relate JIT in IBS as the implementation of JIT philosophy is very beneficial for IBS manufacturer's competitiveness. This study aims to find out:

1. The current practices of JIT among IBS manufacturers in Malaysia.
2. The problems found by IBS manufacturers in applying JIT.

LITERATURE REVIEW

JIT concept

For successful JIT implementation, there are six key principles: 1) *Kanban* or pull system; 2) Top management commitment and employee involvement; 3) Elimination of waste; 4) Total Quality Control (TQC); 5) Uninterrupted work flow; and 6) Supplier relations: Single-sourcing (Low & Chong, 2001a). Firstly, by using *Kanban* system, the flow of materials is "pulled" by the demand-side. The materials are fabricated at the factory and delivered to site only when ordered. Therefore, the pull system decreases the demand for site storage space and reduces holding costs. Secondly, the top management involvement, commitment and efforts are necessary to ensure that discipline and correct operations are carried out in accordance with the JIT concept. Thus, employee improvement must be encouraged and top management must stay committed to JIT philosophy (Low & Mok, 1999).

In order to eliminate waste, JIT concept calls for "zero inventory" or "buffer stocks" because in JIT, waiting time, inspection time and time spent rectifying defects, is deemed wasteful (Akintola A., 1995). Hence, getting things done the "right first time" is another doctrine of the JIT concept. Next, the JIT concept encompasses the TQC concept to ensure smooth, just-in-time execution of work processes as poor quality materials disrupts production workflow and schedules, countering any savings and productivity gains from JIT. In terms of work flow, JIT production assumes an uninterrupted work process. The two techniques that may be used to achieve uninterrupted work flow are: 1)Focused factory and group technology; and 2) Simplification and automation (Chandra & Kodali, 1998). Lastly, JIT emphasizes the need to reduce the pool of suppliers and even to work towards a single supply source. This requires the forging of long-term business relationships.

Meanwhile, according to (Dong et al., 2001), the JIT practices can be divided into four main elements: 1) JIT delivery; 2) JIT inventory; 3) JIT production; and 4) Long-term relationship for single-sourcing. JIT delivery concerns on delivery and transportation. JIT inventory stresses on cost, location and capacity of storage. On the other hand, JIT production gives emphasis to production lead time, and lastly is the target of single-sourcing, which seeks to create partnership and long-term relationship with clients and suppliers (Dong et al., 2001)

Obstacles in the Applicability of JIT

In a wide scope, Emel et al., (2003) found that high inflation rates, high costs of imported technology, maintenance, training and the quality systems; few number of suppliers, low costs of labour, the governments' inadequate approach towards quality, high power distance or uncertainty avoidance culture were the main obstacles for the applicability of JIT in prefabrication in developing countries. In addition, the case of the Turkish prefabrication sector indicated that uncertainties in both the demand and the macroeconomic conditions were the two primary barriers for both quality and productivity improvements (Emel et al., 2003). Nonetheless, according to Low and Choong (2001a), factors such as poor coordination and management of activities, inadequate space for storage and traffic congestion at the worksite can interfere with smooth deliveries and receipt of materials, causing additional expenses to be incurred.

Moreover, Low and Mok (1999) finds that JIT could be badly affected and may be blamed for being inflexible, unresponsive, possibly disrupting work flow, increasing production costs, open to sabotage from suppliers, and reducing quality standards. There could be sudden shortages of materials arising from sudden uncontrollable external factors like inclement weather and earthquakes. For example, the 1996 Kobe earthquake in Japan was blamed to have disrupted many JIT production schedules (Low & Choong, 2001b).

METHODOLOGY

In this research, all manufacturers of IBS components were chosen to be the respondents since all of them are registered with Construction Industry Development Board (CIDB). The list of companies was selected from CIDB website. This study involved a list of 54 manufacturers of IBS components in Malaysia. The number of manufacturers according to different types of IBS products is shown in Table 1. CIDB categorized the company based on their IBS product. Questionnaires were distributed by mail to all the 54 companies located across Malaysia, including Sabah and Sarawak. Out of these 54 companies, only 15 respondents returned the questionnaire forms. It indicates approximately 28%. A low response rate may be due to the following reasons: 1) No interest to participate in this survey; 2) Lack of knowledge on the topic of the research; 3) Time constraints; 4) No staff feels free or willing to answer the questionnaires; 5) Mistake in mailing address as the address was no longer valid.

Table 1. The Number of IBS Manufacturers and Number of Responding Manufacturers

IBS product	No of manufacturers	Number of responding manufacturers
Precast concrete framing, panel and box systems	21	7
Steel formwork systems	10	0
Prefabricated timber framing systems	15	5
Block work systems	8	3
Total	54	15

This questionnaire has 3 sections. It was designed based on instruments developed by Low and Mok (1999) as well as Low and Choong (2001). In Section A, six questions were asked regarding the background of the respondents. Section B is divided into five subs which represents the JIT practices. This section aims to examine the current practices of JIT applied in the operation of the respondent's company. The five subs are: 1) transportation and delivery; 2) inventory level; 3) production; 4) client relationship; and 5) supplier. Section C aims to find out the possible problems found by the IBS manufacturers in practicing JIT in their operations. There are seven possible problems ranked by the respondents, based on their experience. All of them were taken from previous researches on JIT management, which were done by the experts (Low and Choong, 2001a; Low and Mok, 1999). The SPSS software version 17.0 was used to analyze the survey results. Types of analysis involved in this research are descriptive, frequencies, means and reliability.

ANALYSIS

Background of the company

Based on the survey, companies manufacturing precast components are the highest respondents which are about 46.7%. CIDB (2009) data reveals that companies manufacturing precast components are dominant in the industry which constitutes of 21 companies. Companies manufacturing timber framing components make up 33.3%

of the respondents while 20.0% are blockwork components companies. 60% of the respondents have more than 10 years of experience in manufacturing IBS components, compared to the respondents in range of 1 to 5 years and 6 to 10 years of experience, 33.3% and 6.7% respectively. In relation to their operational size measured by number of workers, 10 out of 15 companies (66.7%) are small-sized companies with 5 to 50 number of workers, 20% of them are considered medium (51-150 workers), and the rest of the two companies are considered micro (less than 5 workers) and large in size (more than 150 workers) which represents 6.7% respectively. The table below indicates the alpha value for all the dimensions.

Table 2. The Reliability Result for Different Dimensions

No.	Set of variables	Cronbach's alpha	No. of item
1	Transportation and delivery	0.520	6
2	Inventory level	0.607	4
3	Production	0.884	3
4	Client relationship	0.916	10
5	Supplier relationship	0.859	4
6	Possible problems in applying the JIT practices	0.705	7

Current Practices of JIT

Transportation and Delivery

Table 3. Transportation and Delivery

Variables	Mean	Std. Deviation
Always provide on-time deliveries	4.20	0.862
Feasible to make frequent deliveries of small lot sizes	4.00	1.254
Expand the ownership to ensure more reliable and more frequent deliveries	2.33	1.496
Sub-contract the transport vehicles	1.87	1.246
Increase ownership of lorry crane	1.73	1.280
Increase ownership of trailer	1.67	1.047

Table 3 shows the mean and standard deviation values for transportation and delivery.

'Always provide on-time deliveries' is the most practiced JIT concept among IBS manufacturers (mean= 4.20). Another important factor is 'Feasible to make frequent deliveries of small lot sizes' with a mean value of 4.00.

Inventory Level

Table 4. Inventory Level

Variables	Mean	Std. Deviation
Decrease or increase insurance cover according to the volume of components casted and stored	3.80	1.082
Provide sufficient storage capacity	3.20	1.265
Relocate or lease the storage space nearer to the construction site	2.73	1.223
Expand the storage space	2.53	1.356

Mean and standard deviation values for inventory level are shown in Table 4. The most practiced concept in this category is 'Decrease or increase insurance cover according to the volume of components casted and stored' with a mean value of 3.80. Following that is 'Provide sufficient storage capacity' with 3.20 as the mean value.

Production

Table 5. Production

Variables	Mean	Std. Deviation
Provide demand schedules from main contractors	3.47	1.356
Identify reasons for the lead time	3.13	1.187
Reduce production lead time	2.93	1.223

Table 5 represents the mean and standard deviation values for production. In this category, the highest mean is 3.47 which is 'Provide demand schedules from main contractors'. Another important factor is 'Identify reasons for lead time' (mean=3.13). The least popular concept among IBS manufacturers is 'Reduce production lead time' with a mean value of 2.93.

Client Relationship

Table 6. Client Relationship

Variables	Mean	Std. Deviation
Only maintain good client relationship	3.53	1.125
Create partnerships or long-term agreements with clients	3.47	0.915

Table 6 shows mean and standard deviation values for client relationship. The most practiced concept is 'Only maintain good client relationship' (mean=3.53). Aside from that, 'Create partnerships or a long-term agreement with clients' has a mean value of 3.47.

Table 7. Factors in Keeping Repeat Clients

Variables	Mean	Std. Deviation
Long-term agreements/partnerships	4.00	1.309
Friendly and warm relationships with the contractors	4.00	1.069
Fast response to, and investigation of, contractor's complaints	3.93	1.033
Flexibility in accommodating contractor's changes/requests	3.93	0.961
Good production	3.87	1.187
Reliability in production	3.60	1.298
Reliability in delivery	3.60	1.056
Competitiveness in pricing	3.33	1.047

Mean and standard deviation values for factors in keeping repeat clients are shown in Table 7. The two highest factors with a similar mean value of 4.00 are 'Long-term agreements/partnerships' and 'Friendly and warm relationships with the contractors'. Other important factors are 'Fast response to, and investigation of, contractor's complaints' and 'Flexibility in accommodating contractor's changes/requests' with the same mean value of 3.93.

Supplier Relationship

Table 8. Supplier Relationship

Variables	Mean	Std. Deviation
Establish relationship based on win win situation	4.27	0.961
Only maintain good and qualified suppliers	4.07	0.799
Increase the number of suppliers over the period of time	4.00	1.069
Create partnerships or long term agreements with suppliers to ensure long-lasting business	3.80	0.862

In Table 8, mean and standard deviation values for supplier relationship are shown. The most practiced concept with a mean value of 4.27 is 'Establish relationship based on win win situation'. 'Only maintain good and qualified suppliers' has the second highest mean value with 4.07.

Problems in Applying JIT

Table 9. Problems in Applying JIT

Variables	Mean	Std. Deviation
Reducing quality standards	3.47	0.990
Open to sabotage from suppliers	3.47	1.060
Possibly disrupting of work flow	3.33	1.113
Traffic congestion at worksite	3.07	1.280
Inadequate space for storage	3.00	1.195
Poor coordination and management of activities	2.87	0.915
JIT is inflexible and unresponsive	2.80	0.941

As we can see from Table 9, the highest mean is 3.47. The respondents felt that there are two main problems in applying JIT. The first one is "open to sabotage from suppliers" and the second one is "reducing quality standards". Meanwhile, the respondents ranked "JIT is inflexible and unresponsive" as the least problem found, with a mean of 2.80.

DISCUSSIONS

This study assessed the application and problems in practicing JIT from the perspective of IBS manufactures in Malaysia. The small number of respondents took part in the survey provide a barrier for further quantitative analysis. For example the T-test result found insignificant relationship between the size and the type of IBS manufacturer.

Current Practices of JIT

In JIT, transportation plays an important role in the support and execution of JIT deliveries. The manufacturers must ensure the transportation of the required components are according to schedule, right on time, in the right types and quantities, as well as in the correct order for the arrival or unloading sequence (Low & Choong, 2001a). Based on Table 3, the highest mean of 4.2, is the most practiced JIT concept among the IBS manufacturers. Majority of the IBS manufacturers are confident that they always provide on-time deliveries. This is very important for JIT deliveries to fit with construction progress at site. Delay in IBS delivery will affect the contractor's schedule and the manufacturer can be blamed. The second highest mean is feasibility to make frequent deliveries of small lot sizes which is 4.00. The idea of JIT is to reduce inventory storage on site. This may involve more frequent deliveries to the site as per the demand schedule from the main contractor, or in small lot sizes, depending on the types of components (Low & Choong, 2001a). However, most of them are not interested in increasing the ownership of trailers which gets the lowest mean of 1.67. Low & Choong (2001a) found that this may be due to the common practice to engage a transport for their delivery fleet on a lease or sub-contract basis as they do not want to incur unnecessary fixed costs on the trailer as well as in maintaining a team of drivers and mechanics for servicing. Besides, transport authorities will require a company to set aside adequate parking spaces before the purchase of transport is allowed.

Precast components delivered just-in-time to the site will result in the level of buffer stocks kept on site. If the manufacturers adopt and practice JIT principles in their operations, then the inventory of finished goods will inevitably build up in the manufacturers' yard (Low & Choong, 2001a). Therefore, this question examines the aspects of the manufacturers' storage facilities. Based on Table 4, the results show that the insurance is influenced by the level of inventory, which gets the highest mean of 3.8. The cost of insurance is therefore, a factor in the storage costs of raw or finished inventory. According to Low and Choong (2001b), JIT deliveries to site would mean that precast components are effectively being pushed back to the precasters for storage for JIT production. This results in a need for more storage space and facilities for holding and handling the stocks. When asked if they have sufficient storage capacity to help hold back the casted components for a longer duration until the actual date of installation, the respondents answer positively which lead to the second highest mean of 3.2. They also see the need to relocate or lease the storage closer to the job-sites and the need to expand the storage space to support JIT concept which calls for frequent deliveries. Theoretically, it is better for the suppliers to relocate closer to their clients to facilitate transportation (Low & Choong, 2001a).

Majority of the respondents are manufacturers of precast components. That may be the reason why "reduce production lead time" gets the lowest mean which is 2.93 (table 5). For instance, precast reinforced concrete piles need 28 days for curing before delivery. Hence, in such instances, the casting lead time must be at least 28 days (Low & Choong, 2001a). When asked if the respondents can identify the reasons for the lead time, they answer positively and lead to the second highest mean of 3.13. Based on a study of "The Readiness of Precasters for JIT" done by Low and Chong in 2001, there are several reasons for the lead time in production: 1) Curing time; 2) To make productive use of each mould set-up; and 3) To produce standby stocks so that even if production breaks down, there would still be stocks for the clients.

However, the highest mean is 3.47, which is to "provide demand schedules from the main contractor". Low and Choong (2001a) affirmed that precast concrete suppliers are usually furnished with a tentative demand schedule about two months (or 50 days) in advance of the date of required delivery. Revisions to this draft will be made, on an average, about one-and-a-half weeks (or 10 days) before the delivery date. Some precasters will use this revised schedule as the final confirmation for delivery. However, most precasters will seek a final confirmation with the main contractor about four days prior to the actual delivery date. Demand schedule is very important as JIT focuses on producing the exact amount a company requires at the exact time the company's customers require it. It is done by preventing over-production, minimising waiting time and transport costs, saving resources by streamlining the company's production systems, reducing the capital that the company have tied up in stock, dispensing with the need for inventory operations and decreasing product defects (Manufacturing Innovation: Just-In-Time Production, 2010).

Table 6 shows the results of practicing long-term relationship for single-sourcing. The survey reveals that the respondents prefer to "maintain" relationships rather than "create" partnerships or long-term agreements with their clients. Theoretically, the JIT philosophy emphasizes the need to work towards a single supply source to keep away from less contact time with every one of them. Hence, single-sourcing of suppliers is the eventual goal with well-established long-term supplier-client relationship (Low & Choong, 2001a). However, when the respondents are asked about the factors that keep clients returning to them, they rank "friendly and warm relationships with the contractors" and "long-term agreements/partnerships" as the dominant factors. This is quite incoherent to the statements before, whereby the respondents prefer to only maintain good client relationship rather than create partnerships and long-term agreements with the clients.

Based on Table 7, most of the respondents rank "Friendly and warm relationships with the contractors" and "Long-term agreements/partnerships" as the most important factors in keeping repeat clients, with a mean of 4.00. Additionally, "Flexibility in accommodating contractor's changes/requests" and "Fast response to, and investigation of, contractor's complaints" get the second highest mean of 3.93, followed by "Good production". "Reliability in delivery" and "Reliability in production" are the other two important factors after "Good production". The least important factor is "Competitiveness in pricing" with a mean of 3.33.

With materials flowing on a JIT basis, coordination with suppliers is of utmost importance in order to ensure that the right materials are delivered at the right time. Therefore, JIT philosophy emphasizes the need to reduce the pool of suppliers and even to work towards a single supply source as too many suppliers result in less contact time with each one of them. This requires the forging of long-term business relationships founded on mutual trust and benefit (Low & Choong, 2001b). However, the results show that the JIT philosophy of "single-sourcing" is not preferable to be practiced by the respondents as "create partnerships or long term agreements with suppliers to ensure long-lasting business" gets the lowest mean of 3.80 (Table 8). Meanwhile, the highest mean is 4.27, which belongs to "establish relationship based on a win win situation".

Based on Table 8, two main problems in applying JIT with a similar mean value of 3.47 are "reducing quality standards" and "open to sabotage from suppliers". This shows that quality and trust in others are major concerns of IBS components manufacturers. The problem with the least mean value of 2.80 is "JIT is inflexible and unresponsive". This problem might have the lowest mean value because it can be dealt with quite easily by the manufacturers.

CONCLUSION

This paper has identified the current practices of JIT applied by the IBS manufacturers in Malaysia. In an effort to realize the full usage of IBS in the year 2020, the role of IBS manufacturers is very important in construction industry in Malaysia. Due to the increasing issues related to building quality, poor project performance and heavy dependency on foreign workers, IBS has been the main innovation potentially identified to overcome those problems. In achieving the objective, coordination between manufacturer and contractor is important. As a product manufacturer, IBS suppliers must ensure the timely supply of the IBS components to site are according to project requirement. With site storage constraints, the supply must be in small batches and repeated supply.

The core focus of this study is to examine on the significant part of five JIT practices explicitly being applied in the IBS manufacturing companies that are transportation and delivery, inventory level, Production, client relationship and supplier relationship. Based on the survey, it is found that the respondents were currently practicing JIT in their operation in terms of JIT delivery, JIT inventory and JIT production. For JIT delivery, the most practiced concept among the manufacturers is they always provide on-time deliveries, followed by feasibility to make frequent deliveries in small lot sizes. To support JIT inventory, the respondents provide sufficient storage capacity for holding and handling the stocks. They also see the need to relocate the storage closer to the job sites to facilitate transportation, thus to support JIT deliveries. Provision of demand schedules from the contractors was chosen to be the main factor to support JIT production. This is very important to confirm the exact quantity required by the customers as well as to prevent overproduction, wasting time and transport cost, reduce capital and product defects. However, due to the newness of IBS implementation in the Malaysian construction industry, they are still in the progress of creating partnerships and long-term relationships with clients and suppliers. The results had shown that the respondents preferred to "maintain" rather than to "create" partnerships and long-term relationships with their clients. The JIT philosophy of single-sourcing is not preferable too, as a majority of them chose to establish relationships with suppliers based on a win win situation.

This result strongly indicates the strong commitment of IBS manufacturers in ensuring JIT supply. The most challenges they have to overcome are their relationship with suppliers and to maintain the quality standard. These two problems are interrelated whereby the sabotage would give an impact on the quality of products. This requires the forging of long-term business relationships founded on mutual trust and benefit. However, this study shows that the response for creating partnerships and long-term relationships with clients and suppliers was poor. Hence, it is suggested that in-depth studies should be done on the significance of close relationship among parties in JIT philosophy.

RECOMMENDATIONS FOR A BETTER IMPLEMENTATION OF JIT IN IBS

The success of JIT can be determined by having well planned and close monitoring of the management system. Firstly, for successful implementation of JIT management in IBS manufacturing companies, there is a strong need for positive attitude among the manufacturers. Besides that, IBS manufacturers must always be ready and able to change their traditional mindset. It is a good start to discover that all of the respondents responded positively towards practicing JIT in their operations. They welcome and strongly encourage JIT, and are very much likely to apply JIT practices in their operation. However, there are some major obstacles, such as lags of production and lack of workers. Therefore, it is recommended that all factors that contribute to these problems and constraints should be curbed in order to practice JIT effectively.

To implement JIT, it is therefore recommended that coordination and planning is started from the initial stage of doing the design of IBS based buildings. It must start from the very first stage of thought, design and planning so that IBS is capable of adopting JIT practices. To obtain this, there should be a full implementation of JIT in their manufacturing operation and to be successful in practicing JIT in IBS, the implementation should be done in both government and public projects. There is also a strong need of full commitment from all parties involved in the projects, including the contractor, consultants and other related bodies. All parties have to practice ethics and principles and working habits with a sense of humanism, understanding, consideration and compassion. Standardisation of components as well as cooperation from all parties involved in the project are also as important. Apart from good planning, good coordination between parties is also crucial to ensure the success of JIT. Apart from the JIT practices, some respondents also gave comments and recommendations on the IBS programme. They felt that it is good to have IBS in the line of development, however, the implementations have not been done properly. Thus, it is strongly recommended to all parties especially clients in the construction industry to be “open” to a new system of construction method, namely IBS.

LIMITATION OF THE STUDY

This study only provides a general view of JIT practices among IBS manufacturer in Malaysia. Quantitative approach with only small number of response provides a main barrier for detail analysis. The significant different results could be obtained by studying the differences of the manufacturers in terms of size and types of product, this paper called for a detail case study to be conducted in the future in order to enhance the knowledge gap.

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THE SELECTION OF IBS PRECAST MANUFACTURING PLANT IN MALAYSIA USING GIS

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Abstract:
In Malaysia, the prefabrication technology is known as industrialised building system (IBS) which is defined as a complete process system of construction works where almost all the component structures is manufactured onsite or offsite, and the product is transported to the site and to be installed in the high precision coordinate joint as well as achieve high quality works, and accelerate the time of completion of the projects.The benefits of prefabrication helped the Housing Ministries in various countries to fulfil the high demand for housing especially in the United States, United Kingdom, Australia, Singapore, Hong Kong and Malaysia. Providing affordable homes are becoming a vital issue to meet the increasing demand of IBS components with the policy enforcement in ensuring the continuous demand. The most popular IBS component used in Malaysia is precast components. Over the years, the total number of IBS precast manufacturers has increased from15 in 2009 to 36 factories in 2011. Geographical Information System (GIS) can be seen as an important tool in finding new locations for IBS precast manufacturing. This paper introduced a conceptual GIS suitability model by applying six criterion factors i.e. road characteristic, proximity from the new potential development area, population census, proximity from the existing infrastructure, topography and land-use suitability. Results shows that 16 out of 25 IBS precast manufacturers with on-going production are located in Selangor, Johor and Negeri Sembilan. However, there are still good opportunities in expanding IBS businesses in other states where the number of IBS precast manufacturers are still low.

Keywords: *Industrialised building system (IBS), spatial site selection, construction industry, GIS suitability model*

INTRODUCTION

The trend of the Malaysian construction industry has moved from the traditional method to IBS manufacturing and similarly, the productivity have moved from project based to product based. The phenomenal transition of the construction industry to prefabricate manufacturing has also occurred in Australia, Hong Kong, Singapore, United Kingdom and United States(Blismas and Wakefield, 2009, Tam, 2007, Tuan Seik, 2001, Lovell and Smith, 2010, Jeong et al., 2009). The implementation of prefabrication in the construction industry has enhanced productivity and improved quality as well as several benefits viz. shortened construction time, lower overall construction cost, improved quality, enhanced durability, better architectural appearance, enhanced occupational health and safety, material conservation, less construction site waste, less environmental emissions, and reduction of energy and water consumption (Chen et al., 2010).

After the World War II, prefabrication of building was the best method to fulfil the housing demand. In the early 1970s, the US government explored several prefabrication building systems (Jaillon and Poon, 2009). Among the largest prefabrication building system in the US is the manufactured house (MH) which is the second largest provider of housing units and consist about 20% of the total share of the housing market (Jeong et al., 2006). The houses are constructed in a controlled factory environment based on the national building code specified by the US and the entire structure is transported to the site and installed onsite (Jeong et al., 2009, MHI, 2011). The federal standards regulate manufactured housing design and construction, strength and durability, transportability, fire resistance, energy efficiency and quality. The Department of Housing and Urban Development (HUD) Code also sets the performance standards for the heating, plumbing, air conditioning, thermal and electrical systems. MH provides financial aid, and when compared to the site-built (traditional stick-frame) homes, manufactured homes are about half the cost per square foot.

In the early 1980s, similar action was also taken by the government of Singapore and Hong Kong to spread the use of prefabrication system which was widely used in the building of public housing (Tam et al., 2002). Prefabrication is used to build up high rise buildings, and able to deliver the prefabrication components to the limited access area and the component is directly erected from the crane. In 2011, 84% of Singapore's residents lived in the Housing and Development Board (HDB) flats with 95% owning such homes, is one of the highest achievement in the country (HDB, 2011). While the Hong Kong Housing Authority (HKHA), has recommended the usage of precast units and reusable formwork in all public housing contracts (Jaillon and Poon, 2009). Therefore, IBS is suitable for cities and regions faced with the problem of dense population and with insufficient land for housing development.

The Malaysian government has encouraged the construction industry to move towards Industrialized Building System (IBS) which can produce high volume of houses at affordable cost especially low-cost houses. Government agencies such as Jabatan Kerja Raya (JKR) and Construction Industry Development Board (CIDB); and researchers have played vital roles to educate the main players of the construction industry in the form of policies, financial incentives, strategy guidelines, workshops and seminars to increase the awareness among the end users and clients. Industrialisation of high rise residential building components is critical to competitiveness and has become a new trend in order to solve the housing problem and meet the demand for affordable homes especially in big cities with limited space for development area.

Although, the development of the precast manufacturing plant is expanding based on the demand and the contract value based project but there are some cases of failure in continuity of the IBS production and shutdown of the factory. There are two cases of precast manufacturing plants closed in United Kingdom and Malaysia. In 2003, Living Solutions (IBS manufacturing) was owned by Tata and the company has supplied buildings for an upgrade of the Ministry of Defence garrisons at Aldershot and around Salisbury Plain as part of a six-year £92m (RM460m) contract. In 2010, the weak building industry and "the continuing weak construction market" ended Living Solutions long-term supply contract to supply accommodation for the defence industry. Tata made a decision to close down the factory and concentrate on core business since then had never been profitable (BBC, 2010).

Despite succeeding in constructing a huge number of houses using the IBS technology in UK, the company still faced barrier to continue the manufacturing operation. A similar situation occurred in Malaysia. From 1981 until 1991, they built and operated a very modern precast manufacturing plant at Shah Alam using PratonHaus's belt conveyor and semi-automatic precast production. The overall investment was worth about RM 12.0 million (£3 million) which was considered a relatively huge upfront investment at that time (Kamar, 2011). The company struggled to deal with the operation of the factory which needs high investment in terms of maintenance and factory equipment. The board of management has made the same decision as Tata to close the factory and sold it to a local company due to the unstable demand at that time and small market volume in Malaysia. Both high-tech precast manufacturing plant is operated based on project and failed to operate due to the low demand and high maintenance.

Therefore, the modern IBS technology could not operate due to high operation cost and a feasibility study is vital to understand the setting up of precast manufacturing as well as allocating potential site to ensure the continuous production and demand. The higher the repetitive of production and the much lower the cost of production. The volume of production was important for the company as IBS construction requires repetitive and continuous projects to be profitable. Thus, Government is aware regarding this issue and has taken constructive action with the policy approach to ensure that there is continuity in the demand. With the intention to adapt to the increasingly rapid technological changes and to fulfil the housing demand.

Consequently, CIDB had implemented the IBS Score in construction industry to measure the level of IBS usage in building and become part of the main monitor system of the IBS construction industry. In the Budget 2005, the policies of the usage of IBS components in government building projects increased from 30% to 50% commencing 2005. Housing developers who utilise IBS components exceeding 50%, will be given full exemption on levy imposed by CIDB (Budget, 2004). Based on the CIDB Report (2010), the number of IBS manufacturers is gradually increasing as a result of the government policy which requires 70% of IBS components be used in government projects valued RM10 million above and will receive an exemption of construction levy (CIDB levy – 0.125% of the total cost of the project according to Article 520) for the project(Treasury, 2008).

The scoring system is made accordingly to the principles of usage of prefabricated and precast components, off-site production of components, the use of standardised components, repeatability and design building component based on the Malaysian Standard "Guide to Modular Coordination in Building", MS 1064 (IBSCentre, 2010). Consequently there is a high demand for the IBS precast concrete among the contractors, whereby they can obtain high IBS Score by using the precast components. The two mandated policies cover for the housing (100% levy exemption with 50% IBS Score) and government buildings (0.125% levy exemption with 70% IBS Score).

The Construction Industry Development Board (CIDB), which forms part of the government agency, conducted a series of surveys in 2003, 2005, and 2008 to authenticate the increasing awareness on the IBS concept in construction (Majid et al., 2011). The number of

IBS precast manufacturing has significantly increased as to pertaining the government projects and private projects which are required to use IBS components. This is a good opportunity for the new IBS player to get involved with the IBS precast manufacturing business.

Notwithstanding, choice of location decision process is vital to understand the determinants of location because many important location criteria emerge from the initial stages of the site selection process and among the criteria that could be insert in the study is the market access criteria. Besides, an understanding of the location decision process may improve a local economic activity development and generate the sustainable business environment (Badri, 2007). Geographical Information System (GIS) has been used frequently in the allocation issues to serve as an aid for thinking and decision making which includes a full range of social, environmental, technical, economic and financial criteria (AbuSada and Thawaba, 2011, Malczewski, 2006, Carver, 1991).Therefore, an appropriate study is required to analyse the outlook on IBS precast manufacturing site by GIS.

IBS PRECAST COMPONENTS ADVANTAGES AND LIMITATION

The benefits of IBS adoption in construction activities in order to reduce dependency on foreign labors, to improve construction's productivity and quality, reduce wasteful construction method, to become more environmental friendly, to achieve design standardisation and to speed up construction time. Anecdotally, based on the IBS Survey 2008, the ranking of IBS benefits listed from the most beneficial to the least beneficial are (1) minimal wastage; (2) cleaner environment; (3) less site materials; (4) reduction of site labor; (5) controlled quality; (6) faster project completion; (7) neater and safer construction sites; and (8) lower total construction costs (Majid et al., 2011). The great concern for IBS technology occurred not only in Malaysia but also in other country such as United States, United Kingdom, Australia, Singapore and Hong Kong. Azman (2010) reported that the term IBS have similarity with the United States, United Kingdom and Australia. In the US, manufactured home (MH) industry is described as Off-Site Construction Techniques (OSCT) (Lu, 2009). However in the UK, the Modern Methods of Construction (MMC) is defined in various ways; prefabrication, off-site production and off-site manufacturing (BURA, 2005). While, the term Offsite Manufacturing (OSM) is the term used in Australia construction industry. In addition, the Singapore and Hong Kong use the same term; prefabrication.

The main function of the IBSs is to create synergy, by generating partners in the industry to assist in training, giving exposure on use of IBS techniques, encouraging the setting up of new IBS factories locally, updating on the latest technology, and enhancing current issues on IBS in the local state and international level (CIDB, 2003). The Malaysian construction industry is undergoing a paradigm shift from using conventional technology to a more systematic and mechanised system that utilises the latest information and communication technology. IBS has become a vital component in the construction industry to move towards global competition and update the new industrial trend. The Table 1 shows the strength and the limitation of the benefits of IBS precast.

Table 1. The Benefits of IBS Precast

The Benefits of IBS Precast	Strength	Limitation
Buildability	Suitable for high repetition building especially for the high rise buildings.	Not suitable for less repetitive especially for the low rise buildings.
Less wastage	The concrete waste can be recycled (Tam et al., 2010, Vivian W.Y, 2009). The recycled components can be used in the civil engineering work, landscaping and as a substitute for gravel in concrete components(Hansen, 1986).	Requires initial investment to obtain the basic recycle machine that canbe used for crushing, sizing and stockpiling recycled aggregate.
Constructability IBS	IBS managed to incorporate with new design aesthetics of the variety of shapes, finishes and high quality.	Limitation of new design which required new mould and highly repetitive design.
Reduce cost construction	Less used of foreign labor and early completion projects helps to gain early payment from clients and reduce the number of working days save the construction cost.	The IBS technology requires a high initial capital to start up a project. Requires a few projects to cover the cost of IBS technology.
Completion of project	Fast in two cycled projects and can obtained other projects.	Required proper planning sequence work of IBS precast components to overcome the massive IBS precast components at site.
Maintenance cost	If use mechanization machine and less automation machine the cost will be low.	If used highly automation machine will cause high electricity and high cost maintenance.

METHODOLOGY

Most of the location selections are accomplished by simple analysis in terms of rudimentary calculation, past experience or even predilection. However, there are two approaches in obtaining an appropriate location decision via Multi Criteria Decision Making (MCDM) and traditional GIS. MCDM is defined as the decision makers preference in assuming more than one objective or consider more than one factor or measurement and all these problems will be group into one category (Farahani et al., 2010). Usually, MCDM method will be having the alternative selection to be chosen by evaluating each choice on the set of criteria. In contrast to traditional GIS, the criteria will be converted into GIS map and analysed for identifying new suitable locations. GIS has improved the conventional maps overlay approach in the form of computer graphics (Malczewski, 1999). Thus, the geographic data and attribute data can be captured, stored, updated, manipulated, analysed and display all forms of geographically referenced information (Vitek et al., 1996). Therefore, GIS will be the appropriated method to be used in this research.

The scope of the research is generally focusing on Peninsular Malaysia due to the fast growth of the construction industry and the limitation of geographical information system (GIS) data. Currently, the total number of IBS precast manufacturers registered with the Construction Industry Development Board (CIDB) Malaysia is 36 (IBSCentre, 2011). However, based on the CIDB secondary data, there are 25 out of 36 IBS precast manufacturers which have factories while the others have temporary factories which are based on the term of the construction project. From the IBS precast manufacturer's addresses given by the CIDB, the location of the 25 IBS manufacturers have been identified by means of Google Map WGS coordinates search. To actual coordinate location of IBS precast manufacturer were subsequently validated using GPS tool and through phone enquiries. To obtain the actual coordinate for the IBS precast manufacturer location, these coordinates are validated by using GPS tool and also through phone calls for coordinates validation process. These 25 coordinates of IBS precast manufactures is overlay on the Peninsular Malaysia`s GIS map. In addition, the research also has been conducted using a shortcoming of simple web-searches, a comprehensive search produced a total of 18 manufacturers, whose information resulted a direct involvement with IBS precast components.

CONCEPTUAL GIS SUITABILITY MODEL

The main purpose of this study is to carry out GIS spatial site selection to identify potential locations for IBS precast manufacturing. This research will identify several factors which has direct impact on the site selection of a new IBS precast manufacturing location. Literatures have shown that optimal site selection using GIS is successfully being performed to determine various site location problems. Mohammad (2009) applied optimum site selection to locate new hospital in the urban area of Tehran by combining Geographical Information System (GIS) analysis with the Fuzzy Analytical Hierarchy Process (FAHP). Eddie and Heng (2005) used the GIS approach to find the new location of shopping mall in Hong Kong by deriving four criteria viz. (1) minimum distance, (2) maximum demands coverage, (3) maximum incomes coverage, and (4) optimal center. Various other research works has applied geographical information systems (GIS) to solve or support spatial reasoning problems in different contexts, such as locating convenience stores and other facilities, site selection, screening potential landfill sites, supplier selection and local park planning (Mohammad, 2009). The possibility of using GIS in identifying potential location for IBS precast manufacturing can be clearly seen. A similar approach will be used where the GIS-based land-use suitability modelling is applied. The study will concentrate on the scope of land-use suitability with respect to information science perspective and social science perspective.

The proposed land-use suitability model will generate potential sites for the IBS One Stop Center based on several criterion factor; road , proximity from the new potential development area, population census, proximity from the existing infrastructure, and topography. The justification made for the road railroads proximity characteristic has been mentioned by Cheng and Connor (1994). The research was to identify the potential area for the construction site layout. Meanwhile, the study by Warszawski (1999) on the suitable distance from the new potential development area to the fabrication plant should be the distance with a variance from 50km to 100km. The conceptual spatial site selection parameter for the IBS precast manufacturing is described in Figure 1.

In Boolean method, units in each information layer are assigned by zero or one values (Reisi et al., 2011). This method is mostly used in the first phase of evaluation, to separate suitable sites from non-suitable ones. In this method weights of criteria are not define and cells values are just 0, 1. Although Boolean logic has wide application because of its quickness, it has some limitations and problems. In this model, all input factors have equal values, while selection criteria have various values. Boolean logic cannot separate suitable sites based on their priorities. So with this model, accessing to the goal of optimal decision is impossible. Based on H. Jiang and J. R. Eastman (2000), Boolean overlay all criteria of suitability to produce Boolean maps, which are then combined by logical operators such as intersection (AND) and union (OR). According to Chen,Y.H and Zhu,Q.J. (2010), Boolean overlay represents the extreme cases with no tradeoff. Boolean AND operator represents the MIN decision-making risk and Boolean OR operator represents the Max decision-making risk.

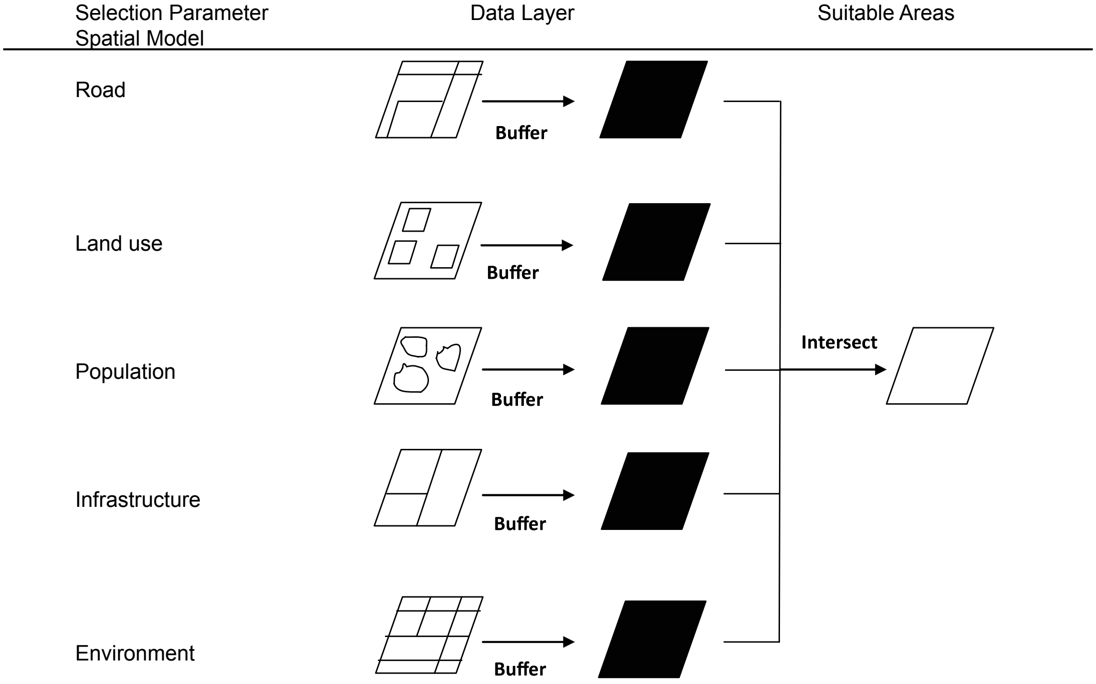

Figure 1. Spatial Site Selection for the IBS Precast Manufacturing

This study describes a type of multi-criteria decision analysis method, called Boolean intersection in a GIS, to evaluate the suitability of the new potential IBS precast manufacturer. The presented method evaluates the entire study area, using scale from 0 to 1, where 0 denotes sites fully unsuitable for IBS while 1 shows sites suitable for IBS. The evaluation criteria used in this study are distance from road, land use, population, distance from infrastructures, and distance from environment area which cover the river, slope and reserved forest.

The approach of layer preparation is explained below:

1) Distance from road: For deriving this layer, 1:25,000 topographic maps were used and then the map of distance from roads was produced. All roads and the areas within 50,000 m of them are considered suitable and to keep costs of development down.
2) Land use: Some of land use such as urban area, protected forest, utilities, water body and residential are not suitable for IBS construction while agricultural land, potential agricultural land, manufacturing zone, pastures, and scrub. Those chosen based on the less cost of land.
3) Population: For this purpose, the data were obtained from Malaysia statistics department and then import to IDRISI® to produce a population map. People with more than 800 are considered suitable for allocating IBS manufacturing and give opportunity unemployed to apply new job.

4) Infrastructure: Water supply structures and 2,000 m around them are considered unsuitable for allocating IBS. Electricity structures within 500 m of them are considered unsuitable. Airport and seaport and 50,000 m around them are suitable for construct IBS. Railway and 50 m around them are considered unsuitable.
5) Environment:
   a) Rivers and areas within 100 m from rivers are considered unsuitable for an IBS establishment. So that can be protected from pollution.
   b) Slope: A topographic map was used (1:25,000) for driving Digital Elevation Model (DEM) and then the slope layer derived from DEM. Areas sloped higher than 10% are considered unsuitable for allocating IBS.
   c) Reserved forest: The reserved forest layer was extracted from land use map. In this study only forest area are protected and forbidden to allocate IBS.

For each criterion, a map was produced based on distances and buffers defined above. Then Boolean intersection in IDRISI® was used to convert criteria map to Boolean maps, in which suitable sites for IBS showed by 1 value and unsuitable sites showed with 0 values. Finally, all Boolean maps were overlaid by 'AND' operation and final suitability map was produced, in which suitable sites are 1 and other sites are 0. The procedure followed in this study is shown in Figure 2.

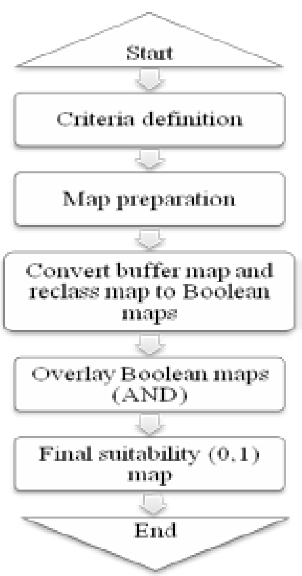

Figure 2. Procedure of Boolean Intersection

RESULTS AND DISCUSSIONS

Based on the registered address of the IBS precast manufacturers 2011 with CIDB and validation process as mentioned in the methodology part; managed to obtain the mapping location of 25 IBS manufacturers managed to obtain by using GIS. The results of the 25 IBS precast manufacturers are shown in Figure 3. The highest number of IBS precast manufacturing is located in Selangor (9) followed by Johor (4) and Negeri Sembilan (3). Based on the growth domestic product (GDP) 2009 report, construction sector was dominated by Selangor with 37.8 per cent, WP Kuala Lumpur (15.8 per cent) and Johor (10.5 per cent)(Statistics, 2010).

Due to the high growth of construction sector in Selangor, there is high demand for the precast components and this contributed to the growth number of IBS precast manufacturers. Its economy is highly diversified, Selangor is adjacent to the Federal Territory of Kuala Lumpur, and there are many resultant close economic and social ties between them(Alias et al., 2010). While the nearest state next to Selangor is Negeri Sembilan which also contribute to the impact of economic growth in IBS precast manufacturing due to the high demand of precast product in Selangor.

Initially in 2009, there is only one IBS precast manufacturer in Johor as reported by Azman et al. (2009). But in 2011, the number of IBS precast manufacturer in Johor has increase to four factories with the demand from Iskandar Regional Development Authority, Nusajaya development and the construction industry development from Singapore. Kimlun Corp Bhd manage to obtain the big tender in mass rapid transit (MRT), with a worth of RM59.2 million (Kimlun, 2012). Kimlun Corp Bhd had been supported by concrete components division under SPC Industries Sdn Bhd that supplies to the construction industry needs in Malaysia and Singapore that cover the comprehensive range of concrete components for both infrastructure and building construction industries. Kimlun Corp Bhd had occupied another two companies to supply the precast concrete; namely Hume Concrete and HL-Manufacturing. Therefore, Kimlun share the economic growth of precast concrete demand with other manufacturers.

Perlis and Kelantan do not have any IBS manufacturer and this has contributed to the benefit of the manufacturers in Kedah and Pulau Pinang to supply the IBS precast components especially for the government projects. While Perak, Terengganu and Pahang are still in the intial state of marketing the use of IBS precast components and educating the contractors and installers on the benefis of using IBS. In the circumstances, it is not easy to setting IBS precast manufacturing plant. Most of the IBS precast manufacturers was concerned on the value obtained from the project before the setting up the IBS precast manufacturing plant and the rule of the thumb for the profit margin of a IBS project is around 10%(Azman et al., 2011).

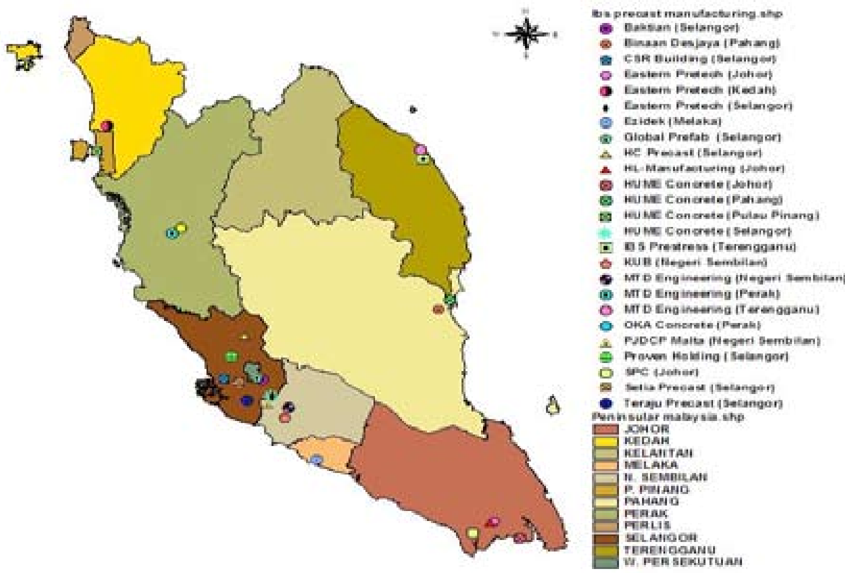

Figure 3. List of 25 IBS Precast Manufacturer in Peninsular Malaysia

With regards to the development of construction industry technology, the government and the researchers have come out with a guideline categorising the off-site system as show in Table 2 (Azman et al., 2010). Table 2 also shows the pattern and the degree of technology changes. The US, UK and Australia have achieved the modular building standard but Malaysia is still in the initial stage to achieved it. The three countries have the similarity in off-site preassembly but UK and Australia have divided the off-site preassembly into non-volumetric and volumetric order. Thus, UK and Australia share the same similarity categorisation of off-site system where most of the Australian researchers referred to the UK.

But Malaysia had improved the production from producing 2D component to 3D (volumetric pre-assembly) component. Thus, the IBS precast component can be divided into a three categories; 2-D, 3-D and system that has been undergone several changes in following the new trend of IBS technology. Table 3 described the 18 companies in Peninsular Malaysia that produce varies types of IBS precast components. The 2-D components are half slab (HS), hollow core slab (HCS), double T-slab (DTS), M-beam (MB), wall panel (WP), plank (P), curve panel (CP), shear wall (SW), beam (B), curve beam (CB), column (C), gutter (G), balcony slab (BS) and toilet slab (TS).While, the 3-D components consist of prefabricated bathroom (PB) and staircase (S). The IBS components manage to produce in the variety of shapes and increase the choice of the construction industry specification favor in order to obtain the market demand.

Table 2. Categorization of Off-Site System

Countries	Categorization of Off-site System	Author
US	- Offsite preassembly - Hybrid system - Panellized system - Modular building	Lu (2009)
UK	-Component manufacture & sub-assembly -Non-volumetric preassembly -Volumetric pre-assembly -Modular building	Goodier and Gibb (2004)
Australia	-Non-volumetric preassembly -Volumetric pre-assembly -Modular building	Blismas and Wakefield (2008)
Malaysia	-Pre-cast concrete systems -Formworks systems -Steel framing systems -Prefabricated timber framing systems -Block work systems -Innovative product systems	IBS Info (2010)

Table 3. List of IBS Precast Components in Peninsular Malaysia

Company	2-D														3-D	
	HS	HCS	DTS	MB	WP	P	CP	SW	B	CB	C	G	BS	TS	PB	S
1. Eastern P.	/	/	/		/	/		/	/		/	/			/	/
2. Hume	/		/	/	/				/		/					/
3. MTD_ACP	/		/		/	/			/		/					/
4. Global G.	/				/		/		/	/	/		/	/		/
5. OKA	/		/		/				/		/					/
6. HC Precast	/				/				/		/					
7. Setia P.	/				/			/	/		/		/	/		/
8. CSR					/											
9. Teraju P.	/								/		/					
10. PJDCP					/											
11. Ezidek	/															
12. HL	/		/		/	/			/		/					/
13. SPC									/		/				/	/
14. Binaan Desjaya	/			/					/		/					
15. KUB	/	/			/				/		/					/
16. Baktian	/				/											
17. P Slabs	/															
18. IBS Prestress	/															
Total	**15**	**2**	**5**	**2**	**12**	**3**	**1**	**2**	**12**	**1**	**12**	**1**	**2**	**2**	**2**	**9**

CONCLUSION

In conclusion, the IBS technology must be affordable, able to suit to the climatic condition in Malaysia using environmental friendly method and contribute to the sustainable development of the construction industry. There is also the need to reduce the knowledge gap between the government and IBS players, and future research should be continued to educate the existing and new IBS players.

Geographical Information System (GIS) can be a computer aided tool to analyse the results with more accessible information, visualisation of data, higher quality of data and established procedures for repetitive analyses. GIS tool manage to show the location of 25 manufacturers in Peninsular Malaysia and identify the development pattern of IBS precast manufacturing. Most of the IBS manufacturers are located in Selangor, Negeri Sembilan and Johor. While other states are still in the process of growing the number IBS precast manufacturing in compliance with the government policy in using IBS. Consequently there are two types IBS precast product produce i.e. 2D and 3D. Malaysia is still in the initial stage of achieving modular building and has managed to produce varieties of 2D and 3D modular precast product.

As a further research recommendation, the conceptual model using GIS in locating new IBS precast manufacturing can be solved by using the Boolean approach. The main parameter needs to be considered are road, infrastructure, land use, population and environment factor. It will definitely help in identifying the new manufacturing location site, knowing the flow of transporting IBS components from IBS manufacturer to the site construction. The research findings will benefit the government or private sector in fulfilling the demand for IBS components where the number of IBS manufacturers in Northern Peninsular and West Peninsular Malaysia region is still few.

ACKNOWLEDGEMENT

The authors wish to thank the Universiti Pendidikan Sultan Idris (UPSI), Universiti Sains Malaysia (USM), Universiti Tun Hussein Onn Malaysia (UTHM), International Islamic University Malaysia (IIUM) for supporting the Industrialisation Building System (IBS) research as well as Construction Research Institute of Malaysia (CREAM) for funding this research.

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MCRJ Volume 10 | No.1 | 2012

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ISSN 1985-3807

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