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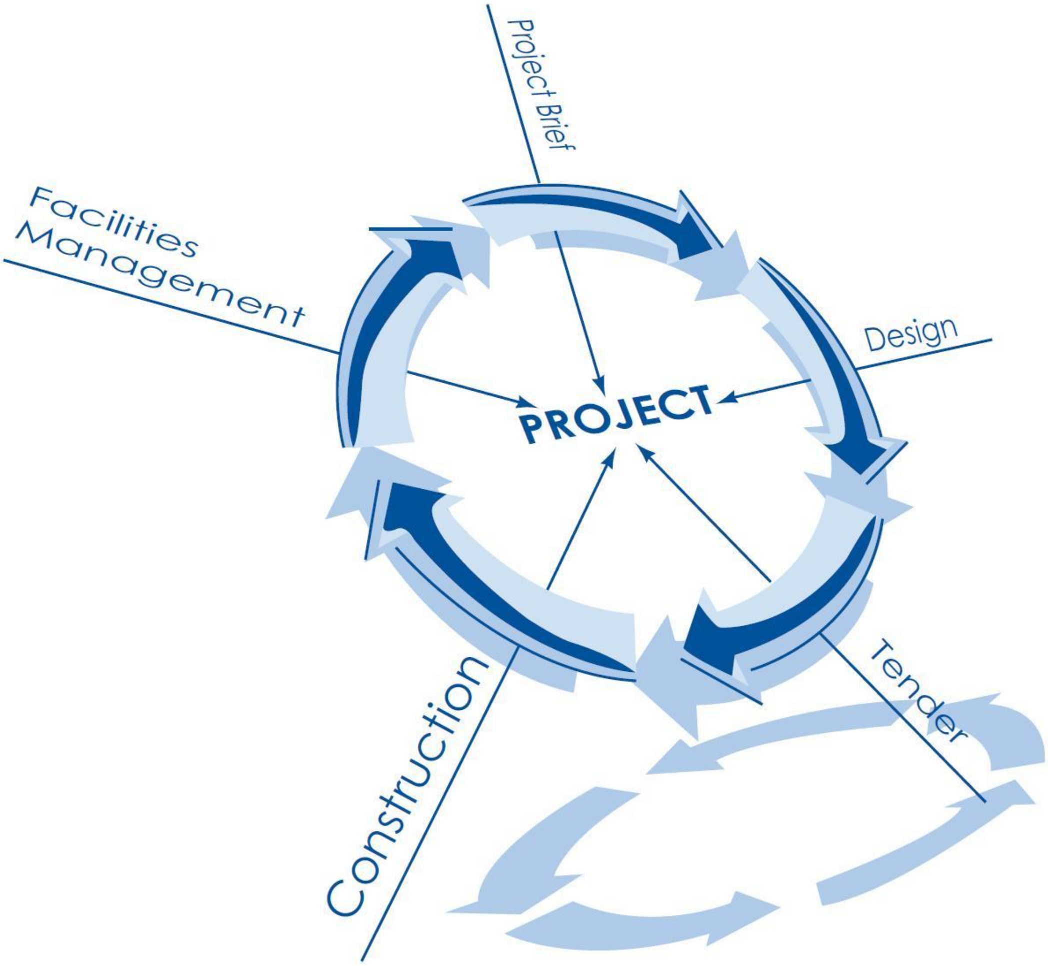

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Contents

Editorial Advisory Board

Editorial

Welcome from the Editors

Welcome to the thirteen 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.

Taksiah A. Majid, et. al., shows the results on a structural behaviour of twenty storeys R.C. buildings with three structural forms (rigid frame, shear walls and wall-frame buildings). Numerous analyses have been carried out in terms of lateral displacements and inter-storey drifts due to various lateral loads by using ETABS software. Two seismicity zones (low and moderate) representing Malaysia was considered using equivalent static procedure. The results concludes that the maximum lateral displacements and inter-storey drifts had occurred at first due to seismic zone-2B for all ranged of buildings periods and latter due to lateral notional loads at higher buildings periods. Results also show that response of buildings in seismic zone-1 dominates at lower periods of the buildings. Rigid frame building showed larger displacements and drifts in both X and Y directions compared to shear walls and wall-frame buildings.

Chin-Siew Choo, et. al., review the effects of large openings in the shear zone of reinforced concrete beams. Seven beams were tested to failure under four-points loading. The beam specimens had a cross-section of 120 mm x 300 mm and a total length of 2000 mm. The openings were provided at both ends; at distances 0, 0.5d, and d from the beam supports. The experimental results were validated using a finite element (FE) program, ATENA. Results show that these openings at the studied locations have significantly reduced the beam capacity to approximately 70 - 80%. Comparison of experimental and FE results in terms of crack patterns and load-deflection behaviour were presented and discussed. Agreeable results in terms of crack patterns and load-deflection curves were obtained between the experimental and FE results; about 50 – 60% and 15 – 20%, respectively.

Muhd Fadhil Nuruddin, et. al. discuss the effects of water-to-geopolymer solids ratio on the workability and curing time on compressive strength of self-compacting geopolymer concrete (SCGC). The experiments were conducted by varying the amount of water and curing time. The water-to-geopolymer solids ratios were 0.31, 0.33, 0.35, and 0.39 and the curing times were 24, 48, 72 and 96 hours. The effects of water -to-geopolymer solids ratio on workability properties such as filling ability, passing ability and resistance to segregation were assessed through Slump flow, V-funnel L-box and J-Ring test methods. Results showed that the workability was improved with the increase in water-to-geopolymer solids ratio; however, compressive strength was decreased as the ratio of water-to-geopolymer solids by mass increased. An increase in strength was also observed with the increase in curing time from 24 hours to 96 hours. The compressive strength of 53.80 MPa was obtained for SCGC with water-to-geopolymer solids ratio of 0.33 and cured for 48 hours.

Afifudin Habulat, et. al., investigate the effect of using *Thermus Thermophilus* (TT) to enhance the strength and permeability of concrete. The properties of the concrete were then assessed by compressive strength and Rapid Chloride Permeability Test (RCPT) after 3, 7, 28, 60 and 180 days. Meanwhile, carbonation test was conducted after 3, 7 and 28 days of exposure in a carbonation chamber. The 10^6 cell/ml of TT was found to be optimum concentration for compressive strength and RCPT; however, there was no optimum concentration which could enhance the carbonation resistance. The maximum improvement in compressive strength, RCPT and carbonation resistance corresponding to that without TT were 27.9 %, 30.6 % and 62.5 % respectively. The microstructure examinations, conducted using Scanning Electron Microscope (SEM), showed significant differences in the microstructure texture compared to the control group (without TT). The results showed that having TT in the concrete mixes was able to enhance the concrete compressive strength, permeability and carbonation resistance characteristic.

Malik M. A. Khalfan, et. al., investigate on the extent of supply chain relationship and integration within Malaysian construction organisations. The basic aim was to test whether the relationships are affected by changes to the way in which a project is delivered, and this was done by verifying the hypotheses that varying procurement methods impact or alter subcontractor - contractor relationships; disputes are resolved without arbitration when differences occur and has affects on future working relationships; and duration of a project potentially allows for a closer bond between parties. A study was conducted using semi-structured interviews with industry representatives last year. The study will help the industry participants in Malaysia to understand the importance of using SCM approach on their projects resulting into building long-term relationship among parties involved.

Ayob Norizan and M.A Malek, discuss the perception on quality assessment system in construction (QLASSIC) implementation in Malaysia. There are many factors that may contribute to the successful of producing quality product for construction project in Malaysia. One of the factor that consider as the contributor is by using legitimate monitoring checklist as assessment. Pilot survey had been used as the main research methodology in order to obtain those relevant data. At the end of this study, the perception by workers in the Constructions and Developers industry towards the implementation of QLASSIC in Malaysia will be established.

Editorial Committee

STRUCTURAL BEHAVIOUR OF 20 STOREYS REINFORCED CONCRETE BUILDINGS DUE TO SEISMIC, WIND AND NOTIONAL LOADS

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Abstract
Most of constructed buildings in Malaysia were only considered wind and notional as a lateral loads in their designs, conforming to Malaysian Standard, MS1553 or to the British Standard, BS6399 for wind loads and to British Standard, BS8110 for a horizontal notional loads. They generally constructed with no special and details of seismic requirements. However, in the last few years tremors were felt in peninsula Malaysia due to large far field earthquakes in Sumatra. Recent studies in Malaysia and Singapore showed that the dynamic responses for tall buildings induced by far field seismic forces are larger than those induced either by wind or lateral notional loads considerably in buildings of high natural periods. Hence, this study has investigated a structural behaviour of twenty storeys R.C. buildings with three structural forms (rigid frame, shear walls and wall-frame buildings). In order to achieve the objective of the study, numerous analyses have been carried out in terms of lateral displacements and inter-storey drifts due to various lateral loads by using ETABS software. Two seismicity zones (low and moderate) representing Malaysia was considered using equivalent static procedure. This study concludes that the maximum lateral displacements and inter-storey drifts had occurred at first due to seismic zone-2B for all ranged of buildings periods and latter due to lateral notional loads at higher buildings periods. Results also show that response of buildings in seismic zone-1 dominates at lower periods of the buildings. Rigid frame building showed larger displacements and drifts in both X and Y directions compared to shear walls and wall-frame buildings.

Keywords: *Inter-Storey Drift; Lateral Displacement; Rigid Frame Building; Shear Walls Building; Wall-Frame Building.*

INTRODUCTION

Tall buildings are exposed to different types of lateral loads in further to the basic functionality of carrying gravity loads and should attain adequate and sufficient stiffness and stability, while the most important lateral loads are wind and earthquake and they considered the major factor which gives distinctive to high –rise buildings designs compared with low rise buildings. The loading on high-rise buildings differs from loading on low-rise buildings mainly in its accumulation over the height to cause very large gravity and lateral load forces within the structure (Smith and Coull, 1991), while the structural designs of low-rise buildings are controlled so far by gravity loads without concerns of overturning or to induced vibrations discomfort problems in contrary of tall buildings. The effects of the wind and earthquake loads are usually considered in terms of horizontal or lateral forces and the structures or buildings must be designed to accommodate those forces with proper evaluation of the loads for safe and economical design.

Malaysia is classified between low to moderate seismicity region based to distance from fault line " Sumatra" , however in the last few years, tremors were felt several times in tall buildings in Singapore and Kuala Lumpur, due to large earthquakes in Sumatra

(Balendra and Li, 2008), where the long period waves are traveling long distance from earthquakes epicentre, and the characteristic long-period waves of distant earthquake could potentially cause damage to certain structures with long period properties (Lam et.al. 2009). The dynamic characteristics and responses of the same height buildings are depending so far on the structural form such as rigid frame, shear wall or wall frame, where those three forms are considered the predominate structural forms in reinforced concrete buildings around the world as well as in Malaysia, while the most of constructed buildings in Malaysia were only considered wind and notional as a lateral loads in their designs conforming to Malaysian Standard, MS1553 or to the British Standard, BS6399, BS8110 for wind loads and a horizontal notional load respectively, as well as they generally constructed with no special and detail seismic requirements. The nature of loads and their effect on structural systems that paves the way for our understanding of structural behaviour and allows the designer to match structural systems to specific types of loading (Tarantah, 2010). Hence this study aimed to determine the most which are dominant lateral loads (wind, notional and earthquake) which can effect on tall building by considering different types of structural forms with various buildings periods.

Buildings with three structural forms

The Uniform Building Code (UBC 97) defined the moment resisting frame, in which members and joints are capable of resisting forces primarily by flexure. This study is only considers Ordinary Moment Resisting Frame (OMRF), where Malaysia located in low to moderate seismicity regions, and ACI 318-08 code states the design and reinforcement detailing requirements for each type of moment frame and each earthquake risk level. Whether shear wall (structural wall) is a wall designed to resist lateral forces parallel to the plane of the wall; sometimes referred to as vertical diaphragm or structural wall (UBC 97). The building braced by structural walls are invariably stiffer than framed structure, reducing the possibility of excessive deformation under small earthquake (Pualy, 1997). The frame-wall system in this study represents, a structural system that uses combinations of ordinary reinforced concrete shear walls and ordinary reinforced concrete moment frames (ASCE7-05 code). The result of that interaction between the two systems larger height can be achieved economically.

Natural frequency

Frequency is defined as the number of complete cycles of vibration made by the load per second depends on the source of the load. Where every structure has a natural frequency of vibration. If dynamic loading occur at or near its natural frequency, the structural will damage and resulting out of all proportion to size of load (Taranath, 2006). The free vibration analysis plays an important role in structural design of tall buildings, especially in the first mode shape because it is the dominant shape in response to wind and earthquake-induced vibrations in tall buildings (Kamgar and Saadatpour, 2011). The natural frequencies and damping ratios of the structure can be measured using full-scale testing techniques once construction is completed, but undesirable results could lead to extremely difficult and costly alterations to the structure if discovered after completion (Alan, 2006). Thus many studies had been carried out to determine and investigate the relationship between natural frequency and lateral deflection of building or by model analyses by utilizing recent infinite elements software. In this study the natural periods and frequencies for the first mode shape for all buildings will be considered for comparison purposes.

Tall buildings and structural analyses in Malaysia

As aforementioned earlier, Malaysia located at low to moderate seismicity region and as matter of fact none of seismic details or requirements entailed the structural design of the buildings, however due to the emerging concern of the effect of lateral loads on high rise buildings substantially to seismic and wind loads, some studies and researches had been conducted in Malaysia and Singapore; where both are located at low-moderate seismic region and they were experienced several tremors in the last few years. The studies and researches are adopted various methods and techniques to investigate and study the behaviour of such forms of tall buildings by utilizing recent finite elements software and procedures, as well as they highlighted the nature and the impact of wind and seismic loads on structures and reasons behind using horizontal lateral notional loads. The wind loading being regarded as critical for taller buildings, otherwise in shorter building where wind load be less significant (Brownjohn, 2005), in other words the notional loads are control in usual buildings heights. Law (2008) has stated that the building drifts caused by wind and notional horizontal loads for 18 story frame-wall buildings in Penang within the acceptable limits stipulated in the Malaysian Standard MS1553, whether the buildings can be vulnerable to damages by excessive lateral drifts due to seismic loads, a comparison also made between the effect of wind and earthquake loads by Adnan and Suradi (2008) for various heights of rigid frame buildings in Malaysia where the results were showed that three buildings might be damages due to excessive lateral drifts induced by seismic loads, moreover; Sharrul B. (2006) has found the lateral deflections for wall-frame buildings due to seismic load is found to be 26.73% greater than that due to wind load, while Calvin and Tso-Chien (2003) have indicated the base shear induced by seismic loads is larger than the notional horizontal load for a rigid frame building, Radhi (2011) has found the lateral displacements and inter-story drifts due to wind and lateral notional loads for shear walls and rigid frame buildings within acceptable limits of Malaysian Standard MS1553. Meanwhile, this study is considering different type of structural forms as well as different type of lateral loadings, where those diversity will enable us to investigate and study the response of such tall buildings if subjected to various type of loadings as well as to determine dominant load that govern the structural behaviour of each structure form.

METHODOLOGY

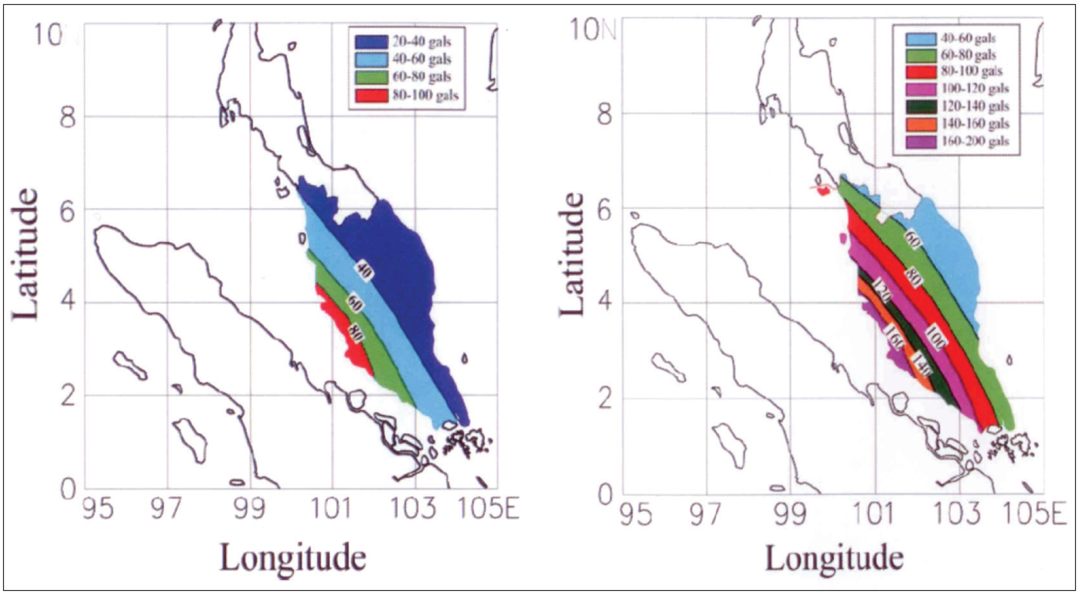
This study has carried out on three different structural types of 20 storeys reinforced concrete buildings of 61.4m length and 54.6m width, to compare the effects of each loading condition with relation of it structural form. The structural types which been selected, rigid moment resisting frame, shear walls and wall-frame buildings. These buildings have not any details or special seismic requirements in their designs. Wind and lateral notional loads are been calculated according to BS 6399-2:1997 and BS 8110-1:1997 codes respectively. The wind pressure calculated according to Eq. (1) and lateral Notional loads calculated as 1.5% of total dead weight of each floor.

$$P = 0.85\ q_s C_a (C_{p\text{-front}} + C_{p\text{-rear}})\ (1 + C_r) \qquad \text{Eq. (1)}$$

Where,

q_s	Dynamic pressure (Pa)
C_a	Size effect factor
C_p-front	External pressure coefficient on the windward side
C_p-rear	External pressure coefficient on the leeward side.
C_r	Dynamic augmentation factor

The seismic loads, base shear and lateral loads distribution are calculated according to lateral equivalent static method of UBC 97 code, where the buildings have a reasonably uniform distribution of mass and stiffness. For such structures, the equivalent static force procedure is most often adequate (Julio, 2001). Two seismic intestines zones of low and moderate zones (zone-1 and zone-2B) were considered respectively the seismic zone of Malaysia which is located between low to moderate seismicity region as shown in the figure-1,wheareas the peak ground acceleration (PGA) according to UBC97 code for seismic zone-1 and zone-2B are equal to 0.075g (75 gals) and 0.2g (200 gals) respectively.



a) PGA map for 10% PE in 50 years (500 years return period)

b) PGA map for 2% PE in 50 years (2500 years return period)

Figure 1. Seismic Hazard Maps of Peninsular of Malaysia (Academy of Sciences Malaysia-2009)

The base shear (V) of the seismic lateral loads and their vertical distribution (F_x) to every floor of the buildings shall be determined by using the equations which described as follows:-

$$V = \frac{c_v \times c}{R \times T} \times W \quad \text{Eq. (2)}$$

$$V_{max} = \frac{2.5 \times c_a \times Ic}{R} \times W \quad \text{Eq. (3)}$$

$$V_{min} = 0.11 \text{ x } C_a \text{ x I x W} \quad \text{Eq. (4)}$$

$$F_x = \frac{W_x \times h_x}{\sum W_i \times h_i} \times (V - Ft) \quad \text{Eq. (5)}$$

Where,

W	Mass weight of the structure
I	Importance factor equal
R	Response modification factor
C_v	Velocity coefficient
C_a	Acceleration coefficient
T	The fundamental period of the structure
W_x	Dead weight of the storey
W_i, h_i	The summation of the dead weight and height of all the stories
Ft	Portion of the base shear, concentrated at the top of the structure
h_x	The height measured from the base to the storey

The research methodology had conducted via six main stages as follows; selection of buildings; loads calculations; modelling and analysing; extracting and comparing the analysis results; modifications in the buildings to obtain different natural periods and re-analysing the building. Figure-2 shows buildings plans and models.

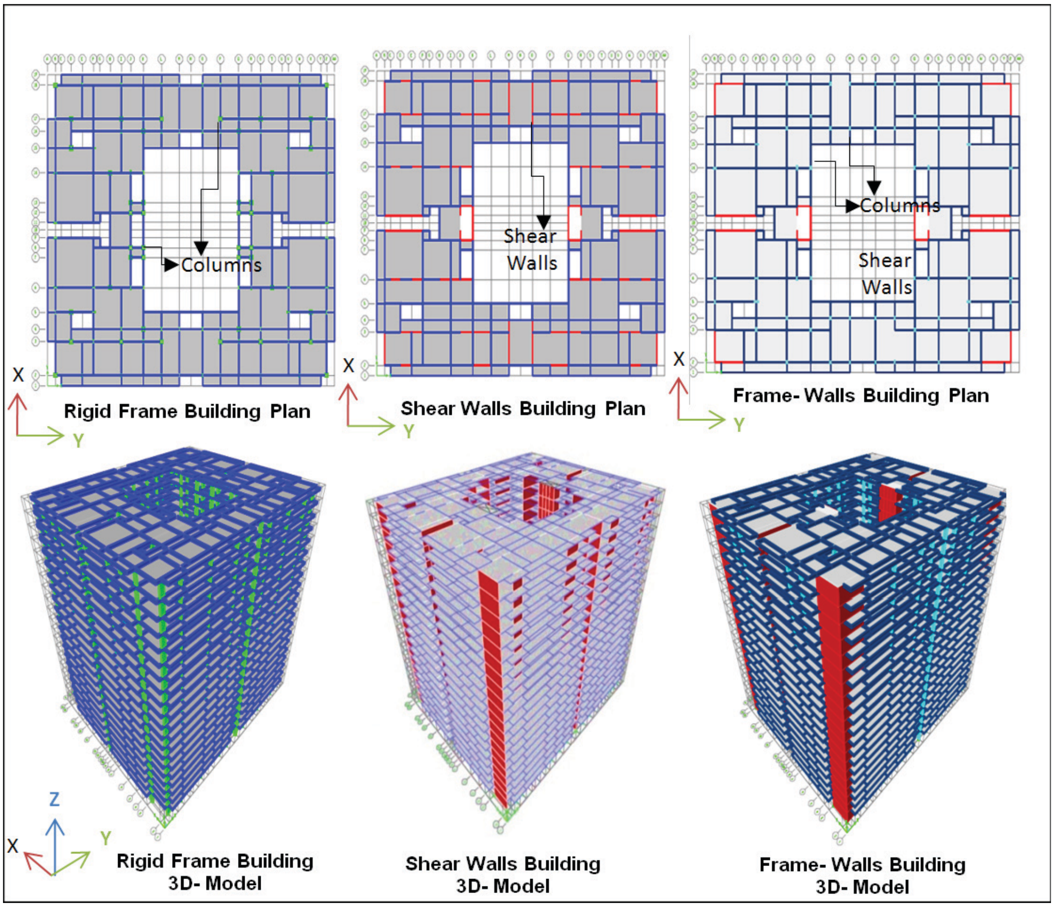


Figure 2. Buildings Plans and Details

Models and loads verifications

In order to confirm the modelling and auto loads computations by ETABS software, the following shows the percentage differences between hand calculations and ETABS results. The hand calculations of wind pressures according to BS 6399-2:1997 is 1.6 kN/m^2 and by ETABS is 1.65 kN/m^2. Tables 1 and 2 show the total base shear forces for each building due to seismic loads (zone-1 and zone-2B) and percentage differences between hand calculation and ETABS results. The insignificant percentage differences between hand calculations and ETABS results are verified the modelling and analyses results which were carried out using ETABS software by utilizing the auto loads computations features.

Table 1. Base Shear Forces and Percentage Differences for Seismic Zone-1

Building	Hand Calculation	ETABS	% Differences
	Base shear (kN)	Base shear (kN)	
Rigid Frame	8727.552	8371.45	4.08
Shear Walls	10741.759	10322.83	3.90
Frame - Wall	7367.966	7065.21	4.11

Table 2. Base Shear Forces and Percentage Differences for Seismic Zone-2B

Building	Hand Calculation	ETABS	% Differences
	Base shear (kN)	Base shear (kN)	
Rigid Frame	19394.562	18603.21	4.08
Shear Walls	23870.576	22939.62	3.90
Frame - Wall	16373.257	15700.46	4.11

RESULTS AND DISCUSSION

Lateral displacements and inter-storey drifts were determined according to the analyses results for all three buildings, where the following is describing each building displacements and drifts for various loads combinations. However the maximum allowable limits for total building drift and inter-storey drifts are according to MS1553: 2002 code. All three buildings have an overall building height of 61m and inter-storey height of 3m excluding 1^{st} floor (4 m height). Thus, the maximum allowable building displacement is 122 mm (H/500) and the maximum allowable inter-storey drift is 4mm for 3 m height (h/750) and 5.33mm for 4m height (1st floor), which caused an abrupt increment in all inter storey drift graphs at storey -1.

Figures 3 and 4 show lateral displacement in X and Y directions for rigid frame building and maximum allowable displacement limit. All displacements magnitudes for all loadings and floors not exceeding the allowable limits and maximum displacements occurred under seismic zone-2B loads and secondly due to lateral notional loads in both directions X and Y for the building.

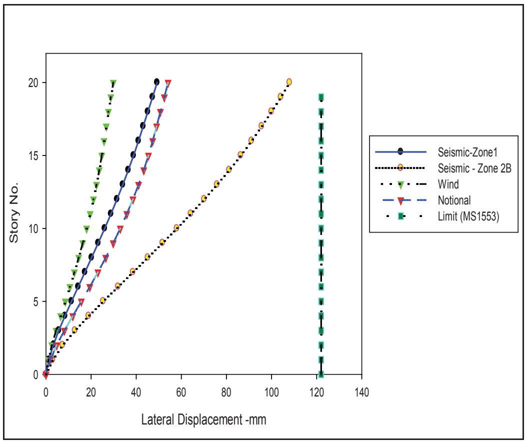


Figure 3. Lateral Displacement versus Storey Number for Rigid Frame Building in X-Direction

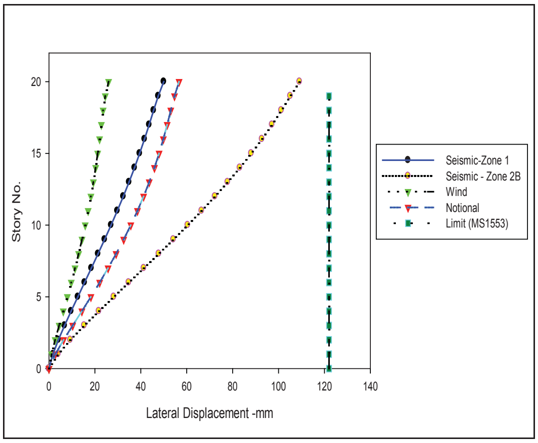


Figure 4. Lateral Displacements versus Storey Number for Rigid Frame Building in Y-Direction

Figures 5 and 6 show lateral displacement in X and Y directions for shear walls building and maximum allowable displacement limit, where all displacements magnitudes for all loadings and floors also not exceeding the allowable limits. The maximum displacements occurred under seismic zone-2B loads and followed by lateral notional loads in both directions X and Y for the building. The displacements magnitudes in Y direction are not exceeded 63% than X direction due to the building is stiffer in X direction than Y (in-plan shear walls).

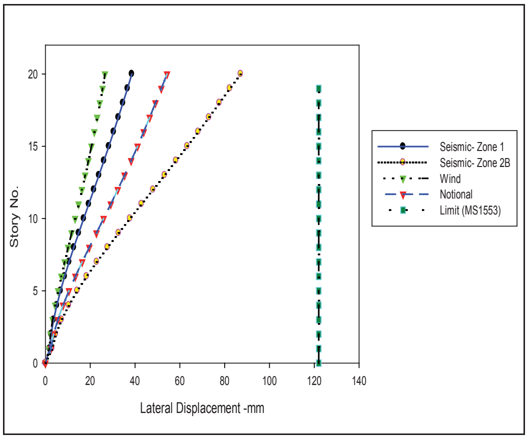


Figure 5. Lateral Displacements Versus Storey Number for Shear walls Building in X-Direction

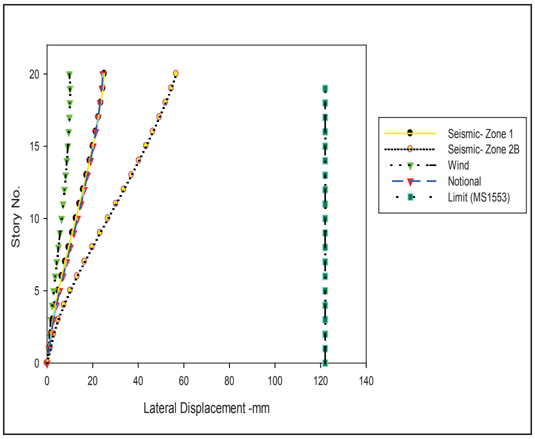


Figure 6. Lateral Displacements (mm) Versus Storey Number for Shear walls Building in Y-Direction

Figures 7 and 8 show lateral displacement in X and Y directions for wall-frame building, where all displacements magnitudes for all loadings and floors not exceeding the allowable limits and maximum displacements also occurred at seismic zone-2B loads and secondly due to lateral notional loads in both directions X and Y for the building.

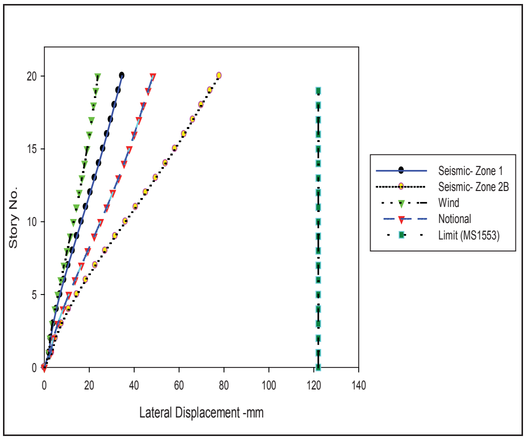


Figure 7. Lateral Displacements versus Storey Number for Wall-Frame Building in X-Direction

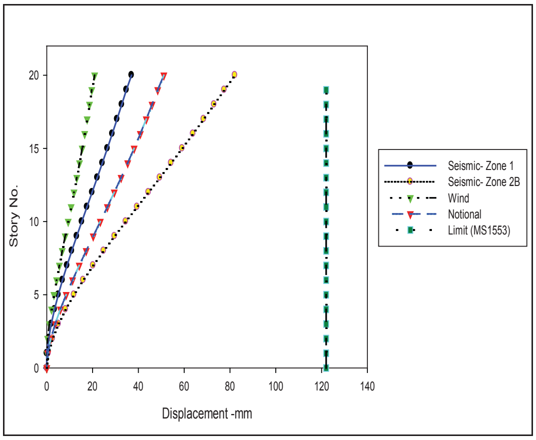


Figure 8. Lateral Displacements versus Number Storey for Wall-Frame Building in Y-Direction

Figures 9 and 10 show inter-storey drifts for rigid frame building versus storey number due to various loads in both X and Y directions. The drifts values were exceeded the allowable limits only in the case of seismic loads zone-2B in both X and Y direction, while other loads cases induced drift that not exceeded the limits. The maximum drifts occurred at seismic zone-2B loads and followed by the lateral notional loads in both directions X and Y for the building.

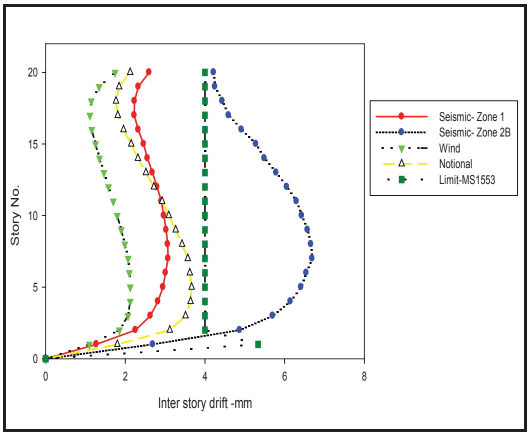


Figure 9. Inter-Storey Drifts Versus Storey Number for Rigid Frame Building in X-Direction

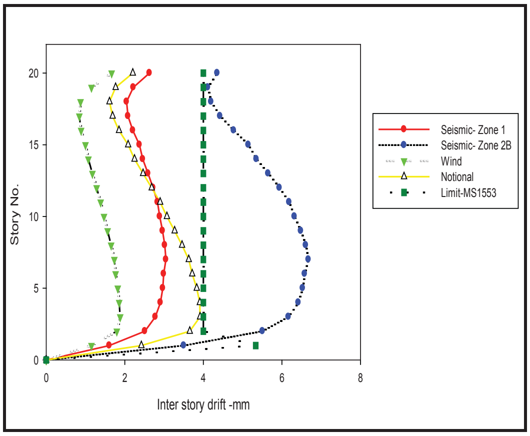


Figure 10. Inter-Storey Drifts Versus Storey Number for Rigid Frame Building in Y-Direction

Figures 11 and 12 show inter-storey drifts for shear walls building versus storey number due to various loads in both X and Y directions. The drifts values were exceeded the allowable limits only in the case of seismic loads zone-2B in Y direction. Other loads cases induced drifts that not exceeded the limits. The maximum drifts occurred firstly under seismic zone-2B loads and secondly due to lateral notional loads in both directions Y in addition to seismic zone-1 loads in X direction.

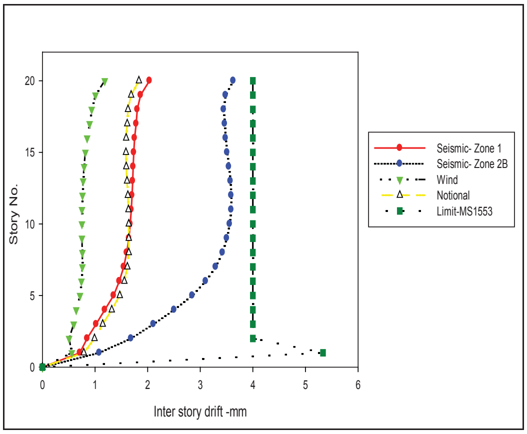


Figure11. Inter-Storey Drifts Versus Storey Number for Shear Walls Building in X-Direction

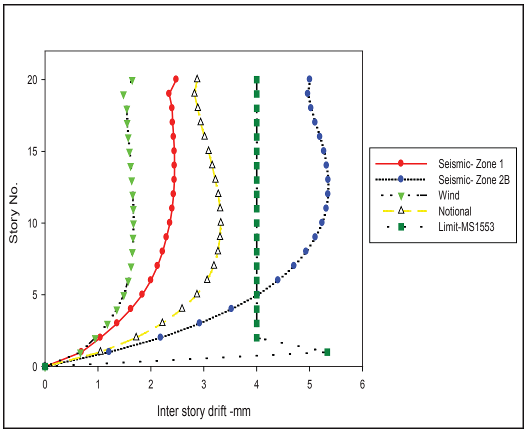


Figure12. Inter-Storey Drifts Versus Storey Number for Shear Walls Building in Y-Direction

Figures 13 and 14 show inter-storey drifts for wall frame building versus storey number due to various loads in both X and Y directions. The drifts values were exceeded the allowable limits only in the case of seismic loads zone-2B in Y direction. Other loads cases also induced drifts that not exceeded the limits. The maximum drifts occurred firstly under seismic zone-2B loads and secondly due to lateral notional loads in both directions Y in addition to seismic zone-1 loads in X direction.

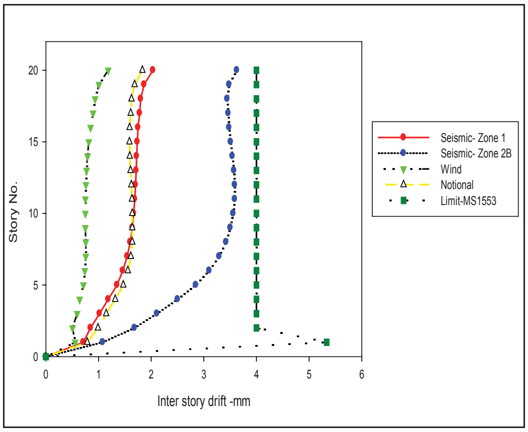


Figure 13. Inter-Storey Drifts Versus Storey Number for Wall-Frame Building in X-Direction

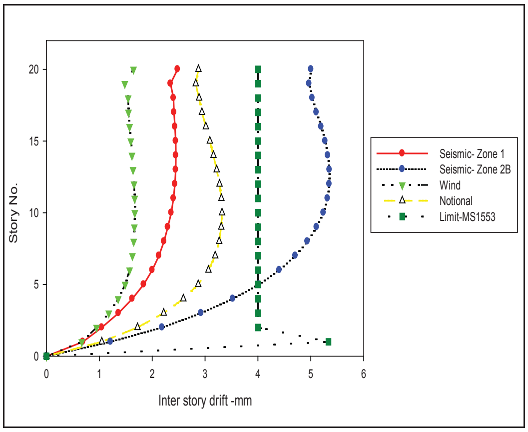


Figure 14. Inter-Storey Drifts Versus Storey Number for Wall-Frame Building in Y-Direction

The previous graphs showed that the maximum lateral displacement and inter storey drifts for all buildings were occurred due to seismic loads zone-2B and lateral notional loads in both X and Y directions, and showed that the maximum lateral displacements and inter-storey drifts in X-direction occurred in the order of rigid frame, wall-frame and shear walls buildings, and the maximum lateral displacements in Y-direction occurred in the sequence of rigid frame, shear walls and wall-frame buildings. Tables 3 and 4 give the percentage differences of displacements and drifts between seismic zone-2B loads and lateral notional loads for all buildings.

Table 3. Lateral Displacements Percentage Differences between Seismic Zone-2B and Notional loads

Storey	Rigid-X	Rigid-Y	Shear Walls-X	Shear Walls-Y	Wall-Frame -X	Wall-Frame -Y
1	30.44	34.66	29.81	15.42	39.58	13.67
2	31.50	35.36	37.71	20.25	28.59	18.43
3	32.70	36.20	41.45	22.73	27.63	20.99
4	33.96	37.16	43.67	24.50	27.85	22.90
5	35.22	38.16	45.22	25.93	28.44	24.51
6	36.44	39.18	46.45	27.16	29.16	25.95
7	37.66	40.22	47.49	28.27	29.92	27.25
8	38.83	41.25	48.40	29.29	30.69	28.45
9	39.95	42.26	49.22	30.24	31.44	29.56
10	41.00	43.23	49.98	31.14	32.18	30.60
11	42.02	44.15	50.69	32.00	32.90	31.58
12	42.97	45.03	51.37	32.81	33.58	32.50
13	43.87	45.86	52.02	33.58	34.24	33.36
14	44.72	46.65	52.65	34.31	34.87	34.17
15	45.54	47.39	53.28	34.99	35.46	34.94
16	46.30	48.08	53.90	35.63	36.03	35.65

17	46.98	48.70	54.52	36.22	36.55	36.31
18	47.58	49.24	55.17	36.75	37.04	36.89
19	47.99	49.62	55.88	37.17	37.48	37.35
20	48.07	49.86	56.82	37.68	37.74	37.94
Average	***40.687***	***43.113***	***48.785***	***30.3035***	***33.0685***	***29.65***

Table 4. Inter-Storey Drifts Percentage Differences between Seismic Zone-2B and Notional loads

Storey	Rigid-X	Rigid-Y	Shear Walls-X	Shear Walls-Y	Wall-Frame -X	Wall-Frame -Y
1	30.44	34.66	29.81	15.42	39.58	13.67
2	31.50	35.36	37.71	20.25	28.59	18.43
3	32.70	36.20	41.45	22.73	27.63	20.99
4	33.96	37.16	43.67	24.50	27.85	22.90
5	35.22	38.16	45.22	25.93	28.44	24.51
6	36.44	39.18	46.45	27.16	29.16	25.95
7	37.66	40.22	47.49	28.27	29.92	27.25
8	38.83	41.25	48.40	29.29	30.69	28.45
9	39.95	42.26	49.22	30.24	31.44	29.56
10	41.00	43.23	49.98	31.14	32.18	30.60
11	42.02	44.15	50.69	32.00	32.90	31.58
12	42.97	45.03	51.37	32.81	33.58	32.50
13	43.87	45.86	52.02	33.58	34.24	33.36
14	44.72	46.65	52.65	34.31	34.87	34.17
15	45.54	47.39	53.28	34.99	35.46	34.94
16	46.30	48.08	53.90	35.63	36.03	35.65
17	46.98	48.70	54.52	36.22	36.55	36.31
18	47.58	49.24	55.17	36.75	37.04	36.89
19	47.99	49.62	55.88	37.17	37.48	37.35
20	48.07	49.86	56.82	37.68	37.74	37.94
Average	***40.687***	***43.113***	***48.785***	***30.3035***	***33.0685***	***29.65***

The following is describing the alteration in natural buildings periods, where the first mode periods of each building are 2.125, 1.86 and 1.74 seconds for rigid frame, walls shear and wall-frame buildings, respectively. The alterations in buildings periods from above mentioned periods values to 1 second periods value were carried out by modifying the stiffness of the structural elements of the buildings. The maximum values of the both lateral displacements and inter-storey drifts for each load, building and periods were calculated. The scheme of the maximum magnitudes of displacements and drifts are continue occurring firstly due to seismic zone-2B loads and secondly due to lateral notional loads at high periods values whether the seismic zone-1 loads been dominates at lower periods for the buildings. This is due to the increasing in base shear forces when the period declined in accordance to equation (2). However, the magnitudes of lateral displacements and inter-storey drifts were decreased when buildings periods declined for all lateral loads. Figures 15 and 16 show the summary of the maximum building lateral displacements versus periods due to seismic zone-2B for all three buildings in X and Y directions. Figures 17 and 18 show the summary of the maximum building inter-storey drifts versus periods due to seismic zone-2B for all three buildings in X and Y directions. The rigid frame building shows larger lateral displacements and inter-storey drifts in both X and Y directions compared with other two buildings (shear walls and wall-frame buildings) for all ranged of periods. Wall-frame building shows larger displacements and drifts than shear walls in X-direction. The shear walls building shows larger displacements and drifts in Y-direction.

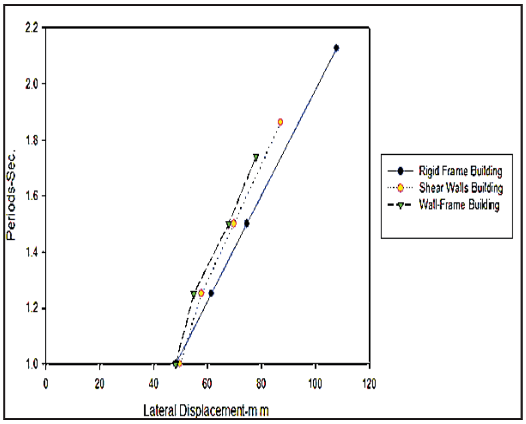


Figure 15. Maximum Building Lateral Displacements versus Building Period in X-Direction for Seismic Zone-2B

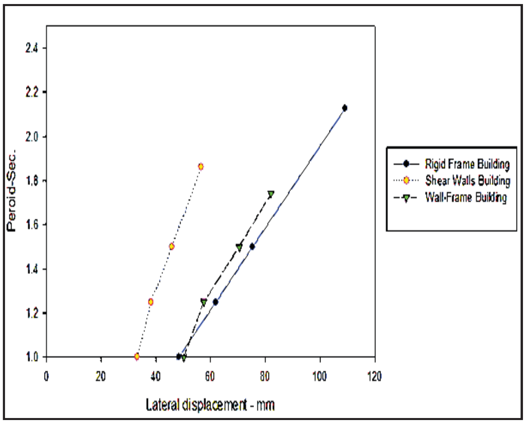


Figure 16*:* Maximum Building Lateral Displacements versus Building Period in Y-Direction for Seismic Zone-2B

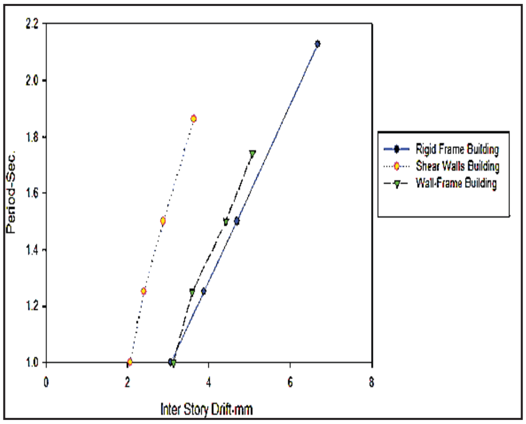


Figure 17. Maximum Inter-Storey Drifts Versus Building Period in X-Direction for Seismic Zone-2B

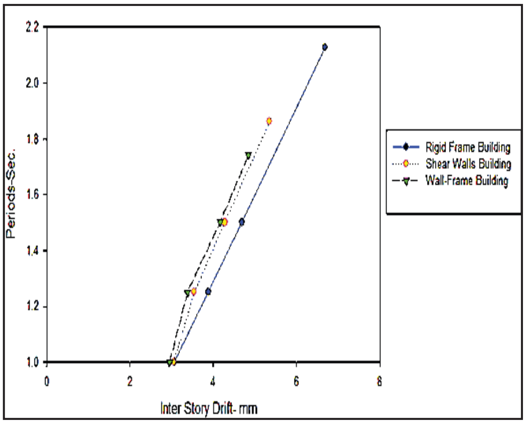


Figure 18. Maximum Inter-Storey Drifts Versus Building Period in Y-Direction for Seismic Zone-2B

CONCLUSIONS

This study has investigated the 20 storey buildings responses in terms of lateral displacements and inter-storey drifts due to various lateral loads and various buildings periods (via alteration of building stiffness) to determine the most dominant load. Thus, in order to achieve the objective of these studies numerous analyses have been carried out for all three buildings (rigid frame, shear walls and wall-frame buildings) by using ETABS software and the following conclusions could be made:

a) Lateral displacements for all buildings due to all loads within the allowable limits which has been permitted by the MS1553: 2002 code.

b) The inter-storey drifts that induced by seismic zone-2B loads had exceeded the allowable limits of MS1553: 2002 code for all buildings except the shear walls building in X-direction.

c) The maximum lateral displacements and inter-storey drifts had occurred at first due to seismic zone-2B and secondly due to lateral notional loads for all buildings.

d) The average parentage differences between seismic zone-2B and lateral notional loads in term of lateral displacements in both (X, Y) directions are (40.69%, 43.11%), (49.6%, 50.14%) and (48.79%, 30.30 %) for rigid frame, shear walls and wall-frame buildings respectively.

e) The average percentage differences between seismic zone-2B and lateral notional loads in term of inter-story drifts in both (X, Y) directions are (49.6%, 50.14%), (50.27%, 34.69%) and (34.47%, 34.49%) for rigid frame, shear walls and wall-frame buildings respectively.

f) The maximum lateral displacements and inter-storey drifts in X-direction occurred in the order of rigid frame, wall-frame and shear walls buildings. Whereas the maximum lateral displacements in Y-direction occurred in the sequence of rigid frame, shear walls and wall-frame buildings.

g) The trend of the maximum displacements and drifts are continue to occur due to seismic zone-2B loads and latter due to lateral notional loads at high periods values for all buildings, however at lower buildings periods the seismic zone-1 been dominate instead of lateral notional loads.

h) Rigid frame building with all range of periods shows larger lateral displacements and inter-storey drifts in both X and Y directions compared with shear walls and wall-frame buildings, while wall-frame building shows larger displacements and drifts than shear walls in X-direction, but in Y-direction shear walls building shows larger displacements and drifts.

i) The buildings may suffer from excessive drifts and deformations that induced by moderate seismic loads and those loads must give a proper considerations in their designs.

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EFFECTS OF LARGE OPENINGS IN THE SHEAR ZONE OF REINFORCED CONCRETE BEAMS

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Abstract
Openings are often provided in reinforced concrete (RC) beams to facilitate the passage of utility pipes and ducts to accommodate essential services in buildings either commercial or residential. They are usually provided by structural engineers in the bending zone (safe zone) to avoid the beams from losing their original beam capacities. However, there are situations when Mechanical and Electrical (M&E) engineers requested to provide openings at critical locations of RC beams to simplify the arrangements of pipes and ducts. This paper provides an investigation to study the effects of large openings (circular and square) in the shear zones of RC beams. Seven beams were tested to failure under four-points loading. The beam specimens had a cross-section of 120 mm x 300 mm and a total length of 2000 mm. The openings were provided at both ends; at distances 0, 0.5d, and d from the beam supports. The experimental results were validated using a finite element (FE) program, ATENA. Results show that these openings at the studied locations have significantly reduced the beam capacity to approximately 70 - 80%. Comparison of experimental and FE results in terms of crack patterns and load-deflection behaviour were presented and discussed. Agreeable results in terms of crack patterns and load-deflection curves were obtained between the experimental and FE results; about 50 – 60% and 15 – 20%, respectively.

Keywords: *Circular, Effects, Large Openings, RC Beams, Shear, Square*

INTRODUCTION

Commercial and residential buildings either in high rise or low rise structures need to be installed with building services such as conduits, electrical cables, air-conditioning, ventilation system and network system access. To accommodate such services, services can be provided through pipes and ducts which run horizontally or vertically. The routes of the pipes and ducts are usually under the ceiling which will penetrate through the beams or suspended under the soffit of the beams. When suspending under the soffit of the beams, the storey-height may be higher to meet the headroom requirement. On the other hand, in order to reduce the storey-height and to maintain the headroom requirement, the pipes and ducts are usually penetrated through the beam structures. However, the provision of openings in the web of RC beams leads to many problems in the beam behaviour including reduction in beam stiffness, excessive cracking and deflection and reduction in beam capacity. In addition, the presence of openings leads to high stress concentration around the openings especially at the opening corners. The reduction of area in the total cross-sectional dimension of a beam changes the simple beam behaviour to a more complex one (Mansur et al. 1992; Mansur, 2006).

Providing openings in RC beams to accommodate the passage of utility pipes and ducts have been a challenging issue. Therefore, many research interests in this area have been dedicated since 1960s. Numerous literatures addressed the problems including the behaviour of beams containing large (Mansur et al. 1985; Mansur, 1988; Tan and Mansur, 1996) and small openings (Mansur and Hasnat, 1979; Mansur et al. 1983; Mansur and Paramasivam, 1984; Mansur, 1999) and multiple openings in simply supported beams, continuous two spans and three spans beams (Mansur et al. 1991) and T-beams (Tan et al. 1996). Also, various models and equations were used for predictions of beams' torsional and ultimate strength (Alwis and Mansur, 1987); and investigation of beams with openings subjected to torsion, bending, shear and combined loading (Mansur, 1983; Abul Hasnat and Akhtaruzzaman, 1987) and torsional strength of beams containing opening (McMullen and Daniel, 1975; Venkappa and Pandit, 1985). Despite the intensive efforts that have been made to deal with the openings in RC beams, many issues are still pending and need to be resolved.

Recent available literatures were found to further investigate the effects of openings in RC beams. Chin (2013) studied the effects of RC beams with large openings placed in bending and critical shear zones conducted in both experimental and finite element analysis. Researchers also compiled the state of the art work on the behaviour, analysis, and design of RC beams with transverse web openings (Ahmed et al. 2012). Meanwhile, Amiri and Masoudnia (2011) investigated the opening effects on the behaviour of concrete beams without additional reinforcement in opening region using FEM method. In terms of the size of openings, Mansur and Hasnat (1979) classified small openings as those circular, square, or nearly square in shape. Meanwhile, according to Somes and Corley (1974), a circular opening may be considered as large when its diameter exceeds 0.25 times the depth of the web. Mansur (2006) reported that openings can be considered as small openings when the depth or diameter of the opening is in a realistic proportion to the beam size, about less than 40% of the overall beam depth whilst openings are considered large when the ratio of the opening size to the beam's effective depth is more than 40% (Pimanmas, 2010).

With regards from previous findings, the research gaps were identified. It was found that most of the studies focused on using small circular and large rectangular openings in mostly T-beams and continuous beams subjected to bending, shear and torsion. However, very little research effort to study the effects of large circular and square openings in the critical shear zone of RC beams. Morever, most of the investigations were experimental work and lack of validation using finite element analysis. In this paper, the effects of large circular and square openings provided in the critical shear zone of RC beams were studied. The percentage (%) of the beam cut depth from the total beam depth for each circular and square openings was 77% and 70%, respectively. The openings are classified as large as both the diameter of circular and size of square openings are more than 40% of the beam depth. The openings were placed at both ends, at distances 0, 0.5d and d away from the supports. Seven (7) RC beams including two (2) control beams and remaining beams contained openings were tested to failure under four-points loading. The experimental results were validated using a finite element program, ATENA. Comparison of crack patterns and load deflection curves between the experimental and FE results are presented and discussed.

METHODOLOGY

Experimental Program

To investigate the effects of openings provided in the critical shear zone of RC beams at both ends, seven RC beams were tested to failure under four-points loading to investigate the structural behaviour including crack patterns and load-deflection behaviour. The following sub-sections describe the detail of the experimental program.

Test Specimens

A schematic diagram of the test specimen showing the reinforcement details is depicted in Figure. 1. The beam specimens had a rectangular cross-section of 120 mm x 300 mm with a span of 2000 mm. The effective depth of the beams was 280 mm while the effective span was in a length of 1800 mm. The tension reinforcements consisted of two 12 mm diameter steel bars while the compression reinforcements consisted of two 10 mm diameter steel bars. The stirrups were 6 mm diameter spaced at 300 mm center to center. In this study, circular openings with a diameter of 230 mm and square openings with the size of 210 mm x 210 mm were considered. The percentage ratio of beam cut depth and the overall beam depth for each circular and square openings was 77% and 70%, respectively, in which researchers classified them as large openings because the diameter and depth of the openings are more than 40% of the overall beam depth (Mansur, 2006). The details of the beam specimens are summarized in Table 1.

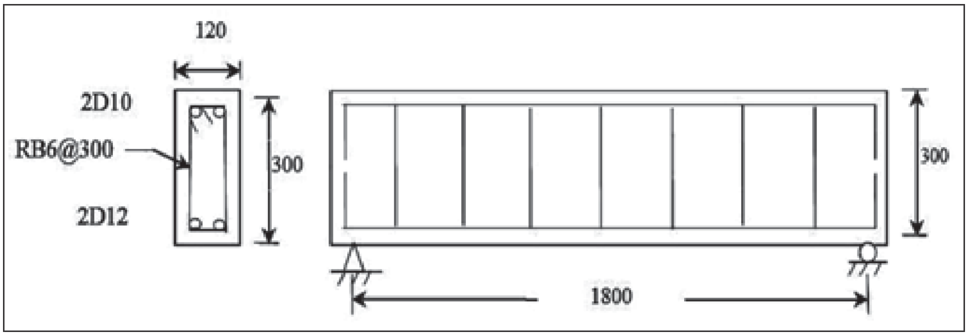

Figure 1. Beam reinforcement details (Unit: mm)

Table 1. Beam specimens and the descriptions of the openings

No	Beam	Openings at both ends		
		Shape	**Location(distance from supports)**	**Failure Mode**
1	CB1	Control	-	Bending and Shear
2	CB2	Control	-	Bending and Shear
3	C0S	Circular	0	Shear
4	S0S	Square	0	Shear
5	S0.5dS	Square	0.5d	Shear
6	CdS	Circular	d	Shear
7	SdS	Square	d	Shear

Test Setup

The beam specimens were tested to failure under four-points loading subjected to static load of 500 kN using a Universal Testing Machine (UTM). The test setup is shown in Figure 2. A spreader beam was used to transfer the load to the test specimen through two loading points at 500 mm apart. The beam deflection was monitored by a number of linear variable displacement transducers (LVDTs) placed at the bottom soffit of the beam. The crack development and propagation were marked and the mode of failures was recorded.

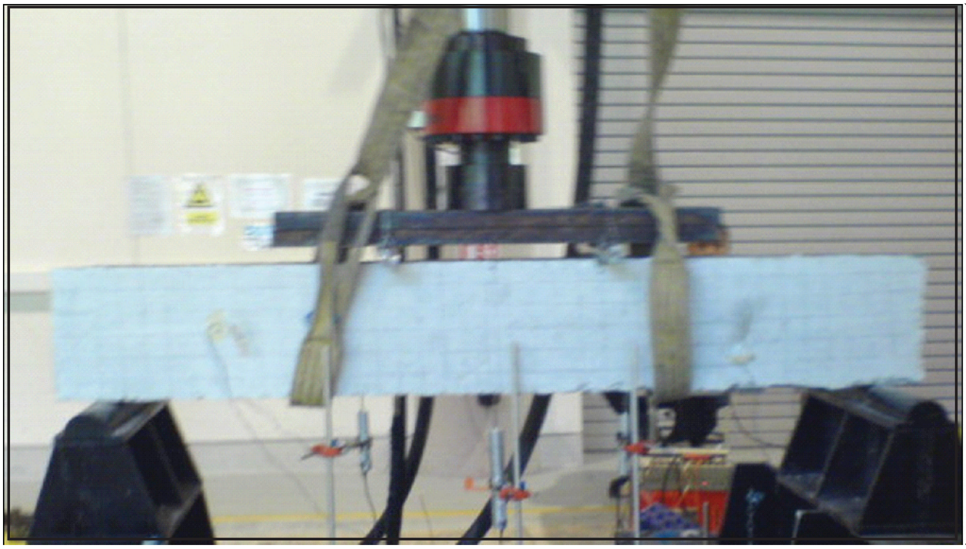

Figure 2. Test Setup

FINITE ELEMENT ANALYSIS

In this study, a two dimensional (2D) non-linear finite element analysis was conducted using the finite element package, ATENA. The material models, geometrical modelling and non-linear solution are presented in the following sections.

Material Models

For concrete, the constitutive model of the finite element package ATENA (Cervenka et al. 2010) was used. In this approach, the elastic constants are derived from a stress-strain function known as equivalent uniaxial law which covers the complete range of the plane stress behaviour in tension and compression. Figure 3 shows the uniaxial stress strain law for concrete. Steel reinforcement was represented by multi-linear law which consists of four lines as shown in Figure 4. This law allows a linear modelling of all four stages of steel behaviour: elastic state, yield plateau, hardening and fracture. The stress-strain relationship of the steel reinforcements was obtained from the experimental study and adopted in the FE analysis.

Geometrical Modelling

To represent the concrete, SBETA material model for two dimensional plane stress elements was used. The tensile behaviour of concrete was modelled by a combination of nonlinear fracture mechanics with the crack band method, in which the smeared crack concept was adopted. The steel reinforcement and stirrups were modelled as discrete reinforcements i.e. a single straight line in a discrete manner; using two node truss elements represented by bar elements.

Non-linear Solution

In this investigation, a displacement-controlled incremental loading method with an iterative solution procedure based on the Newton-Raphson method was adopted.

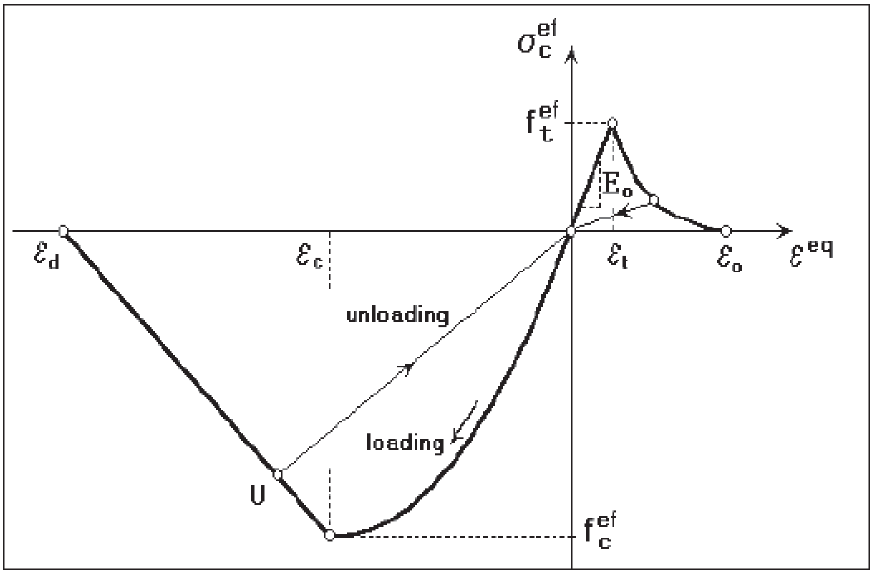

Figure 3. Uniaxial stress strain law for concrete

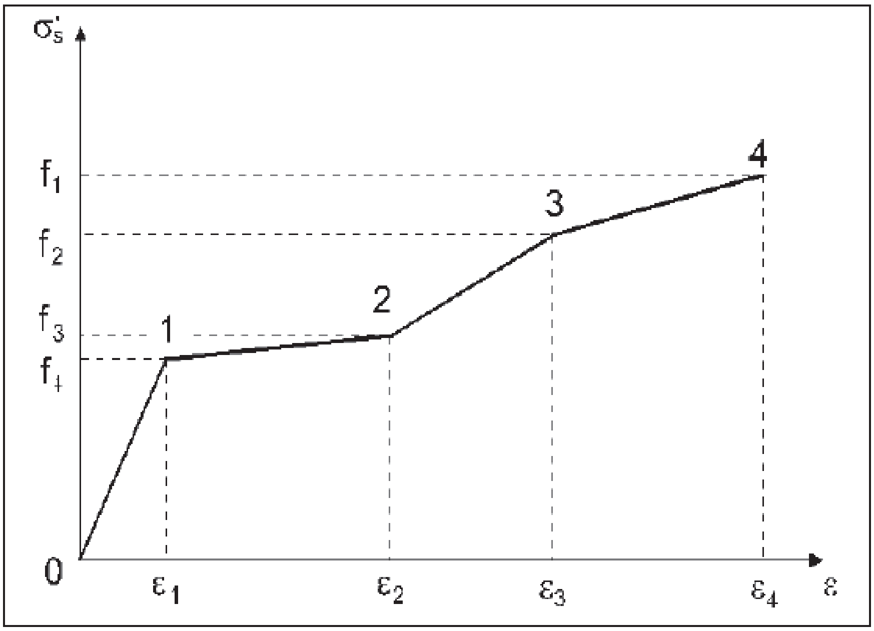

Figure 4. Multi-linear stress strain law for reinforcement

RESULTS AND DISCUSSION

In the first part of the results, experimental results in terms of load-deflection behaviour are presented. The second part of the results shows the comparison of experimental and FE analysis in terms of crack patterns and load-deflection behaviour.

Experimental Results

Figure 5 shows the load-deflection behaviour of beams with circular and square openings at the face of support and compared with their respective control beam, CB1. From the load-deflection curve, the provision of circular and square openings at both ends (at the face of support) did not show significant difference. Both shape of openings significantly reduced the beam capacity to about 78 – 80% of the original beam capacity, CB1.

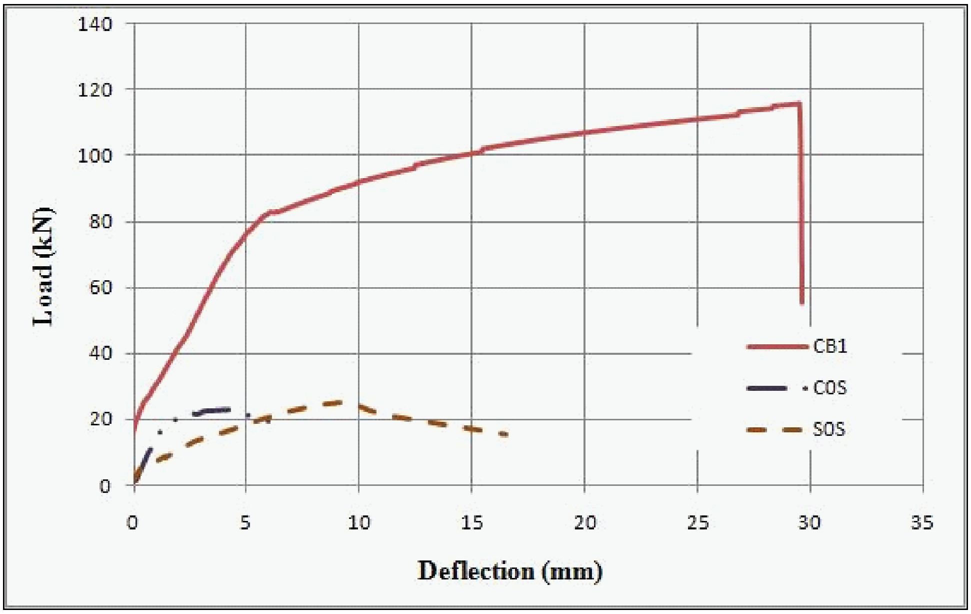

Figure 5. Comparison of load-deflection curves of control beam CB1 and beams with openings at the face of support

Similarly, the load-deflection behaviour of beams with circular and square openings at distances 0.5d and d from the support was compared with their respective control beam, CB2, as plotted in Figure 6. Results show that the presence of circular and square openings in the critical shear locations did not show significant difference, within 5%. It was found that both circular and square openings caused the losses in beam capacity to approximately 69 – 75% of the reference beam, CB2.

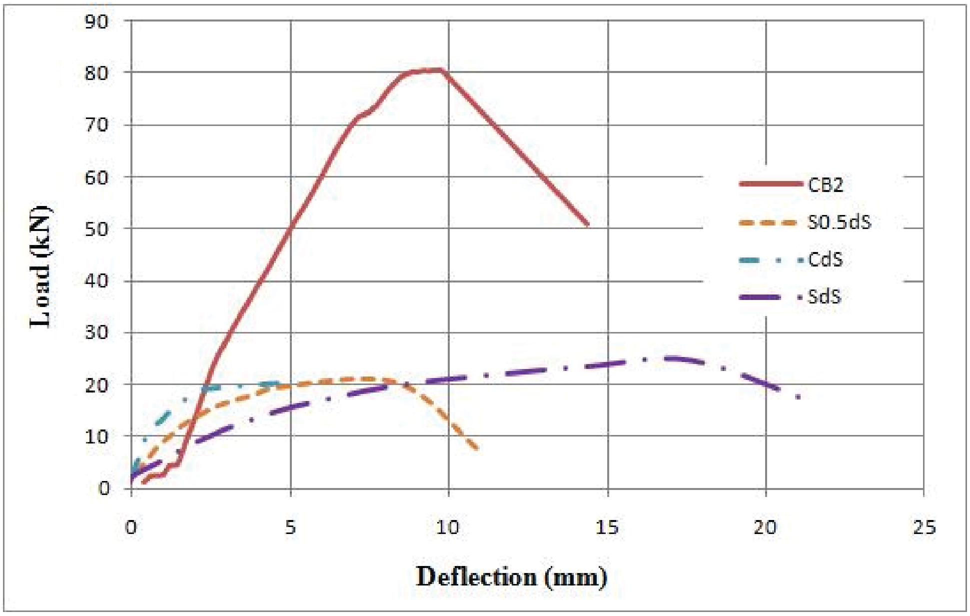

Figure 6. Comparison of load-deflection curves of control beam CB2 and beams with openings at distances 0.5 and d from support

Comparison of Experimental Results and FE Analysis

Crack Patterns

a. Control Beam

The cracks are mainly composed of shear cracks which diagonally oriented at the top side and bottom sides of opening. The FE analyzed beam showed cracks which originated at the top side of opening which then elongated diagonally to the loading points whereas cracks at the bottom side of opening propagated diagonally to the beam support. The beam failed in shear. The crack patterns between the experimental and FE results showed good agreement. Figure 8 shows the crack pattern comparison of beam C0S.

b. Beam C0S

The analyzed and experimental beams showed similar crack patterns, which are composed of flexural and shear cracks, as shown in Figure 7. The flexural cracks were vertically aligned from the bottom up to the middle-third of the beam depth within the middle-third span. The shear cracks were diagonally oriented from the loading points at the top side of the beam and elongated diagonally to the bottom near to the support. At the point of failure of the experimental beam, the main diagonal cracks were very wide, which formed a see-through gap. The failure of the beam was governed by shear failure.

c. Beam S0S

Figure 9 presents the crack patterns of beam with square openings at the face of support obtained from FE results and experimental testing. The FE analysis predicted diagonal cracks at the four corners of the square openings due to high stress concentration, similar as noticed in the experimental beam. The cracks at the top right corner were horizontally aligned when approaching the loading point whereas cracks at the top left corner were diagonally elongated to the edge of the beam. Both of these phenomena lead to the crushing of concrete cover in the experimental beam. The comparison shows a good agreement between the crack patterns of tested and analyzed beams.

d. Beam S0.5dS

Crack patterns of beam with openings at a distance 0.5d from the support, as shown in Figure 10 obtained from FE results and experimental testing are consisted of shear and flexural cracks. The FE analysis predicted the shear cracks at the top chord which then elongated diagonally to the applied loads whereas cracks at each corner of the openings in the bottom chord propagated all the way to the bottom edge of the beam and to the solid section near the beam support, respectively. From the crack pattern results, a close match was obtained between FE analysis and experimental results.

e. Beam CdS

Crack patterns of beam with circular openings at distance d from the support were agreeable between the experimental results and FE analysis as illustrated in Figure 11. The FE crack patterns showed cracks at the top side of the opening which oriented diagonally to the load points and upper edge of the beam whereas cracks at the bottom side of opening penetrated diagonally to the beam support as well as the bottom edge of the beam, similar as shown in the tested beam. The cracks at the top and bottom sides of the circular opening in the experimental beam resulted in crushing of concrete cover with wide cracks spread vertically to the upper edge of the beam and diagonally to the loading point.

f. Beam SdS

Figure 12 shows the comparison of crack patterns between the analyzed and tested beams. The trend of crack patterns for this beam was found similar as observed in beams S0S and S0.5dS. From the FE analysis, due to high stress concentration at opening corners, cracks were initiated at the four corners of the square openings. At the top chord of opening, cracks at the opening corners were observed penetrating vertically up to the top edge of the beam and diagonally towards the loading points, respectively. On the other hand, cracks from the opening corners at the bottom chord stretched to the bottom edge of the beam and all the way to the beam support, respectively. The crack patterns of FE analysis were found comparable to the crack patterns of the tested beam.

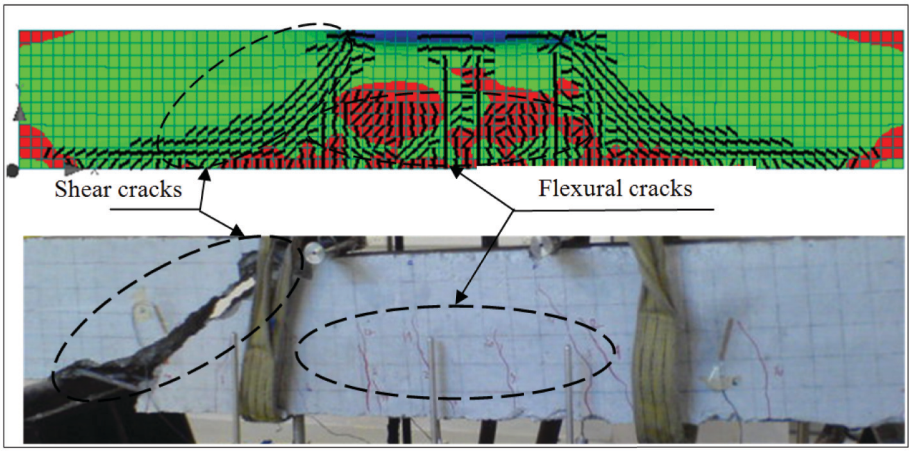

Figure 7. Crack patterns of control beam, CB1 and CB2

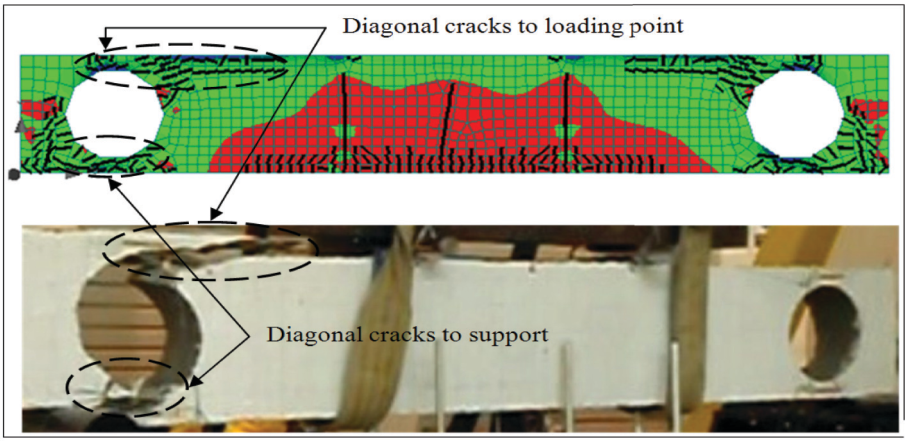

Figure 8 Crack patterns of beam C0S

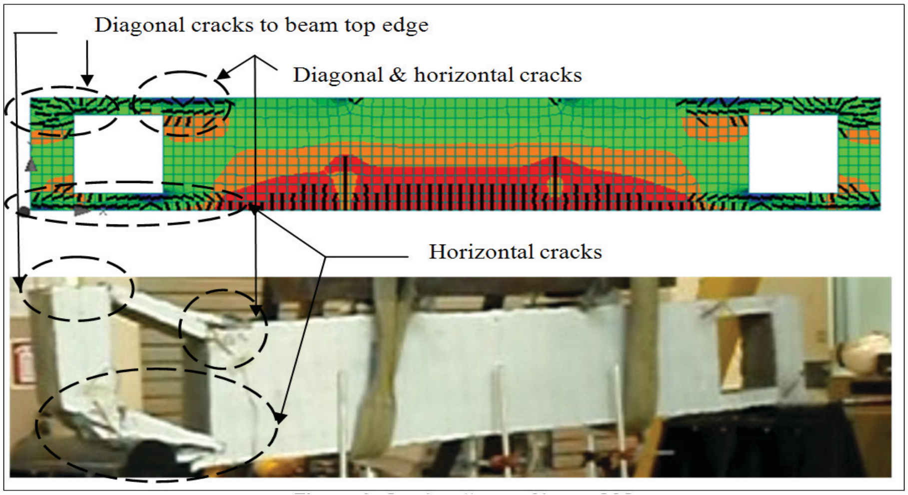

Figure 9. Crack patterns of beam S0S

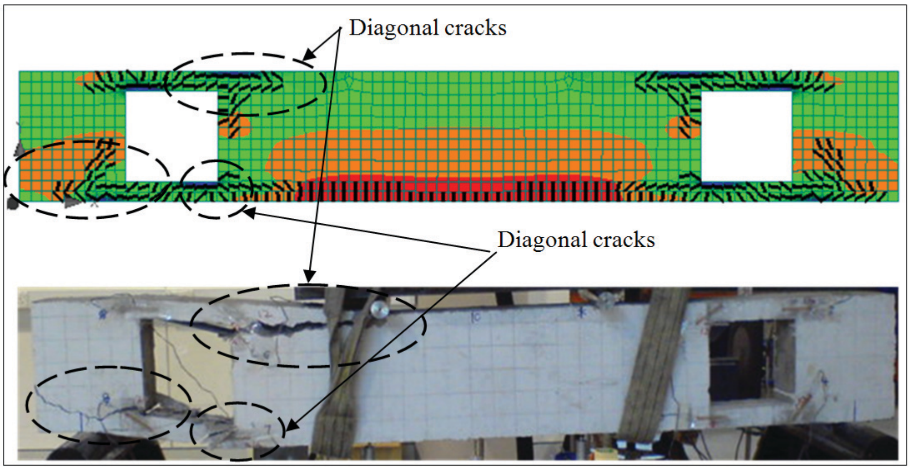

Figure 10. Crack patterns of beam S0.5dS

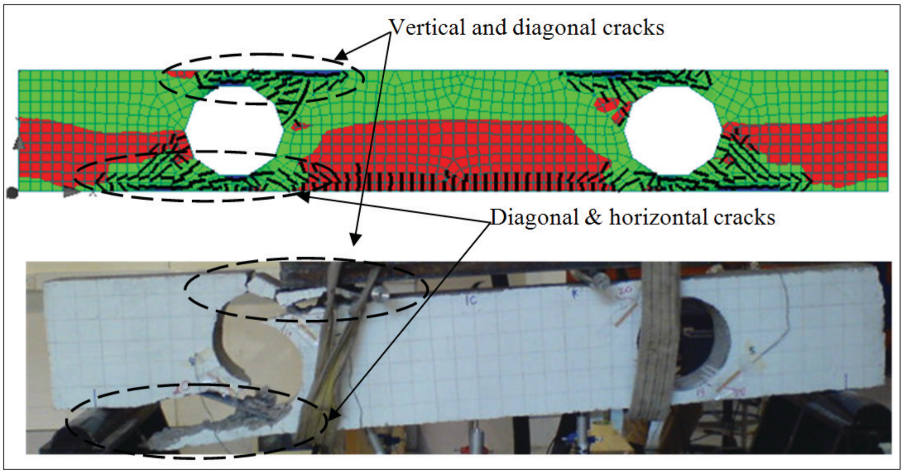

Figure 11. Crack patterns of beam CdS

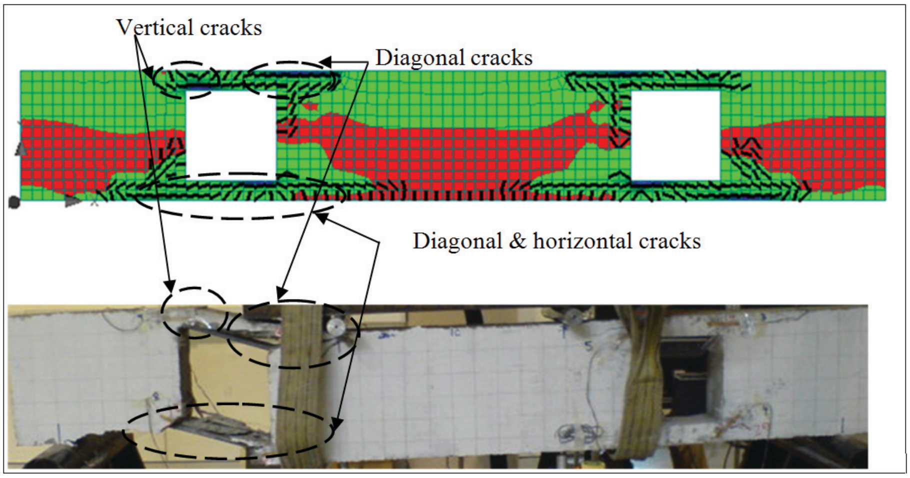

Figure 12. Crack patterns of beam SdS

g. Load-deflection Behaviour

A generalized load-deflection behaviour of experimental and FE results were compared as the results obtained for beams with circular and square openings at distances 0, 0.5d and d from the support did not show significant difference, about 5%. Load-deflection curves of beams with circular openings in shear (CS) obtained from FE analysis and experimental testing are compared in Figure 13. Similar trend of load-deflection curve was observed between the experimental and FE results. Likewise, for beams with square openings in the shear zone (SS), Figure 14 shows the comparison of load-deflection curves between FE analysis and experimental and a close agreement of load-deflection curve trend was obtained.

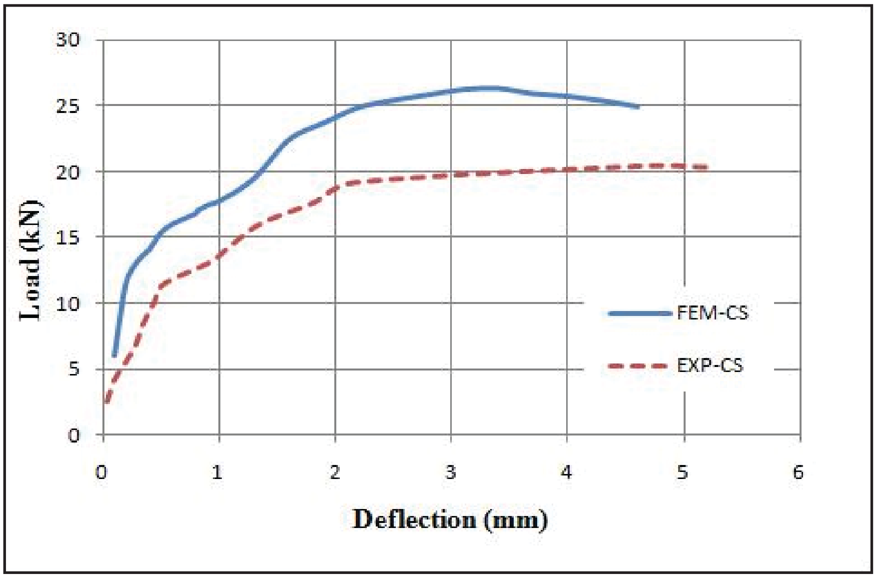

Figure 13. Comparison of load-deflection curves of beams with circular openings

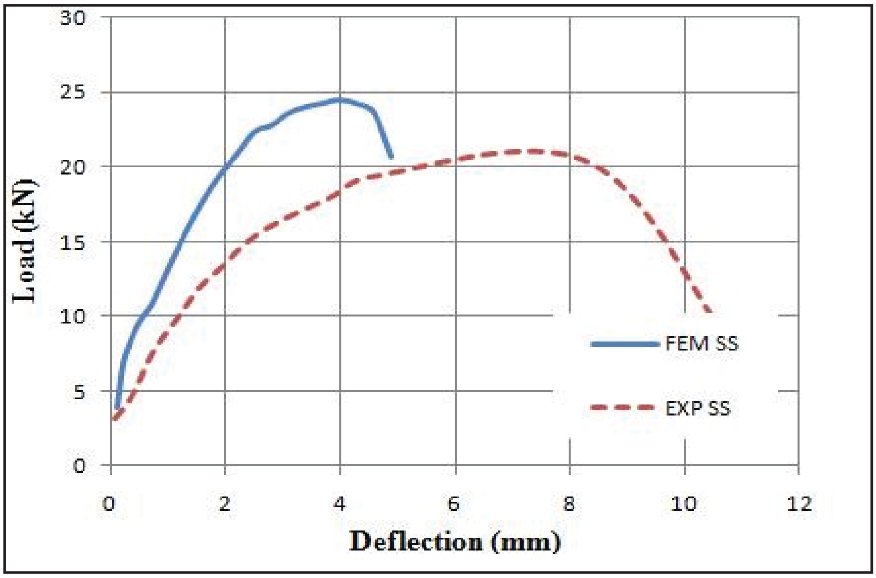

Figure 14. Comparison of load-deflection curves of beams with square openings

CONCLUSIONS

The results obtained lead to the following conclusions:

1. The presence of circular and square openings in the shear zone of RC beams had significantly reduced the beam capacity to approximately 70% - 80% of their original load-carrying capacity.

2. The provision of circular and square openings at distances 0, 0.5d and d from the beam support did not show significance difference, about 5%.

3. Comparison of crack patterns showed good agreement between the experimental and analyzed beams, about 50 – 60%.

4. Load-deflection curves comparison between the FE and experimental results showed comparable results, about 15 – 20% as almost similar trend of load-deflection curves were obtained.

5. FE analysis, ATENA can be used to analyze RC beams contained openings subjected to various size, shape and configuration in order to determine the effects of openings and the behaviour of beams due to openings.

6. In terms of shape, size and location, it is recommended to use openings with rounded edges i.e. circular shape with diameter or depth not greater than 40% of the overall beam depth to be provided at distance greater than d away from the support without jeopardizing much of the beam's carrying capacity.

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INFLUENCE OF WATER-TO-GEOPOLYMER SOLIDS RATIO AND CURING TIME ON THE PROPERTIES OF SELF-COMPACTING GEOPOLYMER CONCRETE

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Abstract
This paper describes an experimental study that measures the effects of water-to-geopolymer solids ratio on the workability and curing time on compressive strength of self-compacting geopolymer concrete (SCGC). SCGC were synthesized from low calcium fly ash, activated by combinations of sodium hydroxide and sodium silicate solutions, and by incorporation of superplasticizer for self compactability. The experiments were conducted by varying the amount of water and curing time. The water-to-geopolymer solids ratios were 0.31, 0.33, 0.35, and 0.39 and the curing times were 24, 48, 72 and 96 hrs. The effects of water-to-geopolymer solids ratio on workability properties such as filling ability, passing ability and resistance to segregation were assessed through Slump flow, V-funnel L-box and J-Ring test methods. Results showed that the workability was improved with the increase in water-to-geopolymer solids ratio; however, compressive strength was decreased as the ratio of water-to-geopolymer solids by mass increased. An increase in strength was also observed with the increase in curing time from 24 hr to 96 hrs. However, the increase in strength after 48 hrs was not significant. The compressive strength of 53.80 MPa was obtained for SCGC with water-to-geopolymer solids ratio of 0.33 and cured for 48 hrs.

Keywords: *Compressive Strength, Fly Ash, Self-Compacting Geopolymer Concrete, Workability*

INTRODUCTION

Concrete is one of the essential materials for infrastructure development due to its versatile application. Portland cement is the major constituent in concrete production but it is not an environmental friendly material. The production of one ton of Portland cement generates about one ton carbon dioxide (CO_2) to the atmosphere which constitutes 5% global CO_2 emission (Hardjito and Rangan, 2005). It is reported that the global production of Portland cement contributes about 1.35 billion tons greenhouse gas emissions annually (Malhotra, 2002; Hardjito et al. 2004a). Due to the manufacture of Portland cement, the CO_2 emission is likely to rise by about 50% from the current levels in 2020 (Naik, 2005). Therefore the ever-increasing environmental concerns on cement industry has made to look for alternative cement technologies and led to develop other materials that can replace cement function in concrete production. Huge efforts have been made to reduce the use of cement as a binder in concrete production. An effort in this regard is the development of geopolymer technology. Geopolymer concrete is one of the recently developed construction material as a substitute for conventional Portland cement concrete. GC is an inorganic polymeric concrete based on alumino-silicates and can be produced by synthesizing from materials of geological origin or from by-product materials, which are rich in silicon and aluminium with highly alkaline solution (Davidovits, 1999).

Earlier, most of the research study was focused on geopolymer synthesis from metakaolin (Davidovits, 1991; Cassagnabère et al. 2010; Rovnanik, 2010), however, since last decade; much research has been done on fly ash to investigate the possibilities of using coal fly ash as an aluminosilicate source material (van Jaarsveld et al. 2003). Due to increased use of pulverized coal, power generation plants are producing huge amount of fly ash, which is being treated as waste (RamaChandran, 1996). Fly ash is considered as the world's fifth largest raw material resource (Mukherjee et al. 2008). However, only a small portion of about 20–30% is presently used, where as the rest of it is being disposed of in landfills (Palomo et al. 1999; Roy, 1999; Duxson et al. 2007). If this waste is left un-utilized, it can pollute various phases of human environment like air, food, land, shelter and water (RamaChandran, 1996; Joshi and Lothia, 1997; Mehta, 2002; Malhotra, 2004). Researchers have been attempting to convert this waste into the wealth by exploring viable avenues for use of fly ash. Fly ash that is rich in silica and alumina is widely used as a source material in the production of geopolymer concrete (Hardjito and Rangan, 2005; Raijiwala and Patil, 2011). Many research studies (Palomo et al. 1999; Fernandez-Jimenez and Palomo, 2003; Hardjito et al. 2004b; Hardjito and Rangan, 2005; Ravindra and Somnath, 2009; Temuujin et al. 2009) have manifested the potential use of fly ash-based GC. For this reason, low-calcium fly ash has been chosen as a base material to synthesize geopolymer in order to better utilise this industrial waste.

Fresh concrete requires compaction efforts for placement and at the same time necessitates skilled labor for execution. This compaction is needed to minimize the air entrapped in fresh concrete so as to obtain homogeneous mix with no cavities or honey-comb (Neville, 2000). Adequate compaction is crucial to achieve good consolidation, uniform properties, strong bond with reinforcement (Dehn et al. 2000) better quality and durability (Ouchi et al. 2003), and enhanced interface between the aggregate and hardened paste (Ahmadi et al. 2007). Normal vibrated concrete may fail to reveal the required fresh and hardened properties while the concrete is being placed and compacted at construction site. The proposed solution for the problem is the employment of self-compacting concrete (SCC) (Okamura and Ouchi, 2003). SCC renovates the concreting execution by replacing the conventional method of vibration during compaction and makes the concrete to flow through sections with congested reinforcement under its own weight and filling the formwork without segregation of its constituent materials (EFNARC, 2005). The motive for the development of SCC in Japan in the late 1980s was because of emergence of heavily reinforced structure and shortage of skilled labor needed for vibration (Okamura and Ouchi, 2003). SCC, a relatively new concept and an emerging technique of concrete technology, has gradually gained popularity throughout the world because it leads to improved concrete quality, productivity and working conditions compared with normally vibrated concrete (Koehler, 2007; Kurniawan et al. 2008; Liu, 2010).

This paper presents the test results of SCGC in fresh and hardened states containing Class F fly ash and the main objective of this study was to assess the effects of water-to-geopolymer solids ratio and curing time on workability and compressive strength of SCGC. SCGC is an enhanced method of concreting operation that does not require compacting efforts and is made by complete elimination of ordinary Portland cement content.

EXPERIMENTAL DETAILS

Materials

The materials used in this study were fly ash, fine and coarse aggregate, alkaline solution, superplasticizer and water. The low-calcium fly ash obtained from local thermo electric power station was used as source material. American Standard Testing and Material (ASTM C618) classify fly ash into Class F and C depending mainly on CaO content. The fly ash used in the research was Class F with chemical composition, as analyzed by X-Ray Florescence (XRF) is given in Table 1.

Crushed coarse aggregate from granite stone was utilized with maximum size of 14 mm and specific gravity of 2.66 at SSD condition while the clean natural Malaysian sand was used as fine aggregate with maximum size of 5mm, fineness modulus of 2.76, and a specific gravity of 2.61.

In geopolymer synthesis, alkaline solution plays an important role in the dissolution of silica and alumina from the source material as well as in the catalysis of polymerization reaction (Khale and Chaudhary, 2007). In this experiment, a combination of sodium silicate and sodium hydroxide was chosen as the alkaline liquid. Na_2SiO_3 (Grade A53) used with a composition of 55.52% water, 29.75% SiO_2 and 14.73% Na_2O. NaOH (99% purity, in the form of pellets) was dissolved in tap water to prepare NaOH solution. The alkaline solution was prepared one hour prior to its use. The concentration NaOH solution was 12M and in order to make 1 Kg of solution, 36.1% of pellets were added to the water.

Super plasticizer (Sika Visco Crete-3430) was used to achiev the required workability for self compactability of SCGC and to contol segregation (stability) and homogeneity of the mix. The quantity of SP used was in accordance with European guidelines (EFNARC, 2002). The water used in the mix was potable water in accordance with BS EN 1008:1997.

Table 1. Chemical composition of fly ash

Compounds	**Mass (%)**	**Requirement as per BS EN 450-1:2005**
SiO_2	51.3	min. 25%
Al_2O_3	30.1	-
Fe_2O_3	4.57	-
SiO_2+ Al_2O_3+ Fe_2O_3	85.97	min. 70%
CaO	8.73	max. 10%
P_2O_5	1.6	-
SO_3	1.4	max. 3%
K_2O	1.56	-
TiO_2	0.698	-

Experimental Setup

The concrete mixing procedure uses dry mixing followed by wet mixing. The solid ingredients of SCGC, i.e. fly ash, fine and coarse aggregates, were dry mixed in the pan mixer for about 2.5 minutes. The liquid part of the mixture, i.e. the sodium silicate solution, the sodium hydroxide solution, extra water (other than the water used for the preparation of sodium hydroxide solution) and the super plasticizer were premixed thoroughly and then poured to the dry mixture. The wet mixing was continued for another 3 minutes.

The fresh concrete was then filled in 100mm x 100mm x 100mm steel moulds and allowed to fill all the spaces of the cube by its own self weight without vibrating for compaction. After casting the samples were kept in an oven at 70°C for different curing durations namely 24, 48, 72 and 96 hours. The specimens were then placed outside the room but protected from direct sunlight and rain and then the specimens were demoulded and tested for direct compression in a digital 2000KN Compression testing machine. The oven curing followed by ambient curing was adopted for this research to facilitate the geopolymerization reaction at elevated temperature and to enhance the mechanical development of the geopolymer material (Nuruddin et al. 2011). The compressive strength test results shown in Table 4 are the average strength of three concrete cube samples**.** The mix proportion designed for this research and details of these mixtures are shown in Table 2. The mass ratios of sodium silicate to sodium hydroxide solution and fine aggregate to fly ash were 2.5 and 2.125 for all mixture proportion respectively. Mix Series S_1, S_2, S_3, and S_4 were prepared to study the effects of water-to-geopolymer solids on workability and hardened compressive strength of SCGC. The water-to-geopolymer solid ratio (Hardjito et al. 2004a; Rangan, 2008) was calculated by dividing the total mass of water with the total mass of geopolymer solids. The total mass of water in the mix was the sum of the mass of water in the sodium silicate solution, the mass of water in the sodium hydroxide solution and the mass of the extra water. The total mass of geopolymer solids was the sum of the mass of fly ash, the mass of sodium hydroxide solids and the mass of sodium silicate solids (mass of Na_2O and SiO_2 in sodium silicate solution) (Hardjito et al. 2004a; Rangan, 2008). Mixes S_2, S_5, S_6, and S_7 were prepared to study the influence of curing time on compressive strength of SCGC. All the other test parameters were kept constant while the curing time varied from 24 to 96 hours.

Table 2. Mix Design Proportion

Mix Series	Fly Ash	Coarse Agg.	Fine Agg.	NaOH	Na-Silicate	Extra Water	Water-to-geopolymer solids ratio	Super Plasticizer	Curing	
									Time	Temp
	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3 (%)	Ratio	Kg/m^3(%)	hr.	^0C
S1	400	950	850	57	143	40 (10)	0.31	28 (7)	24	70
S2	400	950	850	57	143	48 (12)	0.33	28 (7)	24	70
S3	400	950	850	57	143	60 (15)	0.35	28 (7)	24	70
S4	400	950	850	57	143	80 (20)	0.39	28 (7)	24	70
S5	400	950	850	57	143	48 (12)	0.33	28 (7)	48	70
S6	400	950	850	57	143	48 (12)	0.33	28 (7)	72	70
S7	400	950	850	57	143	48 (12)	0.33	28 (7)	96	70

Test Procedure

A concrete mix should satisfy the three workability characteristics to be considered as SCC. Filling ability, passing ability and resistance to segregation are the three fresh concrete characteristics mandatory for SCC. So far, various test methods have been used in attempts to evaluate the three properties of SCC; however, no single standard method is able to determine all the relevant workability aspects at a time. Each mix design should be assessed by more than one test method for the different workability characteristics.

Filling ability and passing ability can be assessed by different test methods as shown in Table 3. Resistance to segregation can be assessed more or less in all the tests based on stability observation through visual inspection. The European Guidelines (EFNARC, 2002) has suggested different test methods to investigate an SCC mix. The test methods that are used to investigate the different properties and their acceptance values given by EFNARC are shown in Table 3. In this research, the test methods used to ascertain the self-compactibility were slump flow, T-50 slump flow, V-funnel, L-Box & J-Ring tests. All those tests are in accordance with EFNARC guidelines. The compressive strength test was performed in accordance with BS EN 12390-3:2002 using 2000 KN Digital Compressive Testing Machine in the Concrete Laboratory of Civil Engineering Department, Universiti Teknologi PETRONAS. A set of three cubes for each mix were tested for compressive strength measurement.

Table 3. Test Methods, Property and Recommended Values as per EFNARC Guidelines

S.No.	Methods	Property	Acceptance Values as per EFNARC Guide lines	
			Minimum	*Maximum*
1	Slump flow by Abrams cone	Filling Ability	650 mm	800 mm
2	T_{50cm} Slump flow	Filling Ability	2 s	5 s
3	V-funnel	Filling Ability	6 s	12 s
4	L-Box (H2/H1) Ratio	Passing Ability	0.8	1.0
5	J-Ring	Passing Ability	0 mm	10 mm

RESULTS AND DISCUSSION

The experimental results of various fresh properties tested by slump flow test (slump flow diameter and T_{50cm}), J-ring test (J-ring Blocking step (B_J)); L-box test (ratio of heights at the two edges of L-box (H_2/H_1)); V-funnel test (time taken by concrete to flow through V-funnel after 10s T_{10S}) for various mix compositions are given in Table 4. All the workability tests were performed as per the European guide lines (EFNARC, 2002). The test results of the quantitative analysis and visual observations showed that except for Mix series S_1, all the other concrete mix series had the desired fresh properties and were with in the EFNARC limits of SCC. The compressive strength test results were also recorded at different ages. The mean compressive strengths of the three test cubes for all mix composition are also presented in Table 4.

Table 4. Workability and Compressive strength Test Results

Mix Series	Workability Test Results					Compressive Strength Test Results			
	Slump Flow	*T $_{50 cm}$ Slump Flow*	*V-funnel Flow time*	*L-Box (H_2/H_1)*	*J-Ring Blocking Step, B_J*	*1-Day*	*3-Days*	*7-Days*	*28-Days*
	(mm)	(sec.)	(sec)	Ratio	(mm)	(MPa)	(MPa)	(MPa)	(MPa)
S1	630	6.5	12.5	0.82	12	53.46	54.33	55.08	56.29
S2	710	4.0	7.0	0.96	5	45.01	45.85	46.94	48.53
S3	770	3.0	6.0	1.0	3	37.31	37.90	38.56	39.78
S4	820	2.5	5.5	1.0	0	22.58	22.98	23.44	24.18
S5	710	4.0	7.0	0.96	5	51.03	51.98	52.26	53.80
S6	710	4.0	7.0	0.96	5	51.41	52.20	52.69	53.92
S7	710	4.0	7.0	0.96	5	51.68	52.33	52.72	53.99
Acceptance criteria for SCC as per EFNARC, 2002									
Min.	650	2	6	0.8	0				
Max.	800	5	12	1.0	10				

Water-to-Geopolymer Solids Ratio, by Mass

Mixes S_1, S_2, S_3 and S_4 were prepared to study the effects of water-to-Geopolymer solids ratio on the workability and compressive strength of self-compacting geopolymer Concrete. The four Mixes had identical mix composition, but different water-to-Geopolymer solids ratio of 0.31, 0.33, 0.35 and 0.39 respectively. The concentration of sodium hydroxide solution was held constant at 12M and super plastisizer dosage of 7% by mass for all mix.

From Figure 1, it can be seen that Mix S_2 with water-to-geopolymer solids ratio of 0.33 showed highest compressive strength as compared to Mix S_3 and S_4 that have water-to-geopolymer solids ratio of 0.35 and 0.39 respectively. The water that was used during the mixing process did not involve in the geopolymerization process and improved the workability of the mix by wetting the solid components of the mix. This water was expelled when the concrete cured at elevated temperature which could increase the porosity of concrete. The spaces previously occupied by water were remained as micropores or nanopores which could decrease the compressive strength and the overall performance of the concrete. The main function of water is to lubricate the surface of all the solid components in the mix and to decrease the friction at the aggregate-paste interface so that the workability can be improved and more over the water potentially in the mix plays a vital role in synthesis and acts as a medium for dissolution, condensation and polymerization of Al and Si precursors in to polymeric structures. A compressive strength of 56.52MPa was recorded for mix S_1 with water-to-geopolymer solids ratio of

0.31 at 28 days of age compared to all other mixes. However, water-to-geopolymer solids of 0.31 failed to give the required workability for SCGC due to insufficient of extra water which is 10% of fly ash with slump diameter of 630mm.

Mix S_2 with water-to-geopolymer solids ratio of 0.33 exhibited the required workability for self-comapactibility and resulted highest compressive strength compared to mixes S_3 and S_4 that have water to geopolymer solids ratio of 0.35 and 0.39 respectively. The experimental results as shown in Figure 1 demonstrate that the compressive strength decreases as the water-to-geopolymer solids ratio by mass increases. This phenomenon is similar to the effects of water to cement ratio on OPC based concrete, eventhough the mechanism of reaction in geopolymer binder synthesis is entirely different from that of cement binder synthesis.

It was observed that at higher water-to-geopolymer solids ratio, the compressive strength performance decreased due to the formation of micropores and micro-path that could lead to failure of concrete at lower stress level. This is due to the fact that specimen with higher porosity and crack led to decrease the compressive strength of the concrete when the water expelled and evaporated at high curing temperature that resulted pores inside the hardened concrete.

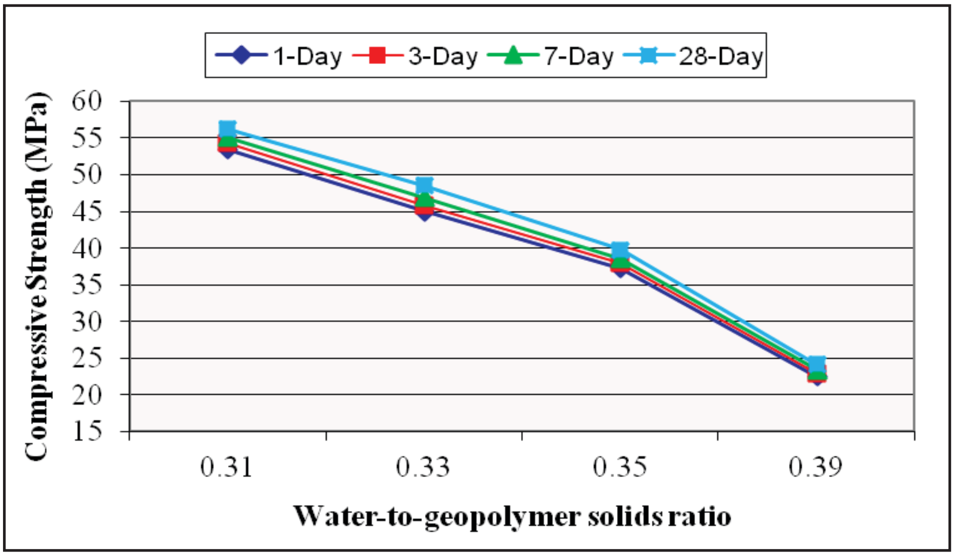

Figure 1. Effect of water to geopolymer solids ratio on compressive strength

Curing Time

Mixes S_2, S_5, S_6 and S_7 were prepared to study the influence of curing time on compressive strength of SCGC. All the other test parameters were held constant while different curing time used. The activator-to-fly ash ratio and water-to-geopolymer solids ratio were held constant at 0.5 and 0.33 respectively. It was observed that all the workability results of the four mixes were with in the range of EFNARC limits. The compressive strength development was assessed at 1^{st}, 3^{rd}, 7^{th}, and 28^{th} days of age and for all days of testing, 96hrs of curing time showed the highest compressive strength namely

51.68, 52.33, 52.72 and 53.99 MPa respectively. As it can be seen from the results (Table 4), the rate of strength gaining was very quick up to 48hrs of curing time which was about 45MPa at 1 day of testing. However, the increase in curing time beyond 48hrs did not show significant effect on compressive strength. Results indicate a small increase in compressive strength as the curing duration increased from 48hrs to 96hrs. This is because the condensation polymerization reaction that took place during the hardening process of the concrete has been totally completed within 48hrs of curing time and further curing was not required.

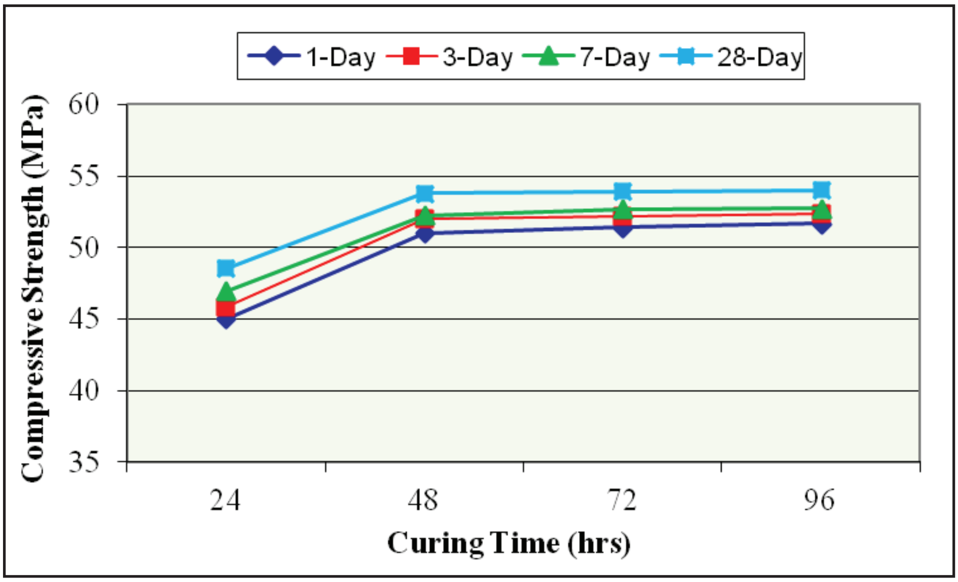

Figure 2. Effect of curing time on compressive strength

CONCLUSION

Based on the experimental work on workability and compressive strength development of SCGC, the following conclusions are drawn.

- It can be seen that except for Mix S_1, all the other concrete mixtures had good filling and passing ability and the workability results were with in the range of EFNARC limits of SCC. The workability study showed that as the amount of water-to-geopolymer solids ratio increased, the flowability of the mix increased.

- The compressive strength decreased as the ratio of water-to-geopolymer solids by mass increased.

- The compressive strength was highest when the specimens were cured for a period of 96 hours; however, the increase in strength after 48 hours was not significant.

- Water-to-geopolymer solids ratio of 0.33 and curing time of 48hrs were found to be the optimum.

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USE OF BACTERIAL SILICA PRECIPITATION TO ENHANCE STRENGTH AND PERMEABILITY OF CONCRETE

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Abstract
Microbial treatments has led to the improvement of concrete but as of yet, few studies showed tangible evidence of using bacteria-induced silica precipitation to improve the strength of concrete. Therefore, this study investigated the effect of using *Thermus Thermophilus* (TT) to enhance the strength and permeability of concrete. The existing silica precipitation by TT was examined under X-Ray Diffraction. TT, in five concentrations of 10^3, 10^4, 10^5, 10^6 and 10^7 cell/ml, were incorporated with the concrete mixes. The properties of the concrete were then assessed by compressive strength and Rapid Chloride Permeability Test (RCPT) after 3, 7, 28, 60 and 180 days. Meanwhile, carbonation test was conducted after 3, 7 and 28 days of exposure in a carbonation chamber. The 10^6 cell/ml of TT was found to be optimum concentration for compressive strength and RCPT; however, there was no optimum concentration which could enhance the carbonation resistance. The maximum improvement in compressive strength, RCPT and carbonation resistance corresponding to that without TT were 27.9 %, 30.6 % and 62.5 % respectively. The microstructure examinations, conducted using Scanning Electron Microscope (SEM), showed significant differences in the microstructure texture compared to the control group (without TT). The results showed that having TT in the concrete mixes was able to enhance the concrete compressive strength, permeability and carbonation resistance characteristic.

Keywords: *Silica Precipitation, Thermus Thermophilus, Concrete, RCPT, Carbonation*

INTRODUCTION

Concrete made of cement is a mechanically strong and durable construction material. Besides, it is known as "man-made geology" (Idorn, 2005) and also the second most utilised substance on the planet after water (Gambhir, 2006). However, concrete suffers from several drawbacks such as low tensile strength and is not totally impervious, which renders it susceptible to corrosion and chemical attack, causing millions of dollars to repair. Malaysia allocated RM 0.7 billion in their 9th Development Plan for maintenance and repair work (Ninth Malaysia Plan 2006 – 2010). Hence, to overcome these shortcomings, concrete is often incorporated with Supplementary Cemetitious Materials (SCM) and synthetic chemical admixtures to improve concrete properties. However, main drawback of using SCM and chemical additives is it cost. For instance, additional of RM 21.00 (USD 6.50) for each 1m^3 of concrete made of 350 kg cementitious material is incurred for every 1 % dosage of superplasticiser added into concrete mix. Besides that, overdosage of chemical admixture in the concrete mix can cause segregation and the chemical admixture of chloride salt based will impose adverse effect to the reinforced concrete in terms of corrosion of steel reinforcement.

Concerning the hazards of chemical use, a new innovation of concrete properties enhancement was established which is by placing single cell bacteria within the concrete matrix. This crossbreed between microbiology and engineering exploration is termed as

"Bioconcrete" (Ghosh et al. 2006). The concrete properties improvement which occurs from these single cell bacteria is produced by a biomineralisation process. This technique is sustainable as it is a natural process involving a living organism forming inorganic solids (Skinner et al. 2007) or mineral deposition. Ehrlich (1999) reported that bacteria are able to precipitate most of the elements listed in the periodic table such as carbon, nitrogen, oxygen, sulphur and phosphorus. Other common minerals precipitated by bacteria are calcium carbonate (calcite) and silica.

In the case of using bacteria, numerous studies showed that the bacteria possessing potentials to induce calcite precipitation which can enhance the concrete strength and properties are *S.Pasteurii*, *Bacillus megaterium*, *Bacillus pseudofirmus* and *Thermoanaerobactor thermohydrosulfuricus* (Chahal et al. 2012; Grabie et al. 2012; Wang et al. 2012). Besides, bacteria-induced calcite precipitations are also used for concrete surface treatment (Muynck et al. 2008; Wang et al. 2010; Arunachalam et al. 2010) and crack healing (Wiktor et al. 2011; Tittelboom et al. 2010). However, only few studies reported on bacteria-induced silica precipitation in enhancing concrete properties (Afifudin et al. 2010). Therefore, it is believed that bacteria-induced silica precipitation in improving concrete properties needs to be explored for further insight and evidence.

Given, this study conducted an experimental programme to monitor the effectiveness of bacteria-induced silica precipitation to strengthen concrete. In this study, thermomophilic bacteria, the *Thermus Thermophilus* (TT), were used to induce silica precipitation in the concrete matrix.

MATERIALS AND METHODS

There were four (4) steps performed in the methodology which are outlined as below.

Microorganism and Silica Incubations

As mentioned, Thermophilic bacteria, TT (ATCC 25104), were employed. This strain, TT (ATCC 25104), is known to have shown an ability to precipitate silica at high temperature in a slightly alkaline environment (Inagaki et al. 1998; Iwai et al. 2010). Castenholz TYE medium broth was used to enrich the incubation.

First a litre of Nitsch Trace Element was prepared. It consisted of 0.5 ml of H_2SO_4, 2.2 g of $MnSO_4$, 0.5 g of $ZnSO_4.7H_2O$, 0.5 g of H_3BO_3, 0.016 g of $CuSO_4.5H_2O$, 0.025 g of $Na_2MoO_4.2H_2O$, 0.046 g of $CoCl_2.6H_2O$ and 1 litre of distilled water.

Then a litre of Castenholz salts was prepared. It contained the following: 0.2 g of Nitrilotriacetic acid, 20 ml of 0.3 % $FeCl_3$ solution, 0.12 g of $CaSO_4.2H_2O$, 0.2 g of $MgSO_4.H_2O$, 0.016 g of NaCl, 0.21 g of KNO_3, 1.4 g of $NaNO_3$, 0.22 g of Na_2HPO_4, 1 litre of distilled water and 2 ml of Nitsch Trace Element.

After that a litre of 1 % TYE was prepared which contained 10 g of tryptone, 10 g of yeast extract and 1 litre of distilled water.

Lastly, this Nitsch trace element, Castenholz salts and 1% TYE were mixed to form the broth. In all, this broth contained five parts of Castenholz salts which were mixed with one part of 1 % TYE solution and four parts of distilled water.

The next step was to place the bacteria, TT, in the broth of 400 ppm of $Na_2SiO_3.5H_2O$. This mixture was gently jiggled at 200 rpm at a temperature of 70 ^oC for 48 hours. This procedure was to incubate the TT to induce the silica precipitation. The silica precipitation was then examined under X-Ray Diffraction (XRD) analysis as described in the following section. The cell concentration of TT was determined by a Hemocytometer. At this stage, the TT was also ready to be placed in the concrete constituents.

X-Ray Diffraction (XRD) Analysis

After 48 hours of incubation, the TT in the broth was collected by centrifuging the Castenholz TYE medium broth mixture to separate the bacteria and broth and form into pellet. The pelleted bacteria then were analysed to show the existence of silica. Meanwhile, another pelleted cell was reacting with aqueous calcium hydroxide as a simulation of the silica precipitation within the concrete environment. This analysis was conducted using Rigaku D/Max 2000 X-Ray diffractometer. The XRD patterns were then accomplished with a sweep speed of 2^o /min from 3^o to 65^o. The 30mA of current and 40kW of voltage was used to generate the X-Ray tube.

Concrete Proportion and Test Specimens

The concrete, cast with water cement ratio of 0.63, consisted of the Ordinary Portland Cement conforming BS 12, coarse and fine aggregate (complying to the BS 882) and distilled water (Table 1).

Table 1. Proportion of Water, Cement and Sand

Water	Cement	Sand	Aggregate
205	325	865	975

Then, six (6) series of concentrations of TT cell were adopted. These six concentrations were 10^3, 10^4, 10^5, 10^6 and 10^7 cell/ml. A control, containing no TT, was also cast.

After 24 hours cast, the moulded concrete specimens were demoulded and cured in distilled water until the day of testing. The distilled water was used to preserve the TT from any contamination. The concrete specimens were then cast into two shapes which were cubes and cylinders. The cubes were of 100 mm x 100 mm x 100 mm for compressive strength and carbonation resistance test. The cylinders 100 mm diameter x 200 mm height was also cast for Rapid Chloride Permeability test (RCPT).

Compression Test

The compressive strength of the concrete specimens with and without TT was tested. The compressive strength was tested at the age of 3, 7, 28, 60 and 180 days, and the compressive strength test performed in accordance with BS EN 12390-3:2000.

Rapid Chloride Permeability Test (RCPT)

The concrete cylinder of 200 mm long (height) was cut into three slices with 50 mm thick. Twenty five (25) mm height of top and bottom of the cylinder were discarded. Sealant were applied all over the side surface of the concrete slice and allowed to dry. The concrete slice proceed with 1 hour air drying, 3 hours vacuum, 1 hour additional vacuum under de-aerated water and followed by 18 hours of immersion in water prior to the testing. The RCPT was tested at the age of 7, 28, 60 and 180 days and the RCPT conducted by procedures stipulated by ASTM C 1202:2010.

Carbonation Test

The concrete specimens sized 100 mm x 100 mm x 100 mm made of different cell concentrations of TT and without TT at the age of 3, 7 and 28 days were exposed to carbon dioxide in the carbonation chamber. The concentration of carbon dioxide were fixed at 10 % and exposed for two (2) weeks which is equivalent to 10 years. The carbonation test was performed following the procedures described in *RILEM* CPC-18 (1988). After two weeks exposure, the concrete was broken into two and sprayed with 1 % phenolphthalein. The pink colour indicates no carbonation while colourless showing the presence of carbonation.

Microstructure Examination

Concrete chips were prepared from the broken specimen of 1 day age. The chips were directly examined under scanning electron microscope (SEM). Without prior coating, the concrete chips were examined under low vacuum SEM (Quanta 200 FEI). For comparison, samples were also coated and examined under high vacuum SEM (Philips SL 40).

RESULTS AND DISCUSSIONS

XRD Analysis of TT Pelleted Cell

Figure 1a illustrates the XRD analysis of TT incubated in a Castenholz TYE medium containing silicic acid for two (2) days but there was no peak of spectra (there is no crystalline silica) observed. Contradicting to Figure 1a, Figure 1b represents the XRD analysis of calcium hydroxide simulation by reacting TT incubated in Castenholz TYE medium containing silicic acid within saturated calcium hydroxide solution. There were numerous peaks of spectra indicating calcium silicate observed. This XRD analysis highly showed that these TT were able to precipitate silica. These findings also reconfirmed that TT is able to precipitate silica, which was also reported by Inagaki *et al.* (1998) and Iwai *et al.* (2010).

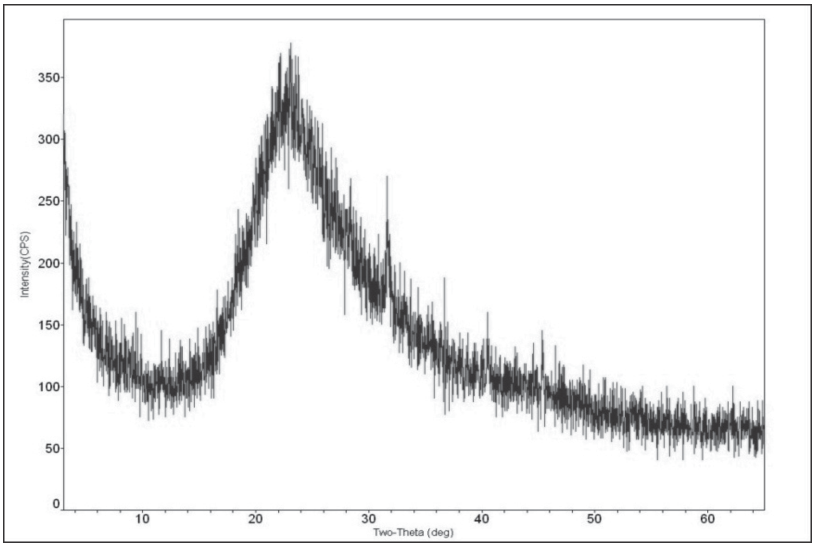

Figure 1a. XRD Analysis of *Thermus thermophilus* (TT) Incubated with Silicic Acids

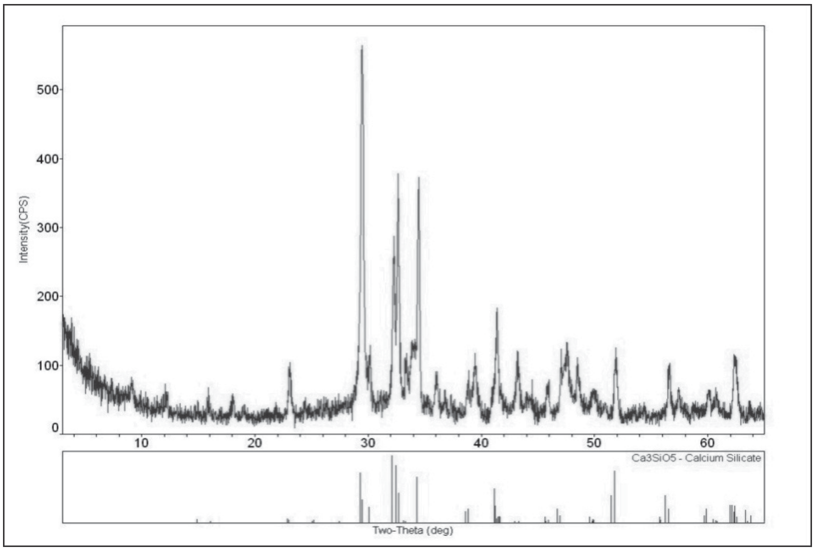

Figure 1b. XRD Analysis of Silica Precipitation Induced by *Thermus thermophilus* (TT) by Reacting with Calcium Hydroxide

Compressive Strength of Concrete Incorporated with TT

Figure 2 summarises the compressive strength of 3, 7, 28, 60 and 180 days of concrete cube specimens containing different cell concentrations with and without TT. Figure 2 shows an improvement for all concrete specimens as a result of incorporating TT. The optimum cell concentration of TT that enhanced the concrete most was 10^6 cell/ml. The improvement made was about 12 %, 12 %, 22 %, 28 % and 28 % respective to 3, 7, 28, 60 and 180 days of age as compared to those without TT (the control group). The observed improvement in the compressive strength with increasing cell concentration could be attributed to the deposition of silica within the cement concrete matrix induced from the *Thermus thermophilus*.

Similarly, Iwai *et al.*(2010) also found that TT has the capacity to form silicious deposits when the former was incubated in supersaturated silica in an alkaline solution. Hence, it shows that a similar phenomenon occurred when TT was included in the concrete matrix in an alkaline environment which has not been reported in the field's literature. Here, the cell concentration beyond 10^6 cell/ml led to significant reduction in compressive strength of the concrete. Higher cell concentration of bacteria will contribute to more dead cells that constitutes organic fibre which is finally disintegrate, making porous matrix and resulting in the reduction of compressive strength of the concrete (Ramachandran et al. 2001).

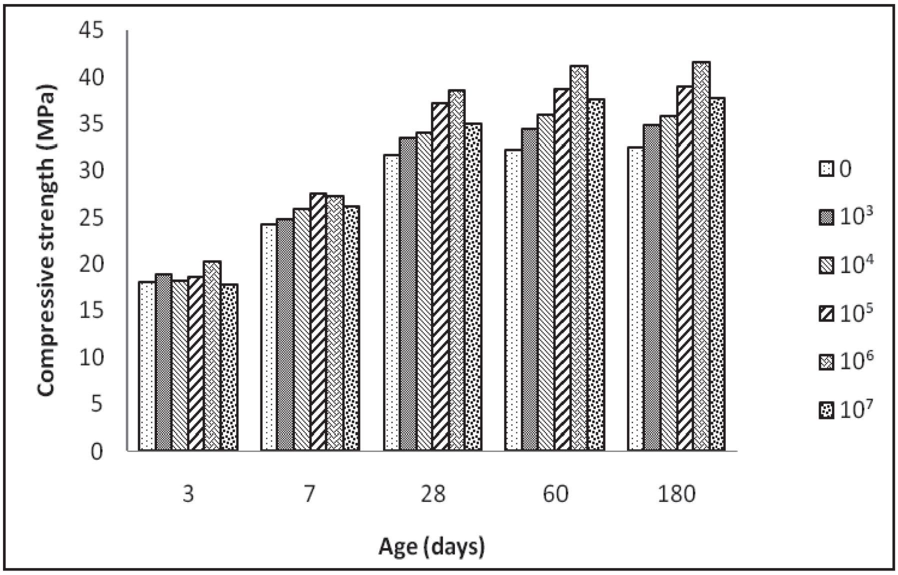

Figure 2. Compressive Strength of Concrete containing different concentration of TT cell

Permeability of Concrete with TT

Figure 3 graphically draws the charge passed (in Coulomb) of six series concrete without and with TT. The results of the charge passed through concrete specimens were taken up to 180 days of age. Figure 3 shows the coulomb charge of the concrete specimens without bacteria (control), attained at 6 hours, was higher than those concrete with bacteria. The charge, attained after 6 hours of 60 V, reduced as the TT cell was poured into the concrete mixes. The reduction of coulomb passed inferred the refinement of pore size within the cement matrix.

The highest concentration of TT that produced the most enhanced effect was 10^6 cell/ml. The enhancement made were 28 %, 29 %, 31 % and 30 % for 7, 28, 60 and 180 days respectively. The observed reduction in permeability could also be attributed to the silica precipitation from the TT as discussed earlier. The formers were derived and plugged into concrete pores and refuse the chloride ion to passing through the pores. This is a display of improved concrete permeability due to the presence of TT cell into the concrete mix.

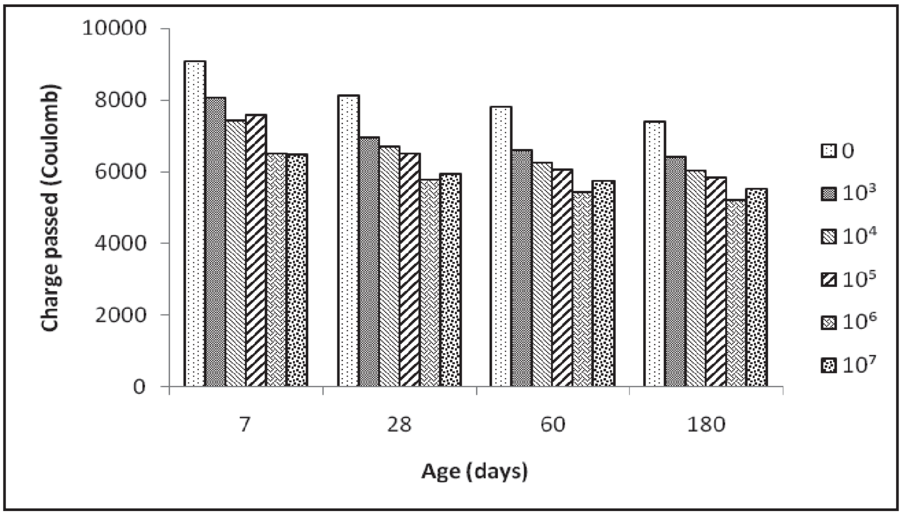

Figure 3. The Effect of TT on Rapid Chloride Permeability

Carbonation Effect on Concrete with TT

It appears that the concrete specimens containing the bacteria seemed to experience less carbonation ingress compared to those without the bacteria. It is suggested that there was a development of a denser pore structure due to the secondary hydration result of silica precipitation induced by the TT. No optimum concentration was noticed in the trend of improvement towards carbonation resistance behaviour of the concrete having the TT. The continuous improvement was observed even the cell concentration increased to 10^7 cell/ml and it was expected that it would further improve the carbonation resistance behaviour if the concentration of the cell added into the concrete mix beyond 10^7 cell/ml. The enhanced effect of the concrete containing TT to carbonation resistance was about 61.5 %, 60 % and 62.5 % when measured at 3, 7 and 28 days of age. It is appeared that the precipitated silica had filled up the concrete pores and resisted the carbon dioxide from penetrating the concrete mixture.

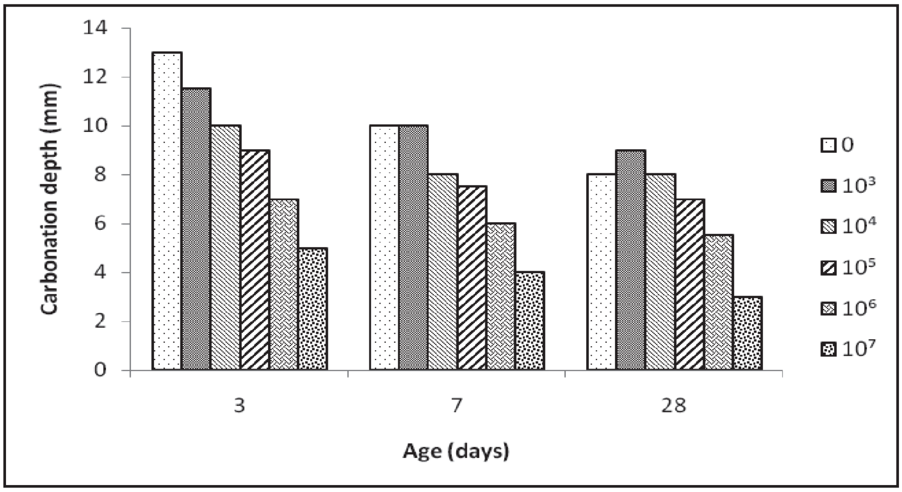

Figure 4. Carbonation of Concrete with and without TT

Microstructure Examination

Figure 5a portrays the control concrete morphology (without the bacteria) at 10000x magnification. No prominent deposition was noticed in this control sample. Figure 5a shows there is no signature of conspicuous crystal growth in the concrete without the bacteria. However, the micrograph shows the presence of an extra of fibre shaped deposition suggested that the silica deposition was observed within the matrix of the concrete with the bacteria (Figure 5b). These extra fibres encouraged the modification, connected the pore size distribution which leads to the improvement of the concrete matrices. Upon comparison, the micrographs shown in Figure 5a and 5b revealed that there was a contrast texture between the concrete with and without the bacteria. This substantiates the findings that the silica precipitation (fibre shape) has improved the concrete properties by 25 %.

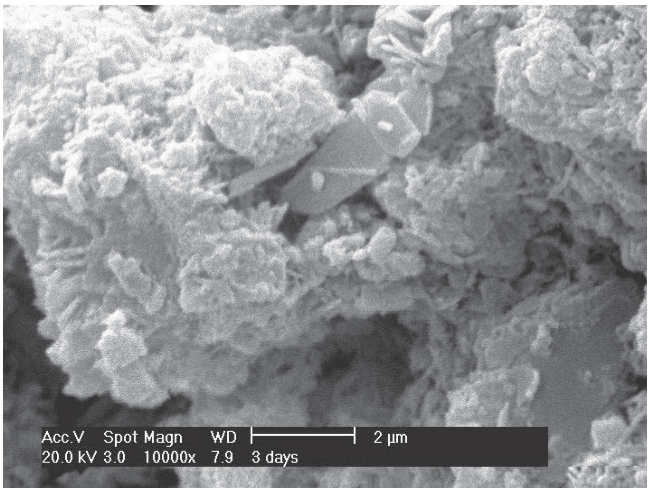

Figure 5a. SEM Micrograph of Concrete without Bacteria

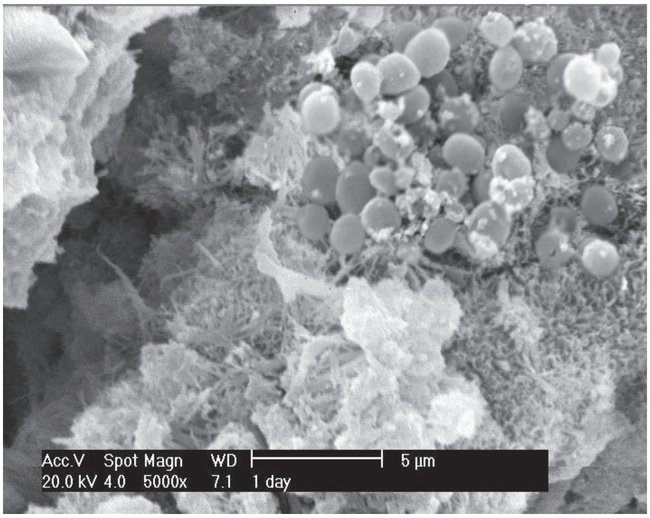

Figure 5b. SEM Micrograph of Concrete with TT

CONCLUSIONS

From these findings**, t**his experiment showed that TT was able to precipitate silica and produce calcium silicate when reacting with calcium hydroxide solution. The blend of TT improved the concrete compressive strength and RCPT by 22% and 29 % respectively corresponding to those without TT. Meanwhile, the maximum improvement in concrete carbonation was about 62.5 %. The optimum concentration of TT to be incorporated into concrete mix for most enhanced compressive strength and RCPT was 10^6 cell/ml. However, there was no optimum concentration observed in the concrete towards carbonation resistance since 10^7 cell/ml was the maximum cell concentration. Microstructure examination revealed the growth of extra fibre which suggested silica deposition within the concrete matrix when TT was included in concrete matrix. This suggested that the existence of TT had modified the concrete matrix which in turn had strengthened the concrete. In sum, the silica precipitation is promising in substituting supplementary cementitious materials to enhance concrete properties. Concerning possible economic benefits, strengthening the concrete would substantially benefit the construction industry as effort, fund and work of repair of buildings would be reduced, which in turn would benefit the nation's economy.

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RELATIONSHIPS AMONG SUPPLY CHAIN PARTICIPANTS IN MALAYSIA

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Abstract
Supply Chain Management (SCM) is a concept that is used right across the world in many industries. SCM involves the management of relationships with all parties including client, contractor and sub-contractor in order to achieve the specific needs of a client's objectives in a project. Construction organisations that have an effective Supply Chain Management in place can expect reduced project costs and increased reliability and speed of facility construction. Several studies have been conducted over the past decade in establishing a preferred procurement method/process used on construction projects and defining the relationships that exist between each party involved in these projects, however, companies differ amongst one another which has resulted in an array of different responses. A short study was conducted using semi-structured interviews with industry representatives last year to investigate the extent of supply chain relationship and integration within Malaysian construction organisations. The basic aim of the study was to test whether the relationships are affected by changes to the way in which a project is delivered, and this was done by verifying the hypotheses that varying procurement methods impact or alter subcontractor - contractor relationships; disputes are resolved without arbitration when differences occur and has affects on future working relationships; and duration of a project potentially allows for a closer bond between parties. The paper concludes that contracting structures and styles significantly affect the relationships between organisations and that procurement techniques and contractor selection is an imperative process in keeping strong relationships for the duration of the project or contract works. This paper also found that the main difference between conventional procurement methods and SCM lay in the emphasis that is placed on incorporating relationships and collaboration between all project parties. The study also revealed that in order to implement any SCM models, the clients' role is crucial because it needs to be initiated by the client predominately in public projects. The study will help the industry participants in Malaysia to understand the importance of using SCM approach on their projects resulting into building long-term relationship among parties involved.

Keywords: *Supply Chain Management, Project Procurement, Construction Industry Malaysia*

INTRODUCTION

Successful construction relies on the contractor effectively bringing together a diverse range of trades and suppliers. The relationship formed from this task can sometimes be described as a temporary organisation in itself. Within this organisation, diverse and complex relationships are formed and integrated into a web of contractual agreements. Due to this bond, it is often very difficult to maintain a relationship without misunderstanding or miscommunication. Often relationships dissolve due to companies protecting their stake in this contractual web.

This paper discusses how relationships are maintained using real-life case studies within Malaysian Construction Industry. It examines the implementation of supply chain management and how it can be used to identify and resolve problems, create better relationships and the understanding between trades and suppliers of services for construction projects, depending on the specific project delivery method used.

The basic aim of the study was to test whether the relationships are affected by changes to the way in which a project is delivered, and this was carried out by verifying the below mentioned hypotheses:

1) Varying procurement methods impact or alter subcontractor - contractor relationships;

2) Disputes are resolved without arbitration when differences occur and has affects on future working relationships; and

3) Duration of a project potentially allows for a closer bond between parties.

The research of this topic was prompted because the practice of maintaining long-term relationships is not generally considered a priority in Malaysia. Hence, this resulted into a short research project utilising a questionnaire survey method for data collection for the Malaysian building contractors, consultants, subcontractors and public sector clients in the Kuala Lumpur and Penang cities.

Karim et al. (2006) explain in Australian context that most of the work is done by subcontractors as the main contractors rely on a large number of outsourcing of work. As much as 90 per cent of the construction work is carried out by a variety of subcontractors while the main contractor tends to focus on management and coordination. Furthermore, a large number of the subcontracting firms are small because the contractors tend to employ pyramid subcontracting by using multiple tiers of subcontractors. In Australia, for example, 94 per cent of construction trades employ fewer than five people, and less than 1 per cent employs more than 20 people (Commonwealth of Australia, 1999). As a consequence, most of these firms simply do not have the resources to adopt modern principles of quality management although their smaller size does provide them the flexibility to be able to adopt innovative methods. Further complications arise because the subcontractors are contractually obligated to the main contractor, whereas the construction process flows from one subcontractor to the other, as shown in Figure 1.

This study shows that construction industry in Malaysia is very similar to the one described above. Furthermore, the main contractor has the final responsibility to deliver quality at a competitive price, make it essential for the main contractor to manage the supply chain effectively. Partnering approaches such as joint venturing have been introduced to overcome these problems. Although the construction industries implementation of these concepts has been far from rapid and is still in its early stages in Malaysia.

The industry is made up of a complex set of relationships; large enterprises take on the role of project managers usually contracting or subcontracting to specialised and generally smaller enterprises for particular parts of the job. Each job brings with it a new configuration of relationships within the work site. In addition to this, the workplace itself is physically in a constant state of change. The changing workplace relationships and the pressure to review and update old work practices inevitably create new configurations of problems (Crowley et al., 2000).

SUPPLY CHAIN MANAGEMENT

Supply Chain Management (SCM) has emerged as one of the primary factors in determining competitiveness in today's construction industry. In recent times the construction industry has realised that competition is no longer dependent on the capabilities of individual organisations but on the ability of tightly integrated supply chains. Traditionally, clients/owners and contractors have generally seen each other as adversaries and in order to improve construction efficiencies, the need to develop relationships throughout the entire supply chain was evident (Khalfan and Maqsood, 2012).

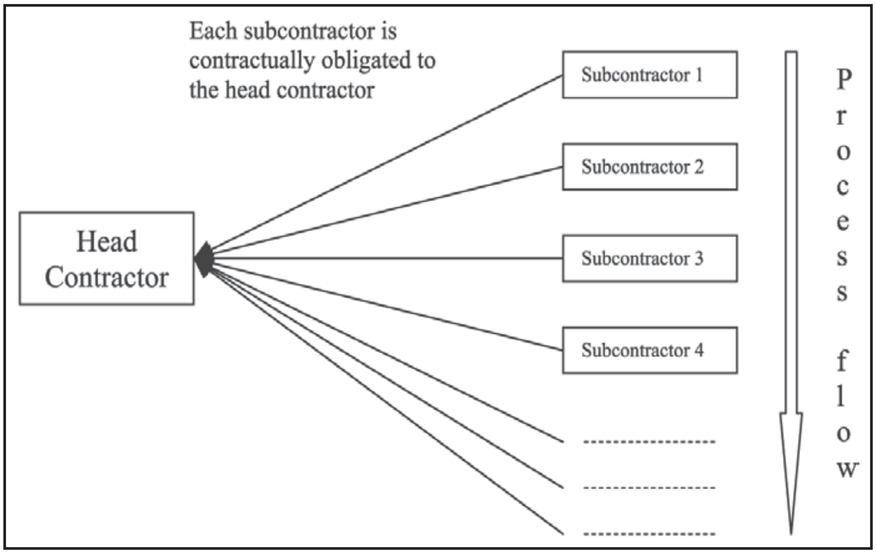

Figure 1. Construction Process Flow

Perspectives of Supply Chain Management

It was suggested that the construction industry had been slow in implementing or could be reluctant to exploit the concept of SCM (Love et al., 2000 a,b), in comparison to retail and manufacturing where they had been quick to realise that SCM has the benefits of maximising the business process in terms of efficiency and effectiveness through internal and external organisational relationships. Ten years on, the above is true now in Malaysian construction industry. In today's competitive construction industry, it is important that construction companies offer the 'best value' to their client and therefore, the need may arise to seek alternative suppliers and or subcontractors to perform the works.

To better understand the concept of SCM, Vollman et al. (1997) has suggested that construction SCM should be seen as an integrated framework to assist in managing and co-ordinating the chain from a project's conceptual idea to completion to its intended client. While there are many individuals in the construction industry that may claim to fully define SCM, there was no such definition that exists specifically related to construction until Barker et al (2000) stated that SCM can be considered as *"the network of facilities and activities that provide customer an economic value to the functions of design development, contract management, service and material procurement, materials manufacture and delivery, and facilities management"*.

The construction industry organisations have consequently realised that the utilisation of SCM in their organisation could be of great benefit. Barker et al (2000) suggest that if the construction industry is to move from an adversarial environment to one that is founded on collaboration then it should openly embrace SCM. It has been noted that SCM is a growing protocol as such that needs to be implemented into any project to ensure that the project is delivered within time and on budget and to assist in the relationship characteristics of the parties involved (Noor et al. 2013).

Procurement Selection

In determining the appropriate procurement method there is no 'better' method than others for an individual project, however no particular procurement method is likely to be better than others for any project (Love et al, 2000a). According to Gordon (1994), selecting an appropriate procurement method could reduce construction project costs by an average of 5%. However, while the selection of the procurement method may have this effect, there are many subjective areas that need to be considered before making this judgement. Consequently, the selection of the 'better' procurement option is impracticable, as client and project characteristics differ constantly and the needs of each projects' characteristics will not be the same.

Links between Supply Chain Participants

Supply chain refers to the links between a client and main contractor or main contractor and subcontractor, which can be perceived as a buyer-supplier type relationship. The parties involved within a project are all involved in the supply of resources for that project, hence the supply chain. Understanding the role of SCM can be a hard process, however there are different areas within a supply chain process that distinguishes different levels of the chain. Giunipero and Brand (1996) define several levels of SCM including initial partnership (e.g. building good relations with suppliers and distributors), logistics management (e.g. implementing and controlling the flow involving all actors in the chain), and "genuine SCM" (e.g. continuous improvement of all aspects of the entire chain).

Influencing Factors

There are many influencing factors involved in construction when supply chain management is used and primary issues that often arise is between the client and main contractor. It is a complex decision to determine what type of procurement method would best deliver a project for differentiating clients. Every party involved in the relationship circle must be confident about what everyone's needs and wants are and most importantly to evaluate the client's criteria and objectives. SCM focuses on delivering a project by integrating all involved parties whereas Rowlinson (1999) states that conventional procurement selection criteria are based around the concepts of time, cost and quality.

Usually clients with many years experience within the construction industry are able to select a procurement approach that has worked for them before, or one that they know will be suited a particular project due to previous knowledge and experience in similar projects. However, clients with less experience in the developing world including Malaysia, need to seek advice from professionals who can set them in the right direction and assist them through the process and selecting the right delivery method.

The process in selecting the correct procurement method involves more than just establishing a contractual relationship between certain parties involved in a project, it involves a unique set of social relationships, which forms certain advantages within an alliance of competing interest groups. Conflicting goals and objectives of power within a project team are often the principal conditions for triggering adversarial relations (Love *et al*., 2004).

Supply Chain Management Implementation

SCM implementation varies according to the type of project and procurement process at hand. However, regardless of the difficulties associated with the procurement process selection, there are several methodologies, tools and models that have been developed and introduced into the construction industry to implement SCM and selecting an accurate procurement process. These approaches are becoming multifaceted and the range in selecting the correct procurement system is so great that it is actually becoming difficult to confidently choose a procurement method. For the purpose of overcoming this complexity, selection systems have been designed to be carried out in a closely controlled way within the framework of the clients overall project objectives (RICS, 2000).

Supply Chain Integration

In order to stay competitive in the construction industry, innovation is the main characteristic that the organisation must embrace. SCM can be seen as an example of evolutionary and cumulative innovation, which is often described as originating from internal programmes aimed at improving overall effectiveness (New and Ramsay, 1997). Overall effectiveness is the key ingredient to managing the project to be delivered on time and within budget.

Greater effectiveness in a construction organisation not only allows smooth handover of projects but also allow the organisation to deliver a quality product reflecting on the organisations mission and goals. Furthermore, it can be seen as a set of practices aimed at managing and co-ordinating the whole supply chain from raw material suppliers to end customers (Vollman et al., 1997) and which develop greater synergy through collaboration along the whole supply chain. Thus, the suppliers working with close relationship with the purchaser to maintain an effective work ethic in achieving the same objectives and form a sense of trust to repeat business in the future.

The significant emphasis on co-ordination and integration is strongly linked to the development of more effective and longer-term relationships between buyers and suppliers

(Spekman et al., 1998; Koskela, 1999) allowing these new types of relationships to utilise resources more efficiently through the whole supply chain. Thus, closer relationships will, as mentioned build the trust and ensure that further works can be negotiated in terms of price and delivery times. In addition effective and efficient characteristics of the construction organisation can pass the savings on to the client through the supply chain, having achieved this relationship between the above-mentioned parties.

Although the integration of SCM can be a long and complex process it forms an imperative procedure in the way the organisation handles its resources to minimise waste and better performance standards in delivering the overall project. SCM can also be seen closely dependent upon the ability to create, manage and reshape relationships between individuals, organisations and networks within the supply chain (Spekman et al., 1998). This procedure demonstrates the shared responsibilities required from internal structures to external linkages and organisation processes to successfully deliver the required project.

Subcontractor Relationships

Disputes often arise due to poor planning and lack of coordination between the clients, contractors and subcontracts. To minimise disputes, the project team will need to ensure that all systems are put into place to overcome project deviation causing disputes to avoid delays and disruptions. Having said this, it is imperative that when disputes arise they are dealt with efficiently and effectively so they are minimised to avoid further costs. Thus if they are not attended to they could 'boil over' and mediation may be involved. In deriving the most productive remedies to reduce disagreements and to ensure the constant flow of works, traditional approach to project planning needs to be re-examined (Koskela, 1999). By re-examining the current practice of project planning, better two-way communication must be committed to, as well as pre-existent relationships.

If main contractors have previous relations with subcontractors and can manage to work closely with them then it enables the contractor to determine the resources required and the level of communication necessary in effectively portraying what need to be done and what is expected of the subcontractor (Ballard, 2000). Alternatively, if what should be done is rendered, then the site personnel may become accustomed to this type of relationship and automatically keep asking for direction in contract works. This can cause uncertainty and lack of production and can cause delay in works due to lack of initiation and bearing on behalf of the subcontractor.

The figure below (Figure 2) outlines the main elements of a typical construction supply network, with the main contractor at the hub of the network. The network primarily focuses on the supply relationship between main contractor and the material suppliers and the production subcontractors.

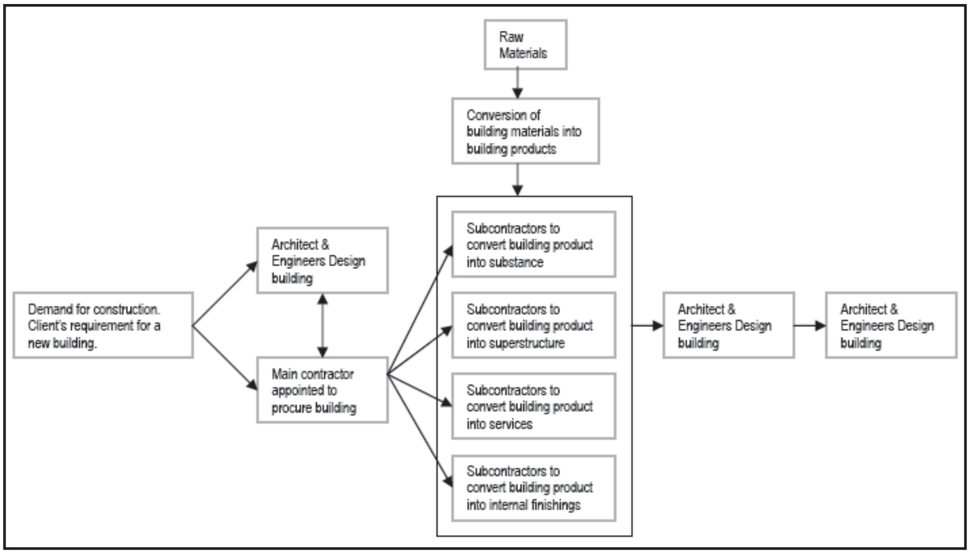

Figure 2. A typical Construction Supply Network

The above presented literature review has briefly demonstrated that there is significant awareness of the importance of SCM and its main objectives to the construction industry. SCM may help construction overcome the 'fragmentation and adversarial culture, improve its relationships and better integrate its process' (Saad et al, 2002). Additionally, the construction industry has been comparatively slow to take off of this kind of management approach; this could be mainly due to an already well-organised and documented construction industry. Reviewing the results of the case study Mahbashi (2007) concludes that contractors are more oriented towards clients rather than their sub contractors and suppliers in the supply chain and would have more arrangements with their clients. It also argues that contractors have tendencies to pay more attention to clients who provide their workload.

However, SCM integration into an unfamiliar construction organisation without prior management systems, it could be difficult to adapt due to its diversity and understanding. This was found as Managers were hesitant or unwilling to rationalise their supplier and customer bases, to establish a clear common purpose and exchange information openly, which can be seen as reluctance to adopt Supply Chain Management relationships into their construction organisation. Aforementioned, another problem with implementing SCM within the construction industry at present is associated with an inappropriate established construction culture and the unique features of the organizational environment. Therefore, the objective of SCM is to create the most value, not only for the client and contractor but also for the whole supply chain network involved.

METHODOLOGY

In order to achieve the objective of this research, i.e. to determine whether varying procurement methods impact or alter subcontractor - contractor relationships, we set out semi-structured interview with industry participants to establish whether the way in which a project is delivered reflects on the relationship between parties and how disputes are resolved when differences occur and in turn how that affects future working relationships.

The industry participants were identified by the existing contacts of the first author in Malaysia and interviews were conducted in limited time available to the first author during his short visits to Kuala Lumpur and Penang cities. A generic questionnaire comprising of 13 qualitative questions was prepared by first author and face to face semi structured interviews were carried out with all the involved participants at their premises individually. The main purpose of semi structured interviews was to provide insight into the different relationships that exist between contractual parties amongst different project delivery methods. Qualitative data was collected through these semi-structure interviews and helped to understand the given research problem from the perspectives of the local industry participants. The design of the questionnaire was carefully composed to address the missing gaps in the literature review and to test the hypothesis.

DATA ANALYSIS

This section presents and analyses the responses from questionnaires filled out by 13 participants. A summary of the questionnaire results has been compiled into a response matrix (Table 1). The questions were developed based on the discussion presented in previous section, to provide closure to the hypothesis presented. The analysis of the results is further discussed and compared to the secondary data from the literature review in the following sub-sections.

Analysis of Results

The primary responses acquired from the participants have provided a solid base to carry out the analysis achieved by the research objective. When comparing the answers to the questionnaire certain trends have been identified.

Firstly it was found that a candidates path in the workplace i.e. degree or master has absolutely no bearing on their understanding of supply chain management in Malaysian context. For example, when asked about the understanding of supply chain management, 12 out of 13 participants stated that the basic concepts of the terminology were understood in a general context. Participant-13 (Project Manager), in his understanding of supply chain management, states that it is 'Contractors management on how contractors obtaining material and services from their supplies and sub-contractors, transportation of material on site and quality issues.' Other views are from Participant-9 (Quantity surveyor): 'Relationship between different team members on a construction project, from inception to completion and beyond' and Participant-6 (Partner): 'In construction phase, is getting resources right from day, getting things in place i.e. labour, material and machinery, organizing resources in time and complete or deliver within the due date'.

According to the responses, it was generally agreed that there was no definitive answer to which procurement method was the most important method in construction industry. As shown in Figure 3, according to all participants, whether the delivery method is Fixed Price/Lump Sum, Design and Construct, Construction Management, Alliance, or a PPP; they are all equally important and each presents a different perspective when it comes to working relationships. However, all participants responded that in the past, they chose 'Fixed Price/Lump Sum' as the most important procurement method for their organizations. 12 out of 13 participants state that they also implemented 'Design and Construct (D&C)' and 2 of them also executed 'Joint Venture (JV)'.

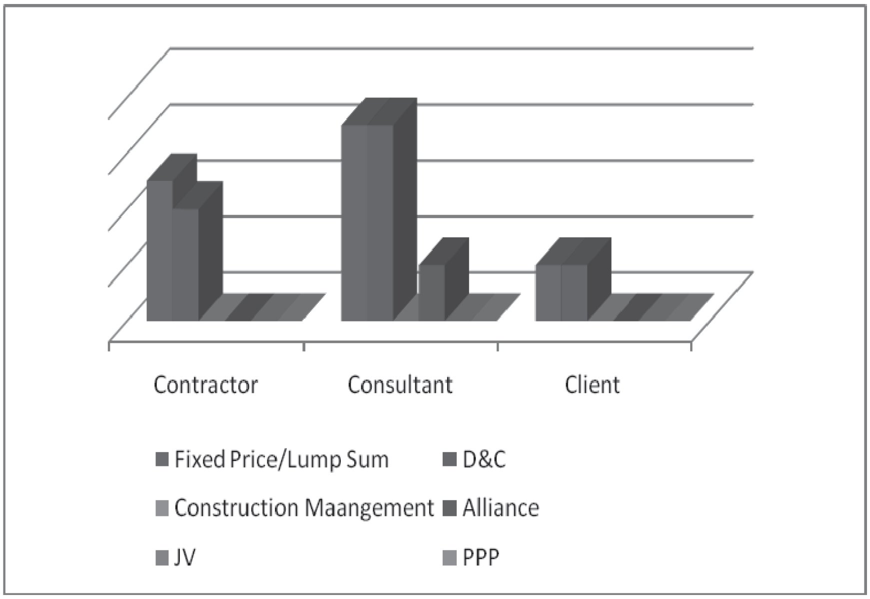

Figure 3. Procurement preference relationships

In order to achieve the objective of this research, i.e. to determine whether varying procurement methods impact or alter subcontractor - contractor relationships, we set out to establish whether the way in which a project is delivered reflects on the relationship between parties. As our initial prediction was that relationships are not affected by changes to the way in which a project is delivered. All respondents answered that yes to a certain extent relationships are inevitably manipulated by the way in which a project is delivered. Such is the view of Participant-12 (Assistant Director): 'Design and Construct (D&C) is more profitable and brings win-win for all parties'. In addition to this, most of the respondents responded on delivery methods and their effects on relationships, particularly in 'Design and Construct' and 'Fixed Price/Lump Sum' as made by Participant-4 (Director): 'Design and Construct - the selection of consultants and architects are based on past relationships and performance' and Participant-10 (Assistant Director representing client): 'D&C - the responsibility is on the contractor which makes client safer, whereas Conventional - the responsibility is on client side'.

Table 1. Summary of the data collected

Participant	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
1	QS & Administrator	Degree, Supplying of materials from suppliers and manufacturer.	Fixed Price/Lump Sum	Applied on D&B, but did not get it No	Quality of work, reputation.	Price based	Technical issues. **VO or request for variation of work.**	**Yes.** *Responsible person is not stated.*	**Not necessarily**. Award to subbies who work presently or in the past or who has got lowest price.	Clients transfer to contractors. Contractors transfer to all subbies.	There was once they terminate a contract of a subbies, might be due to the work not done according to the spec.
2	Project Manager	Master, Supplying of housing and material.	Conventional (mostly), D&B (sometimes)	Yes Less supervision in D&B and contractors responsibility to select consultants	Reputation, Quality of work.	Long term relationship is usually built based on receiving good services and on schedule completion. Open tenders, they inform preferred contractors to bid and select lowest price. **Both**	He (PM) ensures projects are done by the contract. **VO are common** when prices up, but developers do not pay any inflation in price.	**Yes** They are considering ISO accreditation, thus putting procedures in place to evaluate the supply chain participants.	**No** Does not matter.	100% risks on contractors, therefore, contractors should lock up their suppliers in terms of prices as soon as they get a contract rewarded.	Subbies do not performing due to financial problems.
3	QS	Degree, Managing sub-contractors, suppliers and manufacturer.	Fixed Price/LS & D&B	Yes D&B- contractors control their own team. Conventional - contractors being controlled	Quality of work, existing relationships. In D&B, they go with different architects on different projects, therefore not look at price.	Open tender – lowest price Private – price KL- go by books, contracts and paper work **Price**	Never happens. If does, **negotiate.** Payment from client	**Yes** Feedback from site staff. PM is responsible	**No**. Only payment on time can build good reputation and relationship	Yes, to the downstream supply chain	N/A

Participant	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
4	Director	Degree. Procurement acquiring material for construction	Fixed Price/LS & D&B	Yes D&B- selection of consultants and architects based on past relationships and performance.	Quality of work	Continual work.	**Fail in action** In most cases, consultants fail to resolve problems simply because they could not do it.	**Yes.** Specific person does purchasin g and meet with suppliers regularly.	**No.** Issue is the reliability of service and product provider (regular 6 month evaluation to ensure quality).	In D&B – 100% risks by the contractor. In convention al procureme nt, all risks due to design and are clients responsibil ity.	Mutual termination happened once due to relocation of electrical cable.
5	Associate Director	Degree. Processes that take place from inception to completion during constructio n.	Fixed price/LS or conventional D&B or turnkey projects JV (local company involved)	Yes Conventional- appointed by client and they provide the client an estimate of project for bidding. D&B- mostly appointed by contractor.	Performance in an open tender. In direct negotiation (conventional), preferred contractor is picked up and price is taken into consideration. In open tender, overall performance (technical and financial) is considered.	In private sector, it is all repeat work and contractors and consultants have to keep up their performance and lower down their prices. In public sector, always advertised for tender, usually past work and evaluation on technical and financial. **Both**	n/a	**Yes** Their company has worked as PM on a small scale projects managing subbies and suppliers	**Depending** on number of parties. If less organisatio ns, more chances of close relationship s in a supply chain on a project.	Client passes 100% risk to consultant s and contractor s. In D&B, 100% risk is with the main contractor.	Terminated contract of a subbbie because of delay and bad performance and the contract was terminated based on not fulfilling the contractual terms and conditions.
6	Partner	Master. Getting resources right from day, getting	Fixed price/LS D&B	Yes D&B- contractors do not interfere in the design, but prefer simple	Quality of work, reputation Recommendatio n by QS firm,	**N/A,** since most of the work is done in house.	N/A, only once when client wanted to under value the work of	**No** Mostly do not out- source. Only once	**Yes** Clients appoint same contractors but go	They usually transfer risks to contractor s.	Same as Q9.

Participant	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
		things in place, organizing resources in time and complete.		design with low cost material.	local presence, past recommendations and performance.		main contractor, and they went for **arbitration** and won the case. **Usually Negotiation**	when they act as QS. PM appointed to manage the consultants involved and contractors appointment based on quality and price.	through the whole process of procurement.	Contractors quote higher price to balance out the risk they take.	
7	Chairman	Master. Getting resources right from day, getting things in place, organizing resources in time and complete.	Fixed price/LS D&B	Yes D&B- contractors do not interfere in the design, but prefer simple design with low cost material.	Quality of work, reputation Recommendation by QS firm, local presence, past recommendations and performance.	**n/a,** since most of the work is done in house.	n/a, only once when client wanted to under value the work of the main contractor, and they went for arbitration and won the case.	**no** Mostly do not out-source. Only once when they (not the participant) act as QS and PM to manage the consultants involved and advised contractors appointment based on quality and price.	**Yes** Clients appoint same contractors but go through the whole process of procurement.	They usually transfer risks to contractors. Contractors quote higher price to balance out the risk they take.	Same as Q9.
8	Director	Degree. Management of subcontractors and suppliers	Fixed price/LS D&B JV	Yes In traditional, clients and his consultants could do QC and check the	Quality of work, reputation. Private sector- most competitive fee and project specific	Participant has client for last 19 years, retained because of their (participant)	n/a	**No** All work is done in house.	**No. Performance**, not duration. Contractors come to the	They have professional indemnity insurance.	n/a

Participant	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
		depending on the procureme nt route taken.		work. In D&B, client lose control	experience. Public sector- fee is fixed, therefore look for size of firm and staff strength.	performance, services and best price. For new clients, performance record, staff's track record, etc. **Both**			participant and negotiate price because of their track record.		
9	QS	Degree. Relationshi p between different team members on a constructio n project, form inception to completion and beyond.	Fixed price/LS D&B	Yes Conventional- don't get completed on time and lack of proper management on site.	Quality of work Price is the first thing. Secondly, completion time.	**No idea.** New company and did not have many projects.	Traditional project- Delay. Blaming each other. **VO** are submitted but never get confirmed. Contractor over ruling client.	**No**	Not sure	Client did to the main contractor	Not sure
10	Assistant Director (Client)	Master. Supply resources at the right time.	Convention al D&B	Yes D&B- responsibility by contractor, make client safer Conventional- responsibility on client side.	Quality of work, reputation. Performance and capability in past work, financial capability, but lowest bid is what client usually goes for.	Private sector does it, but not public sector. **Price based**	**VO** submitted by contractors- disputes over extra work done by contractors. EOT- loss and damage due to EOT.	**n/a** only MoF can negotiate and authorize the work with specific party.	**No** **Cost** is that matters.	D&B- responsib ility by contractor , make client safer Conventio nal- responsib ility on client side. VO are very less in D&B.	If contractor delaying, performing badly, and not constructing according to the spec- there is agreed clauses in the contract.

Participant	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
11	Executive chairman (consultant)	Degree.	Fixed price/LS. D&B	Yes For consultants, D&B is not good because mostly the contract goes to big contractors who have their own consultants on board based on their past relationship or have in house expertise and do not outsource the service.	Relationship, quality of work, location, existing plant, reputation.	1) Track record 2) Relationship 3) Cost **Both**	No disputes.	**Yes** Directors responsible for that.	**yes** Usually work with the firms they have known in the past.	Share risk with partners.	n/a
12	Assistant director (contractor)	Degree. Managing subcontractors and clients.	Fixed price/LS. D&B	Yes D&B is more profitable and brings win-win for all parties.	Quality of work	**Price based** most of the time, and past record working with them.	No.	**Yes** Director, Assistant Director and project managers.	**Yes** Same for **both**	Share very little risk and mostly transfer it to the subcontractors.	n/a
13	Project manager (PWD)	Degree. Contractors management, how contractors obtaining material and services from their supplies and subbies, transportation of material on site, quality issues.	Fixed price/LS. D&B	Yes D&B- contractors' responsibility, client may have less control. Number of variations would be less. In conventional- contractors follow design, if it is design faults, they are not blamed or held liable.	Quality of work, reputation Price. For selection- past records, company A/C professional/ legal register, staff checks.	3 types; open tender, selected tenderers (min 5), direct negotiation, **(price based)**	Varies from case to case. Resolved through **negotiation** and arbitration is the last resort.	**n/a** Traditional- Not built relationships with contractors or consultants; D&B- MoF does final price negotiation. Relationship starts after contract is awarded.		In D&B, contractor's responsibility; but in conventional, both parties.	No force termination except for any default by contractors.

One of the most important factors that need to be considered when a relationship is dissected is inevitably the price factor. Is lowest price the ultimate decider when tendering or do other issues come into play such as existing or prior relationships, quality of work, the project location, existing plant or past and present reputation and/or perception. A decisive 13 out of the 13 respondents agreed the lowest bid is crucial but more important is a balance of all of the above. Participant-4: (Director): 'speed of their work and delivery, their management and supervision style' and as explained by Participant-7 (Chairman): 'Recommendation by QS firm, local presence, past recommendations and performance.' A further example is that of Participant-13 (Project Manager representing client) who replied: 'We make an estimation based on local prices and comparing our existing projects and also check with suppliers. So within tenders, if tender prices are in the range of +/- (10%-15%) of that estimate, we consider the quote. For selection, we all look at past records, company accounts, professional and legal registration, staff but rarely do reference checks'. This concludes that price although crucial is by no means ever the only player in decision making: 'Price is the most important aspect as far as selection is concerned (both for client and us). Workmanship and performance on the past project were also considered by the client. The client also sees our delivery time on the previous projects (on time or delay) when selecting their contractors.' Participant-1: (QS and Contract Administrator).

Participants were further asked if continual work within existing relationships was a priority or is the decision simply price based. Three of 5 contractors, and all 2 clients stated that price is more important than continual work. The rest of the results were a mixture of the balance of price and continual work (4 out of 13 respondents), continual work being a priority (1 out of 13 respondents) and not applicable (3 out of 13 respondents). Participant-5 (Associate Director) differentiate the factors in the aspect of private and public sector: 'In private sector, it is all repeat work and contractors and consultants have to keep up their performance and lower down their prices. In public sector, mostly no repeat work, always advertised for tender, and there is possibility that the same company wins during the biding process which has done work in the past. The evaluation is fair, based on technical and financial capabilities.' Figure 4 represents the responds of the respondents.

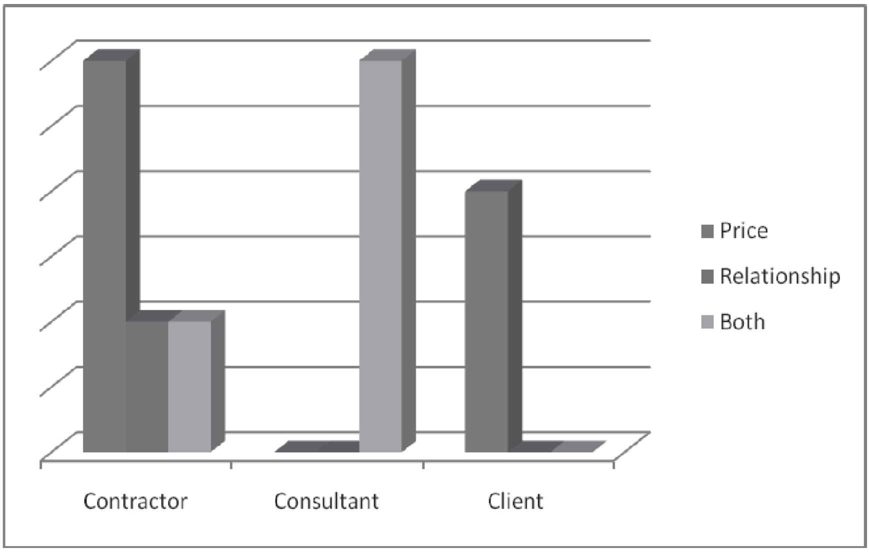

Figure 4. Price vs Relationship

One of the minor concerns of this research relates to how disputes are resolved when differences occur and in turn how that affects future working relationships. Sufficient results have been gathered from the questionnaires to provide the answer to this question. When asked how to best resolve disputes, the majority of respondents replied with some form of negotiation, i.e. Mediation and Settlement. Participant-1 (QS and Administrator) answers the question by 'Mostly the disputes with clients are based on technical issues. They result into variation orders (VO) or request for variation of work'. Similarly, Participant-10 (Assistant Director) adds that 'If there are disputes over extra work done by contractors, VO is submitted by the contractors' and 'Extension of Time (EOT) due to neutral event (third party causing damages) and delay due to client (delay in giving instructions or drawings).' Participant-13: (Project Manager) affirms that 'most of the disputes are resolved through negotiation, and arbitration is the last resort'. However, it was found that results sufficiently demonstrate that all participants (contractors, consultants and clients) agree that disputes in Malaysian construction industry rarely happen and none of the participants gave any feedback to the effect of dispute to future working relationship.

The findings also revealed that maintaining and reviewing company relationships with a strategic approach is one that receives much focus. Outstandingly the results reveal that all 5 contractors and only 2 out of 5 consultants have a technical means whereby they monitor the health of relationships. The rest of the participants explain that their organizations mostly do not out-source work (Participant-6 and -7: Partner and Chairman, vice-versa) and 'all the work is done in-house' (Participant-8 : Director). The client's representatives respond that they do not involve directly in maintaining and reviewing subcontractor relationship as per explained by Particpant-10 (Assistant Director) : 'Only Ministry of Finance (MoF) can negotiate and authorise the work with a specific party' and Participant-13 (Project Manager) : 'we start managing the relationship with contractors after contract is awarded'.

When asked if the duration of a project potentially allows for a closer bond between parties, a fairly mixed response is given. 4 of the 14 respondents agree that it definitely allows for a closer bond. On the other hand 6 of the 14 respondents are under the impression that it is not 'duration' only that allow closer bond between parties as they varies from performance and cost. This tally with Participant-3 (Quantity Surveyor), who responds that 'payment on time in every project results into building good reputation and relationship' and Participant-8 (Director) answers 'Most of the contractors come to us and negotiate price because of their track record. Duration is not the issue – it's performance.' One of the participant (Participant-5: Associate Director) replies that it is depending of number of parties, in a view that 'if more organizations involved, it is less likely to build stronger relationships, however, if there are less organizations, then there are more chances of close relationships'.

To get an overall opinion on the extent that projects have on relationships, a concluding question was asked to understand what the implications of contract termination are, and whether networking with the party will cease if this occurred. In a similar fashion to Question 9's responses – respondents main aim during their daily jobs was to avoid contract termination at all costs and get back to work as soon as possible and deal with problems in a manner that involves a bit of give and take. However, five participants admitted that they had once terminated the contract of the subcontractors because of bad performance, delay and work done not according to the specification. In addition, participant-10: (Assistant Director) claimed that 'there is an agreed clauses in the contract that they can terminate if contractor is delaying, performing badly and not constructing according to specification.'

CONCLUSION

It was found that relationships within the supply chain of construction are influenced by many contributing factors. It was revealed that contracting structures and styles significantly affect the relationships between organisations and that procurement techniques and contractor selection is an imperative process in keeping strong relationships for the duration of the project or contract works. Through Supply Chain Management the above can be incorporated into construction projects as a new method of project delivery. SCM is an emerging concept in the construction industry and this paper found that the participants in the industry have little to no understanding of SCM principles. It was noted however, that almost everyone interviewed within the industry acknowledged the concept of SCM when portrayed in layman terms. This paper found that the main difference between conventional procurement methods and SCM lay in the emphasis that is placed on incorporating relationships and collaboration between all project parties. It is crucial for organisations to move away from traditional procurement and project delivery methods to promote SCM framework in order to stay competitive in the ever changing industry environment.

This paper revealed that in order to implement any SCM models, the clients role is crucial because it needs to be initiated by the client in predominately public projects. This is because there is extensive policy and framework required in order to facilitate the total SCM model. However, experienced private clients should begin researching ways to prepare and hopefully integrate SCM prior to it being a necessity to compete on larger projects. For SCM to occur in Malaysia, it is necessary for industry leaders to be educated about the potential time and cost savings that could be achieved through implementing available SCM models. It has been shown in many studies that through education and training in unfamiliar areas of knowledge, it makes it easier to grasp new principles and concepts. Thus the industry leaders need to be proactive in the learning process of SCM in order to fully understand and appreciate the significant reduction in cost savings that can be achieved through SCM. It was also noted that clients may well invest these savings into other facilities and thus use the same project team to deliver their future projects. This will create additional work for participating SCM users and will benefit the industry as a whole by increasing productivity.

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PERCEPTION ON QUALITY ASSESSMENT SYSTEM IN CONSTRUCTION (QLASSIC) IMPLEMENTATION IN MALAYSIA

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Abstract
There are many factors that may contribute to the successful of producing quality product for construction project in Malaysia. One of the factor that consider as the contributor is by using legitimate monitoring checklist as assessment. In Malaysia, Quality Assessment System in Construction (QLASSIC) had been implemented since year 2007. The main objective of this assessment system is to access efficiency of product produce by contractor. Nevertheless, contractor perceives the assessment system will exhibit their weakness. Hence, there is a need to deliberate the perception of contractors if the assessment system obligated. Pilot survey had been used as the main research methodology in order to obtain those relevant data. At the end of this study, the perception by workers in the Constructions and Developers industry towards the implementation of QLASSIC in Malaysia will be established.

Keywords: *Quality Assessment System; Construction Industry; Developer; Contractors*

INTRODUCTION

There are many factors being considered by purchasers and buyers in determining the ideal and suitable property to be invested. Laurent Stadelmann in his article listed some of the factors considered by buyers such as location, size, mortgage, on off cost, living cost, school catchment area, public transport and others (Nierstrasz et al. n.d.). As an addition, he added that repair and maintenance cost are also being considered under living cost estimation.

To avoid the incur of maintenance cost, quality of the product during construction stages should be scrutinized as a pre-requisite for property developers before handing over the final products to the purchaser.

In order to uphold the buyers' satisfaction on the property purchased and the quality of the product delivered, Construction Industry Department Board of Malaysia (CIDB) had taken the initiative to provide services in terms of evaluating the standard assessment on construction quality to the property developers named QLASSIC. QLASSIC was introduced by CIDB in the year of 2007. This assessment was adopted from the Construction Quality Assessment or CONQUAS currently practiced in Singapore, United Kingdom and others. CIDB's circular indicated that local contractors in Malaysia should adopt QLASSIC approach in their quest to deliver quality construction works. Currently, approximately 10% of total contractors' population in Malaysia are grade G7 contractors which are of the highest grade category. Hence one of the primary outcomes of this study is to establish reasons for contractors refusing to adopt QLASSIC in their construction activities.

PROBLEM STATEMENT

QLASSIC is not implemented by many developers and contractors in Malaysia. The significant of QLASSIC on properties and products can be assessed on only very few companies associated with CIDB.

Prior to this statement, this study will oversee the reasons why developers and construction companies do not perform assessment on the projects and products produced. Some of the common perception on QLASSIC is a burden since QLASSIC involves increase in cost and time consuming.

QUALITY ASSESSMENT SYSTEM IN CONSTRUCTION INDUSTRY (QLASSIC)

Quality Assessment in Construction or known as QLASSIC was introduced in Malaysia by Construction Industry Board Development (CIDB) on 2007. In Singapore similar system is known as (CONQUAS). The effective implementation of CONQUAS, CIDB coherently establish their own CONQUAS with several adjustments made and name it QLASSIC.

QLASSIC sets out the standards for various construction elements in building and other infrastructure works. The quality assessment of workmanship and finishes of the construction work is based on these standards. Points are awarded if the workmanship and finishes comply to the standards. These points are then summed up to give a total quality score named QLASSIC Score (%).

The assessment is conducted at the construction site through inspections and field-testing. The score will be done on construction works that are inspected for the first time. Construction works that are rectified and corrected after the assessment will not be re-assessed. The objective of this practice is to encourage contractors to “do things right the first time and every time” (Board, 2006)

Objective of QLASSIC

Based on CIDB, QLASSIC is a system that evaluates and assesses the quality of workmanship through a sampling and statistical approach. The objectives of QLASSIC are as follows:

1. To elevate the quality level in the construction industry.
2. To have a standard quality assessment system as a benchmark for quality on construction works.
3. To assist contractors to achieve defect-free when carrying out construction work.
4. To be used as criteria to evaluate the performance of contractors based on quality of workmanship.
5. Data compilation to be used for statistical analysis in estimating the quality level and productivity of construction industry.

Assessment Approach and Sampling Process

As it is impractical to assess all elements in a construction project, QLASSIC assessment uses a sampling process to carry out the assessment. The sampling takes into account the size of the building as well as the distribution of the various functional locations. This will enable the assessment to adequately represent the entire building (Hao,2005). Before carrying out the assessment, the assessor will determine the samples (elements or locations) that need to be assessed. The samples must be distributed as uniformly as possible throughout the project and various construction stages. The samples are selected from drawings and plans of the relevant construction project. Sampling of the structural works are divided into two or three stages beginning of the commencement of the superstructure activity until the completion of the structural works depending on the scope of the structural activities (Hao,2005). All locations in the construction project must be made available for the assessment.

There are several elements that the assessor can determine on the standard of quality that are implemented by their client or contractor. Hence, the assessment will depend on the package of assessment required. The package elements are as follows:

Structural Works

The assessment is carried out throughout various construction stages. The numbers of samples are determined based on the gross floor area (GFA) of the building with a minimum and maximum number of samples.

Architectural works

The assessment is carried out upon completion of the building project and before handing over of the project. The samples are determined based on the gross floor area (GFA) of the building with a minimum and maximum number of samples.

Mechanical and Electrical (M & E) works

The samples are determined based on the gross floor area (GFA) of the building with a minimum and maximum number of samples. For completed projects the assessment is carried out upon completion of the building project and before handing over of the project. For ongoing projects the assessment is carried out throughout the various construction stages.

External works

The assessment is carried out upon completion of the building and before handing over of the project. The numbers of samples are determined based on (10m length section/ location) with a minimum number of samples.

Construction Industry Standard (CIS) on Quality Assessment System for Building Construction Work

The Construction Industry Standard is divided into four main components. Assessment on the workmanship is done based on these standards and points are awarded if the workmanship complies with the standards. These points are then summed up to give a total quality score called the QLASSIC Score for the building (Hao,2005). The components that being assess as follow:

Structural works

The structural integrity of the building is of paramount importance as the cost of failure and repairs are very significant. The assessment of structural works comprises:

1. Site inspection of formwork, steel reinforcement, prefabricated or pre-cast elements, etc during construction.
2. Laboratory testing on compressive strength of concrete and tensile strength of steel reinforcement.
3. Non-destructive testing of the uniformity and the cover of hardened concrete.

Architectural works

Architectural works deal mainly with the finishes. This is the part where the quality and standards of workmanship are most visible. Architectural works are works such as floors, internal walls, ceiling, door and window, fixtures and fittings, external wall, roofs, driveway, porch and apron.

Mechanical and Electrical (M & E) works

The quality of M & E works is important in view of its increasingly high cost proportion and its impact on the performance of a building. Generally the assessment covers electrical works, air-conditioning and mechanical ventilation works (ACMV), fire protection works, sanitary and plumbing works, lifts, escalator and other basic M & E fittings.

External works

External works cover the general external work elements in building construction such as the link-ways shelters, drains, road works, car parks, footpaths, turfings, playgrounds, gates and fences, swimming pools, hardscapes and electrical substation. In the Construction Industry Standard, the weightage for structural, architectural, M & E and external works are allocated in accordance to four categories of buildings.

The weightage system, which is aim at making the objective of QLASSIC representing the quality of a building, is a compromise between the cost proportions of four components in various buildings and aesthetic considerations.The QLASSIC score of a building is the sum of points awarded to the four components in each category of a building.

PERCEPTION IN ADOPTING QUALITY ASSESSMENT

In the case of adopting Quality Assessment at the workplace, the same approach was used in determining the satisfaction of customers towards service providers and system implementation. QLASSIC implementation is seen by contractors as a method that can determine and establish the contractors' behavior in providing and completing the work in accordance to the client's requirements.

Based on interviews with CIDB, most of the contractors refuse to adopt this assessment due to their willingness to be assessed based on frauds and unnecessary activities towards the quality benchmarked by CIDB. The assessment requires the assessor to look for suitable package element, where the entire complimentary elements will be put into consideration at the same time.

If the assessor gave low rating to the contractors' work, then the contractors' reputation will be seen as not fulfilling the industry's requirements. At the same time, the future of the contractor in the construction industry may be blurred and may cause other clients not interested to engage them.

On the other contrary, the contractors' reputation may increase after assessment made if the assessor had assessed them with good remarks and rating. (Kadir, 2012)

RESEARCH SURVEY

A thorough search for literature review was performed with the aim of having a better understanding of recent developments in the area of performance measurement. First round of questionnaire was distributed amongst the professional and practitioners that mainly focus on construction industry. In order to exhibit the accuracy of the input, the professional practitioners in this context are Managing Director (12%), Project Managers (30%), Quantity Surveyor (10%), Professional Engineer (10%), Sales and Marketing Manager (5%), Engineers (27%) and Others (6%). Input and attributes from the interview then being consolidated for the final set of questionnaire. With the comprehensive additional literature on performance measurement framework proved helpful in identifying an appropriate theoretical framework for this study. In furtherance, efforts were made to review many of the performance rating systems available in the industry. Aspects of these systems were reviewed to include applicable criteria that could be used in the assessment.

Subsequently, structured questionnaires were used to obtain data (including piloting). This provides opportunity for professionals in the construction industry to identify criteria that are considered vital and applicable in the assessment of contractors. Again, this information then provides some form of prioritization for the criteria. The data received were analyzed using One Sample T-test statistical analysis with the help of Statistical Package for Social Sciences (SPSS) software.

This study focuses on the construction industries located in the state of Selangor. Kuala Lumpur being the capital of Malaysia, where major construction industries take place is located in Selangor. The questionnaire survey was performed primarily to collect representative data from construction industries in Selangor. The result is used to verify the perception on current practice of QLASSIC, to gauge the knowledge among industry practitioners and to formulate the issues related to implementation of QLASSIC.

The questionnaire was divided into four sections as listed:

Section A	-	Basic Company Profile
Section B	-	Respondent Background
Section C	-	Knowledge in QLASSIC
Section D	-	QLASSIC Practice

Section A is basically an introductory section of the form. It briefly exhibit the company's background which entails to degrade company if the company is public listed, certified to International Standard Organization and its business nature. Section B covers the respondents' background which comprised of designation, academic background and tenure of service in the construction industry. Most of the questions in these two sections are close ended. Section C which was aimed to ascertain the level of respondents' knowledge on QLASSIC. The questions were designed to enquire their knowledge on quality cost, brief understandings on QLASSIC and respondents interest in expanding their knowledge in QLASSIC. Lastly, Section D is aimed to collect some insight on the current practice of QLASSIC in construction industry. Most of the questions in section C and D utilize combination of open and close-ended questions; however majority falls under the later.

RESULTS AND DISCUSSION

100 set of questionnaires were distributed across the country of Malaysia with 77 were returned within stipulated period of time. All relevant data obtained were keyed-in into statistical software named Statistical Package for Social Science (SPSS) version 17. The generated results were interpreted and evaluated. It leads to an important finding for the next course of actions.

The findings are summaries as follows:

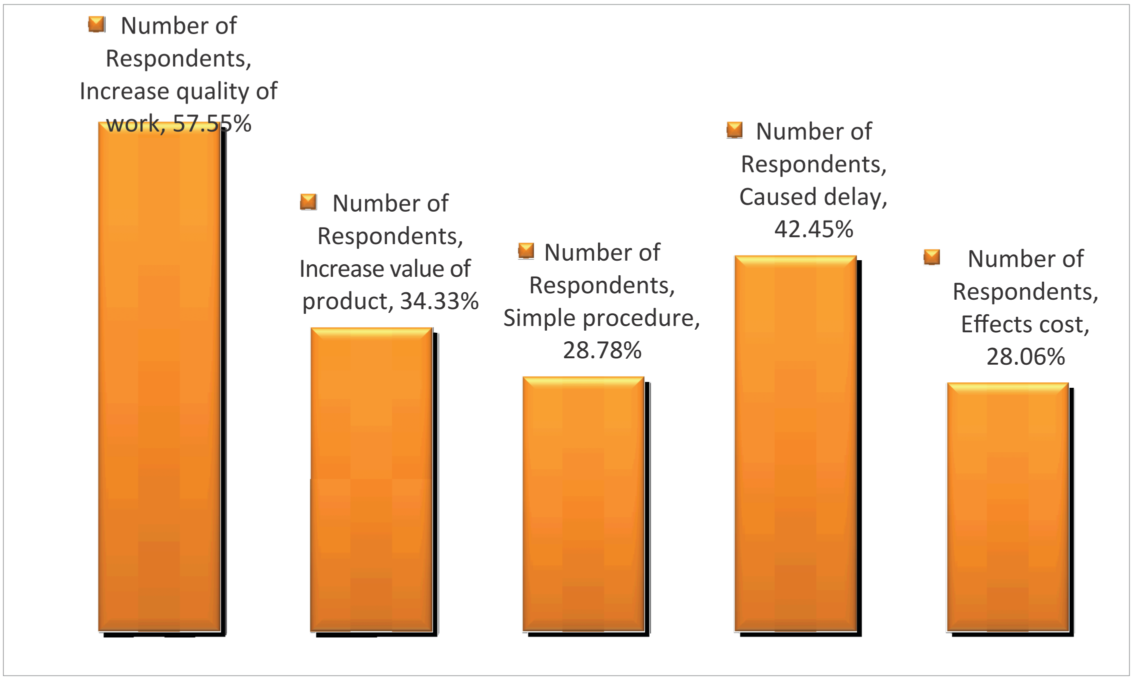

Figure 1. Correspondence Perception Towards QLASSIC Implementation

It was found that 57.55% respondents agree that QLASSIC increases quality of work, 34.33% agrees that QLASSIC will increase the value of products and 28.78% agrees that the procedures in QLASSIC are simple. Nevertheless, 42.45% agrees that QLASSIC will cause delay in the work activities and 28.06% agrees that QLASSIC will affect cost.

Incorporating results and findings deliberated in this study, below are several discussions attain:

1. There are still many companies in Selangor that have not implemented QLASSIC as Quality Assessment.
2. The property developers and contractor workers perceived QLASSIC is able to:
   i. Increase the quality of work
   ii. Increase the value of product

   At the same time, it is also found that procedure in QLASSIC is simple to be adopted. On the contrary, their perceptions on QLASSIC are:
   i. QLASSIC is causing delay in construction activities
   ii. QLASSIC have effect on cost of production.
3. The level of knowledge on QLASSIC depends on the level of the worker in the company's hierarchy. Worker at a higher level has higher QLASSIC knowledge compared to the worker at a lower level.
4. The property developers and contractor workers are willing to adopt QLASSIC as their Quality Assessment method at their workplaces if suitable motivation and incentives are provided.

CONCLUSION

Throughout this study, it is found that there are very few researches in Malaysia pursuing the area of Quality Assessment in construction industry. This is exhibited by the very limited journals and literature reviews on quality cost in Malaysia. Hence, this provides an avenue to explore further in this area.

For establishing the continuity of QLASSIC effectiveness, CIDB is proposed to enforce the implementation of QLASSIC as the main element of project approval for issuance of Certificate of Fitness (CFO) or Certificate of Compliances (C.C.C) in construction industry of Malaysia. Nevertheless, this enforcement will depend on the maturity period of QLASSIC system in Malaysia as compared to others countries.

In addition to that, there is a need to create a measuring tool in order to generate results and output of site inspection. By this mechanism, result of the full report can be obtained in a shorter period and could enhance the efficiency of QLASSIC.

Furthermore, the measuring tools should be included with reliable software in order to monitor the status of their projects. At the same time, CIDB could utilize the data obtained for their inspections. The establishment of this software allows CIDB to diversify their ability and increase the applicants' expectation. Hence, the cost simulations for adopting QLASSIC can also be well established.

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GUIDE TO AUTHORS

Aims and Scope:

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

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

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

Author's name (full name): Arial, 9pt. should follow below the title.

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Abstract: Arial Bold, 9pt. Left and right indent 0.64 cm.

Abstract: it should be single paragraph of about 100 – 250 words.

Keywords: Times New Roman Bold, 9pt (Italic). Left and right indent 0.64 cm.

Keywords: *Cooling tower; Finite element code; Folded plate; Semiloof shell; Semiloof beam*

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

Heading 1: Arial Bold + Upper Case, 11pt.
Heading 2: Arial Bold + Lower Case, 11pt.
Heading 3: Arial Italic + Lower Case, 11pt.

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

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

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

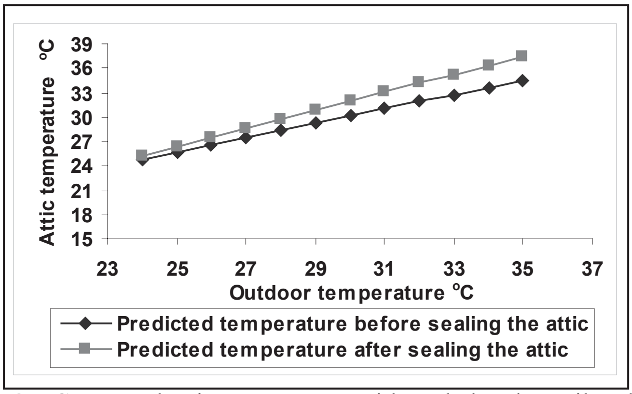

Figure 8. Computed attic temperature with sealed and ventilated attic

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

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

Table Line: 0.5pt.

Table 1. Recommended/Acceptable Physical water quality criteria

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

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

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

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