EFFECTIVENESS OF SILICA FUME LIGHTWEIGHT FOAM CONCRETE WALL PANEL WITH WINDOW OPENING UNDER AXIAL LOAD

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ABSTRACT

Structural wall with opening are widely used as lateral load bearing elements in designing earthquakes resistant for building. Therefore, this study was investigated the performance of lightweight foam concrete with window opening under axial load. The Reinforced Lightweight Foam Concrete with 15% of Silica Fume (SFRLWC) behavior was analyzed and discussed in term of ultimate load, maximum deflection and mode of failure compare to conventional concrete. The cube test (compressive strength test) showed that the SFRWC-WPWO was 46% higher than conventional concrete but the weight was 22% lower than the conventional concrete. In this study, the ultimate load of SFRWC-WPWO was 34% higher than conventional concrete with magnitude of 482kN. The deflection of SFRWC-WPWO was 41% lower than conventional concrete with magnitude of 5.57mm. The failure mode for conventional concrete is due to cracking and SFRWC-WPWO was not failed under 500kN axial load test. Finally, the study explained that the lightweight foam concrete were fragile but more effective compared to conventional concrete in term of compressive strength of cube test, axial load test and the cracking and mode of failure.

ABSTRAK

Dinding struktur yang mempunyai bukaan tingkap adalah sangat meluas digunakan sebagai unsur yang membawa beban di bahagian sisinya dalam merekabentuk bangunan oleh sebab rintangan gempa bumi. Oleh sebab itu, satu kajian terhadap kebolehan SFRLWC-WPWO di bawah keadaan beban tumpu dilakukan. Ciri-ciri SFRLWC-WPWO dengan 15% 'silica fume' telah dikaji dan dibincangkan dari segi beban tumpu maksimum, perubahan lenturan maksimum dan keretakan serta jenis kegagalan dindin struktur berbandingan dengan konkrit biasa. Ujian kekuatan mampatan untuk kiub telah menunjukan bahawa SFRLWC-WPWO 46% lebih tinggi dari konkrit biasa dan 22% lebih ringan dari konkrit biasa. Dalam kajian ini, beban tumpu maksimum SFRLWC-WPWO adalah 34% lebih tinggi berbanding konkrit biasa dengan nilai sebanyak 482 kN. Didapati lenturan maksimum bagi SFRLWC-WPWO adalah 34% lebih tinggi dari konkrit biasa dengan nilai 5.57mm. Jenis kegagalan bagi konrit biasa adalah berpunca daripada keretakan yang berlaku manakala bagi SFRLWC-WPWO pula tidak berlaku dibawah beban tumpu sebanyak 500kN. Akhir sekali, kajian ini dapat menerangkan bahawa SFRLWC-WPWO lebih rapuh daripada konkrit biasa tetapi lebih berkebolehan dari segi kemampuan mampatan, ujian beban tumpu dan jenis kegagalan serta keretakan.

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INTRODUCTION

1.1 Background of Study.

IBS or also known as Industrial Building System has been implementation by Malaysian Industrial Building. The applications of IBS in industry especially in a construction industry are mostly important in this era. Most advanced materials technology with IBS`s engineering and building are mostly useful. This new development of materials will reduce the using of raw materials and less environmental effect. Narayanan and Ramamurty (1999) state that the foam concrete or is also known as aerated concrete is either a cement or lime mortar, classified as lightweight concrete, in which air-voids are entrapped in the mortar matrix by means of a suitable aerating agent. The prominent advantage of aerated concrete is its lightweight, which economies the design of supporting structures including the foundation and walls of lower floors.

According to Alex Liew Ming (2003) Foam Concrete Technology was developed over 60 years ago, it has been on the world-wide market for more than 20 years and being responsible for the construction over one hundred thousand apartments and houses, as well as schools, hospitals, municipal and commercial buildings in over 40 different countries. Some of their benefits are reduces the dead weight of a structure, can be manufactured to precise specifications of strength and densities, possess excellent workability, can be nailed, planed, drilled and sawn, provides excellent heat and sound insulation, can be applied with all traditional surface finishes - paint, tiles, carpets etc and moisture resistant and fire resistant. Foam concrete also has a life span of above 100 years. Previous investigation has shown that sectioned blocks of foam concrete cast 10 years ago indicated only 75 percent of the cement hydrated

BS 8110 Part 1(1997) Clause 1.3.4.1 stated that wall is meaning by a vertical load-bearing member whose length exceeds four times its thickness. The foam concrete was casted to be a wall panel with window opening. The total numbers of model is four (4): two (2) models was casted using foam concrete with addition 15% silica fume and another two (2) models was casted using conventional concrete without any addition as a control model. According to British Standard BS8110 (1997), the slenderness ratio, $\lambda = l_e/h$ was taken not more than 30 to avoid the buckling in minor and major axes.

From the BS8110 the slenderness ratio, *le/h* was calculated to determine whether the wall is braced or unbraced.

Slenderness ratio, $\lambda = \frac{le}{h}$

Where, *le* = effective height of wall.

h = thickness of wall.

The effective height of unbraced plain concrete wall is *le* = 2*lo*

The deflection of reinforced shear wall should be within acceptable limits if the total height does not exceed 12 times the length (BS 8110: Part 1(1997) Clause 3.9.3.8.2).

1.2 Problem Statements.

Present days, the issue of improvement materials and cost of the materials can be a mater. Basically, concrete is mixing the water, cement and aggregate and commonly cement use is Portland cement. Using the foam concrete can improve the strength of structure without paying high cost. In other words, the cost will be reduced with the same or higher strength compare to common Portland cement. Thus, this study was used the lightweight foam concrete with additional 15% Silica Fumed and the comparison with common Portland cement was analyzed. Not to mention, the walls structure today commonly uses to divides the areas and only a few of them are used to receive the load, so this structure is waste the raw materials because there are a lot of others options to divide the area. These happen because of the cost of construction materials and walls properties that are not strong enough to receive high axial forces. Therefore, this study investigates the performance of wall panel with window opening using lightweight concrete under axial load.

1.3 Objective.

The objectives of this study are as follows:

1. To determine the ultimate load for SFRLWFC – WPWO
2. To determine the maximum deflection for SFRLWFC – WPWO
3. To study the changes in behavior in terms of cracking pattern and mode of failure of SFRLWFC – WPWO

1.4 Scope of Works.

This research was studied the structural behaviors of the reinforced lightweig foam concrete wall panel with opening. In this investigation, two (2) samples of wa panel were made of 15% silica fume. The effectiveness of the silica fume reinforc lightweight foam concrete wall panel with opening (SFRLWFC – WPWO) w investigated through the experimentally. The axial load testing was conducted to obta the ultimate loading capacities, maximum deflection, cracking pattern and modes failure. Also, the compressive strength test was conducted to determine the maximu stress and mode of failure. The experimental was carried out as according to AST specification. The testing was conducted at Structural Laboratory, Faculty of Civil ar Environmental Engineering, Universiti Malaysia Pahang. The total four numbers specimens was prepared and designed into four (4), named as SFRLWFC – WPWO SFRLWFC – WPWO 2, RC – WPWO 3 and RC – WPWO 4. All specimens we designed according to standard BS 8110: Part 1(1997), properties and dimension w specified in Table 1.1 below. In plane eccentricity due to forces on single wall w calculated by statics alone accordingly to BS 8110: Part 1(1997) Clause 3.9.4.6. Size walls that were used are 1000mm x 1000mm x 75mm and will be place to the UT (Universal Testing Machine) with 500 kN bearing capacity for axial load test. Four (samples with size 100mm x 100mm x 100mm were tested under compressive streng test where two (2) samples used conventional concrete as a control sample and anoth two (2) samples were casted using the foam concrete with additional of 15% silica fum The size of walls can be referred to Figure 1.1 and 1.2 below.

Table 1.1: Dimension of wall panels.

Sample	Quantity	Density (Kg/m^3)	Dimension (mm)			Reinforcement	Mix Properties
			h	w	t		
SFRLWFC – WPWO	2	1600	1000	1000	75	4 T12	4:1:2
RC – WPWO	2	2400	1000	1000	75	4 T12	1:2:4

Study by Benayoune et al. (2007) found that, the wall with low slenderness ratio will failed by crushing, whereas all with slenderness ratio greater than 20 will failed by buckling. In this experiment study the wall height is 1000mm and the wall thickness is 75 mm and width is 1000 mm will be tested to examine the ultimate loading, maximum deflection, crushing pattern and modes of failure. The sizing for the window opening is 260mm x 260mm. These sizes refer to the journal from axial load behavior of pierced profiled composite walls by K.M. Anwar Hossain (2007). For reinforcement; According to BS 8110 clause 3.9.3.2.1, reinforced wall that is construct monolithically with the adjacent construction, following the procedure given in clause 3.8 for columns. BS 8110 state that the minimum reinforcement for column is 4T12. Thus, T12 steel bar will be used. Since the T12 high yield steel bars have yield and ultimate stresses of 460 Mpa and 469Mpa is required to resist the axial load and to give the high tension strength.

This reinforcement will be welded together to form a network of reinforcement and will placed in the middle of the wall panel before the foam concrete be pour to formwork.

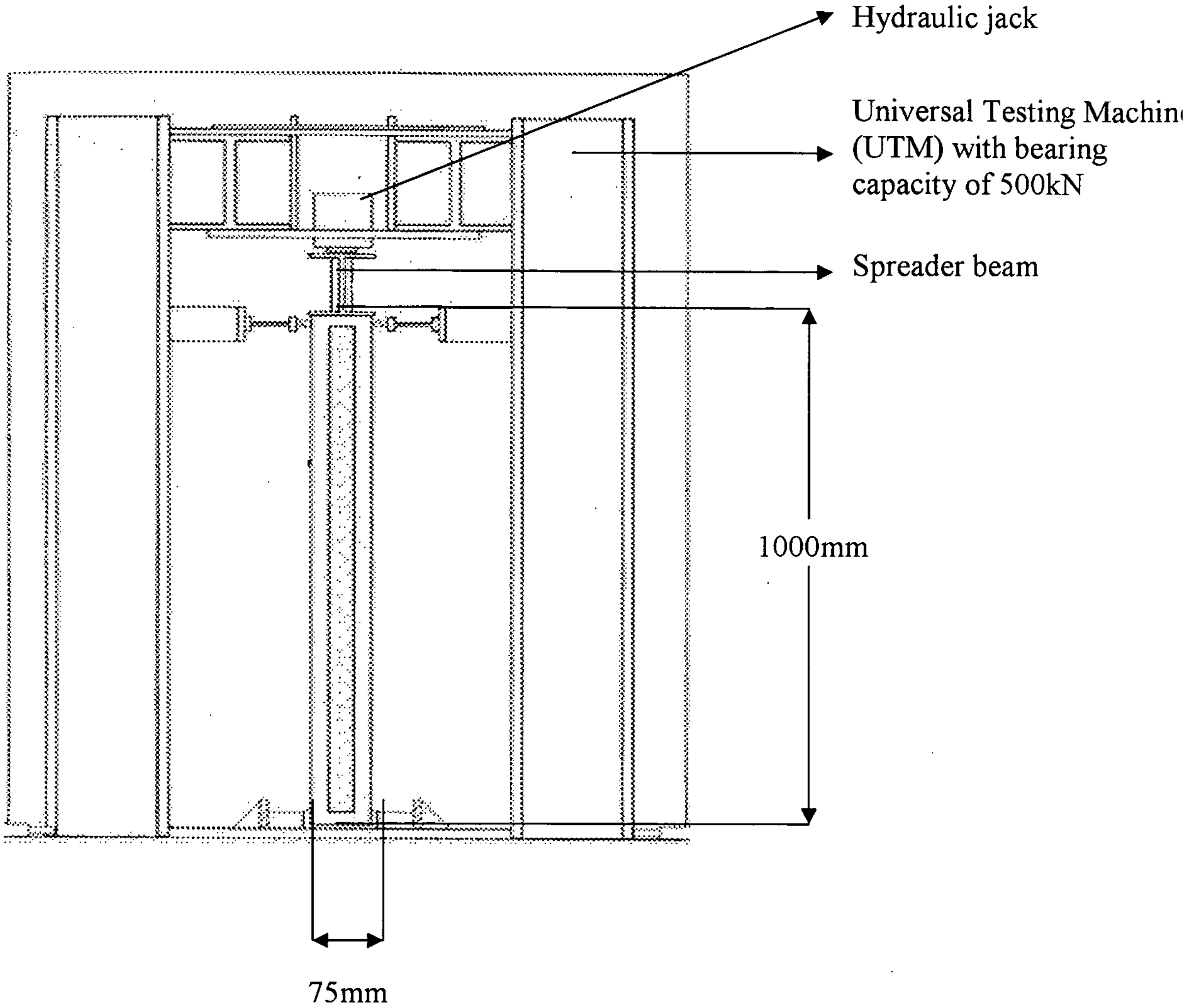

Figure 1.1: Test set up.

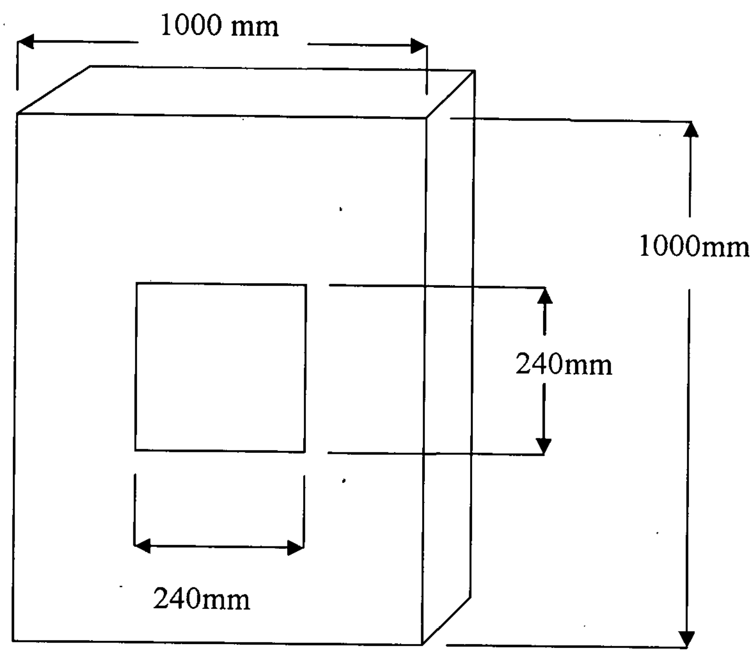

Figure 1.2: Wall dimension.

From this experiment work, the outcome should be able to identify the structure behavior of silica fume lightweight foamed concrete wall panel as a load bearing wall in term of ultimate load, lateral displacement and mode of failure. It is expected that the mode of failure for silica fume lightweight foamed concrete wall panel will fail by crushing and buckling which the maximum lateral displacement occur at 0.7 height of wall panel.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction.

IBS or also known as Industrial Building System has been implementation by Malaysian Industrial Building. The applications of IBS in industry especially in a construction industry are mostly important in this era. Most advanced materials technology with IBS`s engineering and building are mostly useful. This new development of materials will reduce the using of raw materials and less environmental effect. Alex Liew Ming (2003) stated that Foam Concrete Technology was developed over 60 years ago,. it has been on the world-wide market for more than 20 years, being responsible for the construction over one hundred thousand apartments and houses, as well as schools, hospitals, municipal and commercial buildings in over 40 different countries.

Narayanan and Ramamurty (1999) state that the foam concrete or is also known as aerated concrete is either a cement or lime mortar, classified as lightweight concrete, in which air-voids are entrapped in the mortar matrix by means of a suitable aerating agent. Alex Liew Ming (2003) stated that some of their benefits are reduces the dead weight of a structure, can be manufactured to precise specifications of strength and densities, possess excellent workability, can be nailed, planed, drilled and sawn, provides excellent heat and sound insulation, can be applied with all traditional surface finishes - paint, tiles, carpets etc and moisture resistant and fire resistant. Narayanan and Ramamurty (1999) state that the prominent advantage of aerated concrete is its lightweight, which economies the design of supporting structures including the foundation and walls of lower floors.

From research done by ECOSmart-AustralAsia Pty Ltd (2008), Foamed concrete has a surprisingly long history and was first patented in 1923, mainly for use as an insulation material. Although there is evidence that the Romans used air entrainers to decrease density, this was not really a true foamed concrete. Significant improvements over the past 20 years in production equipment and better quality surfactants (foaming agents) has enabled the use of foamed concrete on a larger scale.

According to Norizal (2008), Foamed concrete is considered an environment friendly material since it only uses sand & cement (no large aggregates) and $1m^3$ of raw materials can give nearly 2 m^3 of concrete . This makes it a potential material in housing construction because houses can be built more quickly and cheaply with such lightweight material. Cavaleri et al (2003) stated that lightweight Concrete can be used in structural frames, but it proves to be more suitable for wall system structures, where the local ductility demand (in seismic zones) and the required strength of the materials are reduced and the dead load to live load ratio is very high.

Lightweight concrete can be prepared either by injecting air in its composition or it can be achieved by omitting the finer sizes of the aggregate or even replacing them by a hollow, cellular or porous aggregate. Particularly, lightweight concrete can be categorized into three groups which are No-fines concrete, Lightweight aggregate concrete, Foamed concrete as shown in table 2.1.

Table 2.1 : Types of Lightweight Concrete.

Type Of Lightweight Concrete	**Type Of Aggregate**	**Grading of Aggregate (Range of Particle Size)**
No-fines concrete	Natural Aggregate Blast-furnace slag Clinker	Nominal single-sized material between 20mm and 10mm BS sieve
Partially compacted lightweight aggregate concrete	Clinker Foamed slag Expanded clay, shale, slate, vermiculite and perlite Sintered pulverized-fuel ash and pumice	May be of smaller nominal single sizes of combined coarse and fine (5mm and fines) material to produce a continues but harsh grading to make a porous concrete
Structural lightweight aggregate concrete	Foamed slag Expanded clay, shale or slate and sintered pulverized fuel ash	Continues grading from either 20mm or 14mm down to dust, with an increased fines content (5mm and fines) to produce a workable and dense concrete
Foamed concrete	Natural fine aggregate Fine lightweight aggregate Raw pulverized-fuel ash Ground slag and burnt shales	The aggregate are generally ground down to fine powder,passing a 75 μm BS sieves, but sometimes fine aggregate (5mm and fines) is also incorporated

2.2 Foamed Concrete.

According to Aldridge (2005), the lightweight foam concrete has been discovered for a very long time ago. Two thousand years ago the Romans were making a primitive concrete mix consisting of small gravel and coarse sand mixed together with hot lime and water. They soon discovered that by adding anima blood into the mix and agitating it, small air bubbles were created making the mix more workable and durable. The Egyptians were also gained the same result over 5000 years ago.

According to Ali (2001), foam concrete technology was developed in Housing, Building and Planning – Universiti Sains Malaysia as early as 1987 (Norizal, 2008).Lightweight foam concrete as a structural material has many uses. This includes multistory building frames, curtain walls, shell roofs, folded plates and precast elements.

Light weight concrete or foamed concrete can define as a versatile material which consists primarily of a cement based mortar mixed with at least 20% of volume air. Lightweight and free flowing, it is a material suitable for a wide range of purposes such as, but not limited to, panels and block production, floor and roof screeds, wall casting, complete house casting, sound barrier walls, floating homes, void infills, slope protection, outdoor furniture and many more applications.

Lightweight foamed concrete have many advantages compare with other materials. This technology was increased tremendously in Malaysia. There are many advantages uses of foam concrete in Malaysia such as due to high temperature lag, buildings constructed from foam concrete are able to accumulate heat, which allows minimizing heating expenses by 20-30%.

According to M.N Haque et al (2002).Lightweight concrete (LWC) is a very versatile material for construction, which offers a range of technical, economic and environment-enhancing and preserving advantages and is destined to become a dominant material for construction in the new millennium. Table 2.2 shows typical properties of foamed concrete.

Table 2.2 : Typical properties of foamed concrete.

Dry density (kg/m^3)	**Compressive strength (wet) (MPa)**	***E*-value (GPa)**	**Thermal conductivity (3% percent moisture) (W/mK)**	**Drying shrinkage (%)**
400	0.5-1.0	0.8-1.0	0.10	0.30-0.35
600	1.0-1.5	1.0-1.5	0.11	0.22-0.25
800	1.5-2.0	2.0-2.5	0.17-0.23	0.20-0.22
1000	2.5-3.0	2.5-3.0	0.23-0.30	0.15-0.18
1200	4.5-5.5	3.5-4.0	0.38-0.42	0.09-0.11
1400	6.0-8.0	5.0-6.0	0.50-0.55	0.07-0.09
1600	7.5-10.0	10.0-12.0	0.62-0.66	0.06-0.07

2.3 Advantages of Lightweight Concrete.

An innovative new technology has been developed for the construction of residential housing. The very versatile controllable lightweight concrete has excellent thermal and sound insulation properties, it is non-combustible, has good fire rating. It can be produced easily and can be used for casting into any shapes and can be pumped straight to where it is required.

Tommy Y. Lo et al (2006) stated that in recent years, more attention has been paid to the development of lightweight aggregate concrete. Lightweight concrete reduces building costs, eases construction and has the advantage of being a relatively 'green' building material.

Alex Liew Ming (2003) stated that combining a series innovative and visionary method, we have come out with a systemize way of casting lightweight concrete houses which are stronger, better and most of all very much more economical then whatever current methods. Even projects infrastructures will gain tremendously from this system as roads conceal perimeter drainage and storm water drainage can be cast in-situ as well with the system. By just using lighter weight walls for high-rise buildings, up to 25 % saving are achieve just on the pilings and structures not to mention its expected economical side of LCM wall castings.

According to Narayanan and Ramamurthy (1999), foam concrete offers many benefits such as reduces the dead weight of a structure which economies the design of supporting structures including the foundation and walls of lower floors.

Alex Liew Ming (2003) also stated that the benefits of foam concrete is wide, some of their benefits are reduces the dead weight of a structure, can be manufactured to precise specifications of strength and densities, possess excellent workability, can be