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Potential of lightweight foamed concrete in construction

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Progression in construction industry plays an important role to discover advanced methods and technologies for the future. Traditional technology which utilize conventional method in producing concrete has been established and being in use up to now. It used for different applications in construction such as architectural structures, wall partitions, foundations, runaways and highways. However, new innovative materials that can cater for different construction purposes are significant these days. Selection of proper building materials has to be done in order to minimize the energy usage in buildings. In addition, particular attention should be given on thermal insulation and fire resistance properties because low thermal conductive materials will enhance the thermal comfort of indoor environment. Hence this paper highlights on potential of utilizing lightweight foamed concrete in the construction industry.

Keywords*: concrete, lightweight, foamcrete, construction, technology*

1. Introduction

Development in construction industry plays a vital role to ascertain advanced approaches and technologies for the forthcoming. The traditional technology which utilize conventional method in producing concrete has been established and being in use up to now [1]. It used for different applications in construction such as architectural structures, wall partitions, foundations, runaways and highways. However, new innovative materials that can cater for different construction purposes are significant these days. Selection of proper building materials has to be done in order to minimize the energy usage in buildings. In addition, particular attention should be given on thermal insulation and fire resistance properties because low thermal conductive materials will enhance the thermal comfort of indoor environment.

In conjunction with that issue, construction industry is seeking for a new building structure which able to function as a thermal barrier, prevent heat and fire spread. Designing building structures against fire is constantly attracting more at-

tention and importance. As a remedy for unforeseen circumstances due to uncontrolled fire, the construction industry is gradually switching their interest towards the use of lightweight foamed concrete instead of using traditional concept building materials due to many encouraging characteristics such as lighter weight, excellent thermal and acoustical insulation, easy to fabricate, durable, minimal consumption of aggregates and cost effective [2]. These noticeable qualities indicate its strong potential as a material in building construction to increase indoor thermal comfort by reducing heat absorption. Global apprehension and governance on carbon footprint emissions have driven a considerable amount of research on green concrete around the world. In particular, special attention has been given on environmental deliberations with respect to base mix material sourcing, concrete mix design, design of structural component, construction method, construction technology, and the aspect of concrete structure maintenance. Therefore, it can be stated that concrete industry players in Malaysia play a significant role in achieving a holistic and sustainable development of the society.

In the present day, it should be acknowledged that most of the construction products are produced using materials that require a high amount of energy and not naturally sustainable which can lead to global problem. Hence, the use of natural fibers in lightweight foamed concrete is considered as a useful option in making concrete as a sustainable material to overcome this problem. In regard to this matter, it should be understood that there are various advantages in using foamed concrete which include lightweight, able to deliver good thermal insulation, and influent savings of several materials such as cement, fine aggregate, stable foam, and water. These materials are the basic components of foamed concrete but there are other types of admixture that can be used to enhance the strength of foamed concrete. Moreover, the low density of foamed concrete is caused by the absence of coarse aggregate which subsequently leads to lower self-weight. On another note, foamed concrete can be used for structural elements, semi-structural, non-structural partitions, and thermal insulating materials. In addition, foamed concrete are usually developed in various densities ranging from 400 kg/m^3 to 1800 kg/m^3 [3]. More importantly, foamed concrete are ecologically clean, inflammable, and easy to produce compared to other materials despite the fact that the mixing time of foamed concrete is longer than the conventional one to ensure proper mixing.

Furthermore, foamed concrete can be categorized as a wider class of lightweight foamed concrete which is made up of cement, water, fine sands, and trapped bubbles that stands in as an aggregate. More importantly, the mixture of lightweight foamed concrete can be replaced or added with other materials in order to enhance the strength and durability; for example, replacing the sand with other sand-like materials such as silica fume and fly ash [4]. In addition, it should be noted that foamed concrete encompasses of mortar matrix with at least 20% of entrapped air void which indicates that it can simply be produced with outstanding

workability, high level of sound insulation, good thermal protection, excellent fire resistance, decent heat absorption, good flowability, and self-compatibility

2. History of Foamed Concrete Technology

Foamed concrete is described as a cementitious material with at least of 20 per cent by volume of mechanically entrained foam into a cement paste or slurry in which air voids entrapped by means of suitable foaming agent. Foamed concrete is also known as porous concrete. The most basic definition of foamed concrete is that "mortar with air bubbles". The air content up to 75% by volume of the cement paste. Foamed concrete consist of Portland cement paste or cement filler matrix with homogeneous pore structure together with sand, water and foaming agent. Foamed concrete can be produced in a wide range of densities from 400 kg/m^3 to 1600 kg/m^3 by properly controlling the quantity of foam added into cement paste and its compressive strength ranging from 1MPa to 15MPa respectively [5].

Foamed concrete is not a new material in the construction industry and surprisingly it has a long history. It was patented first in 1923 and its usage is very limited until 1970. Romans used air entrainers to decrease density. Moreover, foamed concrete was mostly used as insulation material and its application as semi-structural lightweight material has increased after a few years. Also, it started to be applied in Netherlands for ground engineering and void filling works and in United Kingdom, a full-scaled assessment on the application of lightweight concrete as trench reinstatement was carried out in 1987 [5].

Foamed concrete can be placed easily and does not require compaction, vibrating or leveling. Foamed concrete can be used as a partition or light load bearing walls in low rise building although the mechanical properties of foamed concrete is low when compared to normal weight concrete. The density and the mechanical properties is inversely proportional to the percentage of porosity of foamed concrete. On the other hand, thermal conductivity of foamed concrete is also influenced by the density of constituent materials in the mortar slurry. Therefore, the thermal conductivity can be reduced by replacing cement with finer particles such as fly ash and silica fume. The ingredients used to cast foamed concrete into a desired shape are similar with the conventional concrete. Foaming agent used to generate foam with the aid of foam generator machine to substitute the place of aggregates. The contributions of foamed concrete which in faster building rates and reduction of dead load of structural elements are essential for current building industry. Due to fluidity, it can be poured into various shapes and sizes to fulfill current worldly building design structure. Although foamed concrete possess many attractive characteristics, its mechanical properties are lower compared to normal weight concrete. The previous studies conducted by many researchers have sorted out this issue and it has been proven that foamed concrete still can be used as a structural

element in buildings. This experimental study is divided into two main stages. The first stage is to conduct pilot study on the properties of foamed concrete. At this stage, detailed study and investigation were carried out to look into the properties of foamed concrete used for further applications [5]. In the second phase, experiments are performed to observe fire resistance and structural performance of foamed concrete wall panel in a big scale by means of suitable procedure and equipment.

3. Advantages and Disadvantages of foamed concrete

Foamed concrete possess more advantages in terms of its properties compared to normal strength concrete. It has faster building rate in construction industry and also reduction of dead load. Since foamed concrete is light in weight, it has low handling cost and lower haulage. Advantage of lower density foamed concrete is excellent thermal conductivity which can gives better insulation properties in terms of fire and sound absorption due to the cellular microstructure. Thermal conductivity of a foamed concrete sample with density of 1000 kg/m^3 is reported to be one-sixth of the value of common cement-sand mortar. The values of thermal conductivity are 5-30% of those recorded on normal weight concrete and the range between 0.1 W/mK and 0.7 W/mK for dry densities of 600-1600kg/m^3. Foamed concrete classified to be less efficient than denser concrete in reducing the transmission of air-borne sound. Normal weight concrete tends to deflect sound waves, meanwhile foamed concrete absorbs it, thus foamed concrete has higher sound absorption capacity. The cellular concrete does not contain significant acoustic insulation characteristics. On the other hand, foamed concrete also has its disadvantages as shown in table below. Table 1 shows the advantages and disadvantages of foamed concrete.

Table 1. Advantages and disadvantages of foamed concrete [6]

Advantages	Disadvantages
Rapid and relatively simple construction	Very sensitive with water content in the mixture
Economical in terms of transportation as well as in reduction of manpower	Difficult to place and finish because of the porosity and angularity of the aggregate. In some mixes, the cement mortar may separate the aggregate and floats towards the surface
Significant reduction of overall weight results in saving structural frames, footing or piles	
Most of lightweight concrete have better nailing and sawing properties than stronger conventional concrete	Mixing time is longer than conventional concrete to assure proper mixing

Higher air content within the foamed concrete will result in lower density, higher porosity and decrease of strength. The bubbles are sized typically 0.3-0.4mm diameter enclosed by cement. The stability of foam is actually created by these bubbles in foamed mortar. Meanwhile, the bubbles produced from the foam machine will replace the coarse aggregates and lead to reducing of density and compressive strength as well. The air voids in low density are typically bigger than in high density because of the dosage of foam added. The high amount of foam will generate more continuous pores within the concrete meanwhile less and rarely continuous pores in high density as shown in Figure 1.

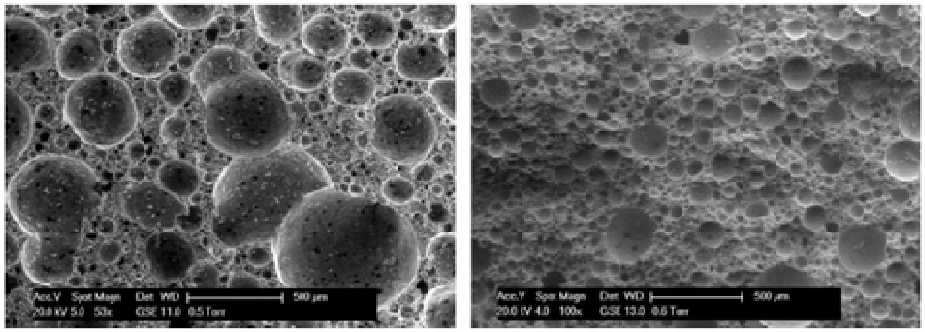

Figure 1. Air voids in 500kg/m^3 (left) and 1000kg/m^3 (right) [8]

The past centuries had shown that the Romans were able to create the earliest concrete consisting well-mixed small gravel, coarse sands, with hot lime and water. Meanwhile, a few years following the innovation, it was found that the concrete can have better durability and workability through the addition of animal blood into the mix which tend to produce small air bubbles when it is stirred. Apart from that, horse hair was also added into the mixes as admixture with the aim of enhancing the strength and reducing the shrinkage which is more or less similar to the use of fibers today. Incorporation of fiber into lightweight foamed concrete is for the purpose of improving its durability properties. Meanwhile, low volumetric of short fiber has been demonstrated to decrease the effect of early age on concrete durability. On another note, the development in the eminence of surfactants (foaming agents) and foam generator further facilitates the utilization of foamed concrete on a much greater scale such as roof insulation, concrete blocks, floor screed, and road sub-base in-fill material

4. Applications of foamed concrete

Basically, foamed concrete can be used as structural components, non-structural partitions and thermal insulating elements. In order to fulfill these

requirements for each application, various density of foamed concrete must be developed. The range of density (300kg/m^3 – 1840kg/m^3) plays important role in applications such as trench reinstatement, bridge abutment, large void filling works, bulk filling, backfills for retaining walls, insulation for foundations and roof tiles, pipeline infill and grouting for tunnel works, sound insulation and sandwich fill for precast units. Based on Gao et.al (1997) drops in density of foamed concrete with the same strength level permits preserving of dead loads for structural design and foundation. Foamed concrete can be used as lightweight blocks or bricks for high rise building. Also, panels and partitions can be produced by precast and cast in-situ from foamed concrete. It can be used in low cost terrace house, bungalows and low rise building for segmentations. The application elements can be structural, partially-structural and non-structural. High density product of foamed concrete will be used in structural elements meanwhile partially structural elements will be occupied by medium density and following with low density material of foamed concrete will be for non-structural elements. Water absorption by foamed concrete blocks is lesser than bricks, thus it has a longer lifespan. Table 2 shows various applications of foamed concrete with different density [9].

Since foamed concrete has good thermal insulation properties, its contributions for the construction industry especially in insulation works are mostly acceptable. Low in weight and better thermal properties make foamed concrete is potential to be used in housing applications. Foamed concrete is already been used as roofing insulation material in South Africa, meanwhile its low density influences the creation of roof slopes.

Table 2. Applications of foamed concrete with different densities [9]

Density	Applications
Density 300-600kg/m^3 (Made of cement & sand)	• Used in roof and as insulation against heat • Interspace filling between brickwork leaves • Insulation in hollow blocks and any other filling
Density of 600-900kg/m^3 (Made of sand, cement and foam)	• Manufacture of precast blocks and panels • Slabs for false ceilings • Thermal insulation and soundproofing screeds • Bulk fill application
Density of 900-1200kg/m^3 (Made of sand, cement and foam)	• Used in concrete blocks and panels for outer leaves of buildings • Architectural ornamentation and partition walls
Density of 1200-1600kg/m^3 Made of sand, cement and foam)	• Used in precast panels of any dimension for commercial and industrial use • In-situ casting of walls, garden and ornaments

Besides that, foamed concrete has been used to manufacture support structure in mining area in South Africa, while a research is conducted on thermal resistant performance in Ukraine [10]. In Malaysia, the application of foamed concrete as wall panel attracts the attention of developers and becoming popular in these 10 years. The major application of foamed concrete is SMART tunneling project in Kuala Lumpur. Foamed concrete was used to shield the diaphragm wall when the tunneling machine is moving out into junction box. In Middle and Far East area, 3000 residential buildings were constructed using foamed concrete with density of 1100 to 1500kg/m^3 in 1948 and 1958. After 25 years, the buildings were assessed and found that these housing performed better with least maintenance compared to contemporary timber or bricks and concrete houses [11].

4. Conclusion

Foamed concrete is generally used as insulation and void filling material but it contributes many benefits with various applications as it has noticeable characteristics such as lighter weight, good thermal and acoustical insulation, fire resistant, ease in fabrication, is cost effective and environmentally friendly. Since foamed concrete has good thermal insulation properties, its contributions for the construction industry especially in insulation works are mostly acceptable. Low in weight and better thermal properties make foamed concrete is potential to be used in housing applications.

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