PERFORMANCE OF LIGHTWEIGHT FOAMED CONCRETE USING LATERITE AS SAND REPLACEMENT

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ABSTRACT

Lightweight foamed concrete (LWC) has been successfully used and it has gained popularity due to its lower density than conventional concrete. It is created by uniform distribution of air bubbles throughtout the mass of concrete. Recently, most studies on LWC concern on the influence of filler type and the particle size of sand on the strength. In this study, the strength of LWC with density 1400 kg/m^3 was produces due to different percentage of laterite as sand replacement. Four series of LWC mix designs with ratio 2:1:1 comprises of 0%, 5%, 10% and 15% as sand replacement (by total weight of sand) were considered. Two types of testing were conducted namely compressive strength and modulus of elasticity (MOE). The tests were prepared in order to determine the effect of using different percentage of laterite due to different curing ages. The results revealed that, increasing the percentage of laterite as sand replacement, the strength improves significantly due to compressive strength and MOE for all mixes. It also indicated that the curing ages significantly affect its strength. However, it is noted that the optimum mix design to produce LWC-Laterite was obtained by using 5% of laterite as sand replacement.

ABSTRAK

Konkrit buih berongga (LWC) telah digunakan secara meluas dan mendapat sambutan yang baik kerana ketumpatannya lebih rendah berbanding dengan konkrit biasa. Ia dicipta dengan pengagihan yang seragam dari gelembung udara melalui jisim konkrit. Pada masa kini, kebanyakan kajian telah dijalankan terhadap konkrit buih berongga yang mempengaruhi kekuatannya dari pelbagai segi jenis dan saiz butiran pasir. Dalam kajian ini, kekuatan mampatan konkorit buih berongga dengan ketumpatan 1400 kg/m^3 telah dihasilkan dengan menggunakan perbezaan peratusan laterit sebagai pasir gantian. Empat siri konkrit buih berongga telah disediakan dengan campuran nisbah 2:1:1 akan diggantikan dengan peratusan laterit yang berbeza iaitu 0%, 5%, 10% dan 15% sebagai pasir gantian daripada jumlah berat pasir sebenar. Dua jenis ujian dijalankan iaitu kekuatan mampatan dan modulus elastik. Perlaksanaan ujian ini adalah untuk menentukan kesan-kesan dari penggunaan peratusan laterit dengan masa pengawetan yang berbeza. Keputusan daripada kajian mendedahkan, kekuatan mampatan dan modulus elastik konkrit buih berongga meningkatkan apabila peningkatan peratusan laterit sebagai pasir gantian. Peningkatan masa pengawetan akan mempengaruhi kekuatan mampatan konkrit buih berongga. Walaubagaimanapun, didapati rekabentuk campuran yang optima untuk menghasilkan konkrit buih berongga dengan laterit adalah campuran yang mengandungi 5% laterit.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is known as a common material which is widely used in the construction industry, from basic work to multi-storey building and mega structure. Concrete is a material where mixture by cement, water, and aggregate (fine and coarse) which must be workable, resistance to freezing, chemicals resistance, low permeability, wear resistance, and economy (Metha & Monteiro, 2006).

Lightweight foamed concrete was used nearly a century ago in the special precast application of autoclaved aerated concrete, with the first reported applications being two apparently independent initiatives in 1923, one in Denmark the other in Sweden. In this application, the entrained gases is actually produced by the generation of hydrogen gas using powdered aluminum in a slurry mix made alkaline by the inclusion of Portland cement and sometimes lime addition (Beningfield et al., 2005).

Lightweight foamed concrete based on this concept began to adopted in the early 1980's and at that time take up began to accelerate in much of Europe with Germany in particular leading the way. Within the UK specifications began to appear in the early 1990's and the market has continued to grow rapidly, with current estimates of perhaps 300,000 m^3 to 350,000m^3 per annual used in the UK (Gaimster et al., 2005).

Aldridge (2005) stated that, lightweight foamed concrete is more popular usage in the construction field due to reduce the cost, lightness and easy to work in this field. In its basic form foamed concrete is blend of sand, cement, and water (the base mix) and a pre-formed foam, which in itself is a mixture of foaming agent (either synthetic or protein based), water and air.

Lightweight concrete also know as foamed concrete which is lightweight material formed by entrapping or generating small bubbles of air into Portland cement mix by mechanical or chemical means. Lightweight foamed concrete with density from 400 kg/m^3 to 1800 kg/m^3 can be produced strength up to 12 MPa. Characteristics of lightweight foamed concrete is depends on the mix design there are however a number of general properties which are constant across a range of mix designs are high strength to weight ratio, low coefficient of permeability, low water absorption, good freeze/thaw resistance, high modulus of elasticity, low shrinkage, thermal insulating properties, and fire resistance.

This study is important to determine the performance of lightweight foamed concrete by adding various percentages of laterite as sand replacement by weight of sand and determine compressive strength of it and determine the effect of using different percentages of laterite as sand replacement to lightweight foamed concrete.

1.2 Objectives of Study

The objectives of this study are:

i. To determine the compressive strength of lightweight foamed concrete with different percentage of laterite (LWC-Laterite) as sand replacement.

ii. To determine the modulus of elasticity of lightweight foamed concrete with different percentage of laterite (LWC-Laterite) as sand replacement.

iii. To determine the effect of using different percentage of laterite as sand replacement to lightweight foamed concrete.

1.3 Problem Statement

The ways to control the density of lightweight foamed concrete become difficult. By using different quantities of foamed agent will affect the strength and quality of foam concrete.

Through this problem, one of the solutions suggested is the use of laterite as sand replacement with a portion by total weight of sand. Lightweight foamed concrete can be made cheaper by replacing some of sand with laterite.

Currently, problem is every construction was using the river sand as their main material to construct the element of building that be less of river sand in green mother nature. In this study, using the laterite as sand replacement could be use to overcome this problem. To determine the optimum percentage of laterite as sand replacement to get the maximum strength of the lightweight foamed concrete.

1.4 Scope of Study

In this study, the lightweight foamed concrete were produced to investigation the compressive strength and modulus of elasticity using different percentage of laterite as sand replacement. The percentage of laterite as sand replacement by total weight of sand such as 0%, 5%, 10% and 15%. Laterite were mixed with cement, fine aggregate, water and foam agent. The design of density for lightweight foamed concrete must be obtained is 1400 kg/m^3 with mix proportion ratio 2:1:1 comprises of cement to sand to water ratio 0.5. Otherwise, the lightweight foamed concrete without sand replacement were design as a control mix.

36 cubes concrete were prepared to be test on compressive strength and 36 cylinders are prepared to be test on modulus of elasticity. Minimum three samples will be prepared for each parameter and the sample must accordance to BS: 1881: Part 108: 1983 for 0%, 5%, 10% and 15%. For cubes and cylinder have the dimension 150 mm x 150 mm x 150 mm and 150 mm x 300 mm respectively. All the specimens were tested after expose to air curing at 7, 28, 60 days. The number of sample prepared as shown in Tables 1.1 and 1.2.

After the specimens matured at the followed curing days, the compressive test and modulus of elasticity was conduct in the FKASA Laboratory. The method of testing is according to the BS: 1881: Part 116: 1983.

Table 1.1 Numbers of Cube Specimens Replace with Laterite

Mix Design	Mix proportion	Percentage of laterite (%)	Numbers of sample (cubes)		
	Cement: sand: water		7 days	28 days	60 days
1400 kg/m^3	2 : 1 :1	(Control)	3	3	3
		5	3	3	3
		10	3	3	3
		15	3	3	3

Table 1.2 Numbers of Cylinder Specimens Replace with Laterite

Mix Design	Mix proportion	Percentage of laterite (%)	Numbers of sample (cylinder)		
	Cement: sand: water		7 days	28 days	60 days
1400 kg/m^3	2 : 1 :1	(Control)	3	3	3
		5	3	3	3
		10	3	3	3
		15	3	3	3

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Conventional concrete made with natural aggregate originating from hard rock has a high density lies within the range of 2200 to 2260 kg/m^3 and represents a large proportion of the dead load on a structure. According to BS: 8110: Part 2: 1985 classifies the lightweight foamed concrete is one with a density of 2000 kg/m^3 or less. Lightweight foamed concrete can be gaseous or foamed concrete that uses specially prepared chemicals; it can be a no-fines concrete that uses ordinary gravel or crushed stone, a normal-weight aggregate concrete with an excessive amount of entrained air, or a concrete that is made from lightweight aggregates.

Lightweight foamed concrete is a class of aerated concrete. Aerated concrete can be classified according to the methods and agents used to introduce air in the concrete. Aerated concrete can be produced by introducing air entraining agent, gas forming chemicals and foaming agents. Concrete which is aerated using foaming agent is known as lightweight foamed concrete. Foaming agents can be synthetic based or protein based.

The use of lightweight foamed concrete offer many benefits and advantageous particularly cost saving, fast completion and easy application compared to other materials such as steel and timber. Lightweight foamed concrete is characterized by its low compressive strength and high insulation against heat and sound. The compressive strength and other functional properties of lightweight foamed concrete are greatly influenced by the amount of air content introduced by foaming agents.

The application of lightweight foamed concrete in civil engineering works is very broad as it can be used in almost every parts of building from the superstructure right down to the substructure, including wall panels and roofing. Any conventional panels or masonry units used for load and non-load bearing walls using normal concrete can be replaced directly by foamed concrete panels and units. Very low density lightweight foamed concrete can be used as thermal and sound insulation panels, filtering media and floating blocks for fishery purposes.

Lightweight foamed concrete can also be used to cast elements for architectural purposes, pottery, void filling, trench reinstatement, foundation raising and swimming pool. In highway construction, lightweight foamed concrete can be applied as soil filling for sub-base, bridge abutments and bridge embankment. It is worth noting that the use of lightweight foamed concrete is popular in other countries such Europe, Japan and United Kingdom.

2.2 Historical Development of Lightweight Foamed Concrete

Romans in the second century where 'The Pantheon' has been constructed using pumice, the most common type of aggregate used in that particular year (Samidi, 1997). Since then, the use of lightweight foamed concrete has been widely spread across other countries such as USA, United Kingdom and Sweden. In UK, 10 years ago the usage of lightweight foamed concrete has grown more rapidly than any other "special" concrete product. Lightweight foamed concrete can be defined as a type of concrete including an expanding agent in that it increases the volume of the mixture while giving adding qualities such as fallibility and lessened the dead weight (Zakaria, 1978). Lightweight foamed concrete is 87% to 23% lighter than the conventional concrete with a dry density from 300 kg/m^3 up to 1840 kg/m^3. The main specialties of lightweight foamed concrete are its low density and thermal conductivity. Its advantages included reduction of dead load, faster building rates in construction and lower haulage and handling costs.

2.2.1 Application of Foam Concrete

Rudnai et al., (1963) and Narayanan et al., (2000) stated that lightweight foamed concrete also includes in structural elements, non structural partitions and thermal insulating materials. Manufacturers developed lightweight foam concretes of different densities to suit the above requirements. The density of lightweight foamed concrete ranges from 300 kg/m^3 to 1800 kg/m^3 and these products were used in trench reinstatement, bridge abutment, void filling, roof insulation, road sub-base, wall construction, tunneling etc.

According to Gao et al., (1997) noted that self weight represents a very large proportion of total load on the structure, and there are clearly considerable advantages in reducing the density of concrete in concrete construction. A decreased density of concrete for the same strength level permits a saving in dead load for structural design and foundation.

Lightweight foamed concrete can be applied in the field of construction such as: in lightweight bricks or blocks for high-rise buildings, in panels and partition walls of various dimensions either pre-cast or poured in place, cast in-place for a unit of low cost terrace houses and bungalows, in all types of insulation works, including cavity walls, in roofing and ceiling panels, in sound proofing application, in pre-cast industrial and domestic building panels, both internal and external, in pre-cast or in-place exterior wall facades for all sizes of buildings, in foundations for roads and sidewalks, in sub-surface for sport arenas, e.g. tennis courts, in infill sections between beams of suspended floors, in aircraft arresting beds, in crash barriers, in explosion-resistant structure, in highway sound barriers and in floating barge, jetties, walkways, fish cages and floating homes.

Lightweight foamed concrete (LWC) has several and always increasing applications in all types of construction work. Some of the most common applications are shown in Table 2.1.

Table 2.1: Application of Foamed Concrete

Source: Neville, 1985

Density (kg/m^3)	Applications
300 to 600 kg/m^3	Lightweight and insulating cements for floors foundation, for heat insulation and slope for flat roofs, rigid floors foundation, tennis courts foundation, interspace concrete filling, raceways insulation; thermo insulating blocks, steel structures fireproofing, tunnels and pipelines compensating mass, dumps, foundation and coverings land reclamation and consolidation underground cavities infill and all types of infill where an elevated thermal insulation is required.
600 to 900 kg/m^3	Stables and pig-sties foundations; industrial foundations, partition and tampooning slabs, ceiling slabs, concrete and Lightweights Concrete mixed panels.
900 to 1200 kg/m^3	Blocks for outside walls, slabs for partitions, concrete and light weight concrete mixed panels for covering, foundations for elastic floors.
1200 to 1700 kg/m^3	Prefabricated panels for civil and industrial buildings plugging; walls casting, gardens ornaments.

In Malaysia the first major application of lightweight foamed concrete in Malaysia is at the SMART tunnel project in Kuala Lumpur. The lightweight foamed concrete specified was density 1800 kg/m^3 which achieved compressive strength of 3 N/mm^2 at the age of 28 days. Otherwise lightweight foamed concrete inert, finely divided materials such as powdered waste plastic, rice husk and other locally available biomass are also being experimented. The composition is proposed to be injected at prescribed locations with innovative precast lightweight hollow-core concrete pile to effect replacement of portions of the soft soil. The system is expected to provide cost effective geotechnical solution as the surrounding soft ground becomes compacted while foamed concrete solidifies in situ. Foundation system with the utilization of used tyres are being experimented in some housing project in Malaysia. Successful deployment of the system is expected to provide a fast track method for affordable quality assured housing. The system is applicable for the homeless people who urgently need a decent shelter. Technical specification has been prepared for an industrialized building system complying with modular coordination (Lee, 2005).

2.3 Compressive Strength

Kearsley (2000) stated that the compressive strength decreases exponentially with a reduction in density of foamed concrete. The compression strength will be influenced by the specimen size and shape, the method of pore formation, direction of loading, age, water content, characteristics of ingredients used and the method of curing. According to Aldridge (2005) found that, the mixture ratio between the cement, water and sand, curing regime, type and particle size distribution of sand and type of foaming agent used also will affecting the strength of foam concrete.

Kearsely (2000) noted that dry density of foam concrete between 500 kg/m^3 and 1000 kg/m^3, the compressive strength decreases with an increase in void diameter. For densities higher than 1000 kg/m^3, as the air-voids are far apart to have an influence on the compressive strength, the composition of the paste determines the compressive strength. Jones et al., (2005) reported that small changes in the water to cement ratio does not affect the strength of foam concrete but the compression strength increased due to higher water and cement ratio.

2.4 Factor Affecting the Compressive Strength of Foam Concrete

The compressive strength of lightweight foamed concrete is depend on many factors such as the sand to cement ratios (s/c), curing duration, water to cement ratios (w/c) and particle size distribution of sand. In this present section, the factor affecting the compressive strength of lightweight foamed concrete will be discussed.

2.4.1 Different Density of Lightweight Foamed Concrete

Hamidah et al., (2005) studied on compressive strength of lightweight foamed concrete mix of different sand cement ratio and curing conditions was shown the compressive strength of lightweight foamed concrete increases as the density increases and sand-cement ratio decreases. That is means lower-density lightweight foamed concrete can achieve a strength equals to higher density foamed concrete by increasing the cement content. Otherwise cheaper mix of foamed concrete would only be possible at higher sand content. In a lower density foamed concrete, the amount of sand also limited to avoid segregation and collapse of the mix.

Generally, the density of a porous media is dependent on the amount of pores and pores size distribution in the media. It would have been expected therefore, that a higher density foamed concrete would record a higher compressive strength therefore, that a higher density foamed concrete would record a higher compressive strength due to its lower porosity. Narayanan (2000) studied the relationship between pore size and compressive strength. They concluded that the compressive strength is dependent on the amount or distribution of pores and pore sizes. The size and the amount of pores influence the compressive strength of a porous material, with smaller size air pores leading to higher compressive strength (Tang, 1986).

2.4.2 Different Curing Day

For lightweight foamed concrete (LWC), curing plays an important role for strength development. In this study, the compressive strength was tested at different curing condition of the LWC, which are water and air curing. The samples were cured in three different ages before test the specimen, namely 7 days, 28 days, and 90 days.

Once more it proves that the strength for air cured sample is higher than water cured sample (Shan, 1995). More Durable Concrete Good concrete, properly cured, has fewer pores and crevices where water can enter, freeze, expand and crack the concrete. Air entrainment helps make more durable concrete, but its use must also be accompanied by proper curing.

Improper curing can easily the strength of even the best lightweight foamed concrete by 50%. Curing simply means keeping the water in the lightweight foamed concrete where it can do its job of chemically combining with the cement to change the cement into tough "glue" that will help develop strong, durable concrete. Good curing means keeping the LWC damp and above 50° F (10° C) until the foamed concrete is strong enough to do its job (Anon, 2009a).

2.4.3 Effect of Compressive Strength Due to Different Percentage of Fly Ash

The strength development with time of all the foamed concretes as shown in Figure 2.1. Overall strength between 0.5 MPa and 2 MPa were observed, exception of Portland cement with the 70% Fly Ash after 90 days of curing. Portland cement/ Fly Ash mixes achieved strengths greater than that of the reference Portland cement concrete. In addition, whilst the Portland cement foamed concrete strength remained fairly constant between 28 and 90 days, the strength of the Portland cement / Fly Ash mixes contained to increase beyond 28 days (Papayianni, 2005).

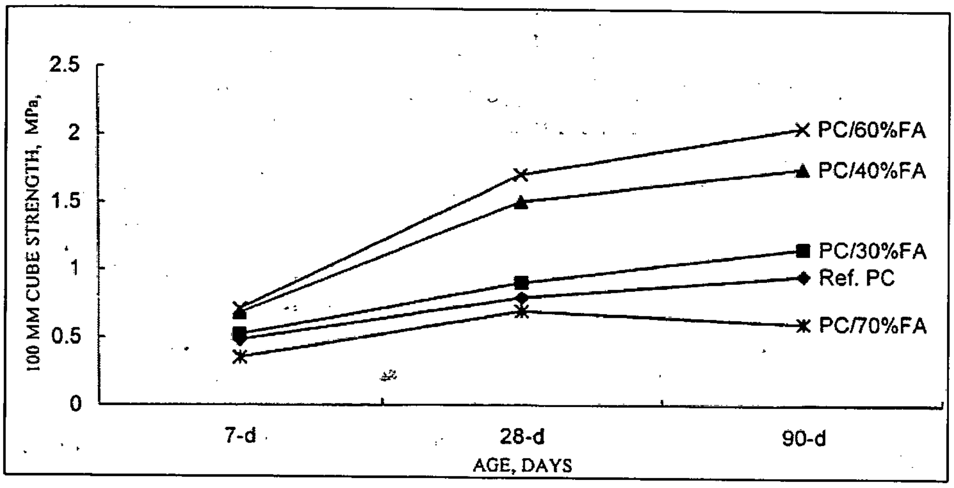

Figure 2.1: Compressive Strength Development of Cellular Concrete Mixtures

2.5 Mechanical Properties of Lightweight Foamed Concrete

Mechanical properties of lightweight foamed concrete is more related to the samples size and shape, method of pore formation, direction of loading, age of samples, characteristic of the ingredients were used and method of curing.