EFFECT OF FOAMED CONCRETE WITH EGG ALBUMEN

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ABSTRACT

In Malaysia, the usage of foamed concrete is widely used in construction of buildings which can reduce the cost and time of project. This study is to investigate the effect of foamed concrete strength with 1% and 5% egg albumen were used. This study was conducted to improve the performance of foamed concrete by using egg albumen where egg albumen is considered as an agriculture waste material. The tests conducted in this study were compression strength, flexural strength and drying shrinkage. A total of 54 cubes (150mm x 150mm x 150mm) and 54 prisms (500mm x 100mm x 100mm) were casted according to three different mixtures including control foamed concrete of 1400kg/m^3 density. The samples were cured under two curing conditions which were air and water curing for 7, 14 and 28 days before testing. Three types of mixtures were cast based on 1% egg albumen foamed concrete (1% EAFC), 5% egg albumen foamed concrete (5% EAFC) and 100% foamed concrete (100% FC). The result for 1% EAFC mixture in air curing shows 30% higher compressive strength and 90% higher flexural strength with increase density when compared with control foamed concrete at 28th days while compressive and flexural strength in water curing was 84% and 80% higher. As for 5% EAFC, it consists of unstable compressive strength and higher flexural strength with increase density when compared with control foamed concrete which was 64% and 35% higher for air curing while compressive and flexural strength in water curing was 19% and 14% higher at 28th days. Water curing for 100% FC and 1% EAFC mixtures has higher compressive and flexural strength compared to air curing while 5% EAFC is vice versa. Shrinkage value for 100% FC and 1% EAFC are more stable while shrinkage value for 5% EAFC is not consistent. The significant of this study is to produce a lightweight concrete with waste material which is more environment friendly and improved properties.

ABSTRAK

Di Malaysia, konkrit buih digunakan secara luas dalam industri pembinaan kerana ia boleh mengurangkan kos dan masa untuk sesuatu projek. Kajian ini adalah menyiasat kesan kekuatan konkrit buih dengan 1% dan 5% telur putih. Kajian ini dijalankan untuk meningkatkan prestasi konkrit buih dengan menggunakan telur putih dimana telur putih adalah dianggap sebagai bahan buangan pertanian. Ujian yang dilakukan dalam kajian ini adalah kekuatan mampatan, kekuatan lenturan dan pengecutan kering. Sejumlah 54 kiub (150mm x 150mm x 150mm) dan 54 prisma (500mm x 100mm x 100mm) dibancuh mengikut tiga campuran yang berbeza termasuk konkrit buih kawalan dengan 1400kg/m^3 kepadatan. Sampel-sampel tersebut diawet dalam dua keadaan pengawetan iaitu pengawetan udara dan pengawetan air untuk 7, 14 dan 28 hari sebelum pengujian. Tiga jenis campuran dibancuh berdasarkan 1% konkrit buih telur putih (1% EAFC), 5% konkrit buih telur putih (5% EAFC) dan 100% konkrit buih (100% FC). Keputusan pengawetan udara untuk campuran 1% EAFC mencapai 30% kekuatan mampatan dan 90% kekuatan lenturan yang lebih tinggi berbanding dengan konkrit buih kawalan pada hari ke-28 dengan peningkatan kepadatannya manakala kekuatan mampatan dan lenturan untuk pengawetan air adalah 84% dan 80% lebih tinggi. Bagi 5% EAFC, kekuatan mampatannya tidak stabil dan kekuatan lenturannya adalah lebih tinggi berbanding dengan konkrit buih kawalan dengan peningkatan kepadatannya dimana ia mencapai 64% dan 35% lebih tinggi untuk pengawetan udara manakala kekuatan mampatan dan lenturan untuk pengawetan air adalah 19% dan 14% lebih tinggi untuk hari ke-28. Pengawetan air untuk campuran 100% FC dan 1% EAFC mencapai kekuatan mampatan dan lenturan yang lebih tinggi berbanding dengan pengawetan udara manakala 5% EAFC adalah sebaliknya. Pengecutan untuk 100% FC dan 1% EAFC adalah lebih stabil manakala pengecutan untuk 5% EAFC adalah tidak konsisten. Signifikan kajian ini adalah menghasilkan konkrit ringan mesra alam sekitar dan sifat yang dipertingkatkan dengan bahan buangan.

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LIST OF ABBREVIATIONS

ASTM	-	American Standard Testing Method
BS	-	British Standard
EAFC	-	Foamed Concrete with Egg Albumen / Egg Albumen Foamed Concrete
EC	-	Eurocode Standard
FC	-	Foamed concrete
LCM	-	Lightweight Construction Method
MS	-	Malaysian Standard
OPC	-	Ordinary Portland Cement
cm	-	Centimeter
in	-	Inch
kg	-	Kilogram
kg/m^3	-	Kilogram per meter cube
m	-	Meter
m^3	-	Meter cube
mm	-	Millimeter
N/mm^2	-	Newton per millimeter square
N/mm^3	-	Newton per millimeter cube
kN/mm^2	-	Kilo Newton per millimeter square
MPa	-	Mega Pascal
W/mk	-	Watt per meter per kelvin
b	-	Width
d	-	Depth
f	-	Flexural strength, N/mm^2
F	-	Maximum load
l	-	Distance
m	-	Modulus of rupture, N/mm^2

P	-	Load
%	-	Percent
$\leq$	-	Less or equal to
>	-	More than

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In the 21st centuries, structural construction is one of the famous fields in the world. Mega structure constructions such as longest bridge or tallest building in the world were constructed between potential countries to shows the country's ability and also to ease people's life. Concrete is an important construction material used since ancient time and is widely use in nowadays. Concrete demand is increasing in the construction industry depending on the development of the country. A lot of research and methods are tried to improve the quality of the concrete in every country all around the world. Foamed concrete is an example of research that has been done to improve the properties of concrete. In west Malaysia, the usage of foamed concrete is widely used in construction of buildings which can reduce the cost and time of project. Basically, the dry density of the foamed concrete ranges from 300kg/m^3 to 1700kg/m^3 as stated by Aldridge, D. (2005). Several characteristic in using foamed are high strength to weight ratio, lower water absorption, thermal insulating properties, shock absorbing qualities and others.

Nevertheless, the innovation of concrete production should not cease and need to be continued to improve the concrete properties which can provide benefits in construction world in future. There are various types of additive added into the concrete to improve the properties of the concrete in term of strength, durability and others but this type of additive is mostly chemical additive and could be costly. So, this led to discovery of the potential using agricultural wastes as an additive to the foamed concrete.

Waste materials are a problematic thing that needs to be dispose to avoid pollution to the environment while disposing waste material usually uses a lot of energy such as petrol usage, implementation of factory work, burning and so on. So, the reuse of the material in the way which can benefits the society is important. The example of solid wastes used in foamed concrete in the previous study is rice husk, expanded polystyrene beads and paper sludge which was stated by Lee, Y. L., and Hung, Y. T. (2005).

Egg albumen is considered one of the agriculture wastes because of the primary usage of egg yolk only to make mayonnaise, custard, cake or others. The egg albumen is approximately 2/3 of the egg's weight without its shell with nearly 90% of that weight is from water. The remaining weight of egg albumen comes from protein, trace mineral, fatty material, vitamins, and glucose. This constituent such as protein may contribute to some effect in the properties of foamed concrete. In Malaysia, the application of egg albumen in foamed concrete is low and it can be consider as new research in foamed concrete. This study was focused on the effect of foamed concrete with egg albumen (EAFC).

1.2 Problem Statement

Nowadays, time, budget and environment issue is very important in the construction world. The usage of foamed concrete can reduce the dead load of the building or structure which indirectly reduces the cost and time of the project. The weight of concrete influence the cost of the project because the heavier the concrete, the better the quality of the beam or column concrete need to be constructed to support the dead load from above with the increase of number of storey in the building. With this, the cost of the project will be increase highly proportional with the number of building storey constructed. The usage of waste material will also reduce the cost of the project. Nowadays, waste materials are becoming a serious problem in our society which pollutes our environment and it keeps on increasing. Decomposing waste materials would cost a lot of money and energy in which it is not economical. So, a solution needs to be done by reuse the waste materials which can bring benefits to the society. In this study, a solution is needed by using agriculture waste material such as egg albumen as an additive to improve the strength of foamed concrete (FC). If this research is successful, the uses of EAFC will contribute to the society with lighter and more environmental friendly concrete with waste to wealth concept applied.

1.3 Objectives

1. To determine compressive strength of FC by using egg albumen as additive to foamed concrete with air and water curing.

2. To determine flexural strength of FC by using egg albumen as additive to foamed concrete with air and water curing.

3. To determine drying shrinkage of FC by using egg albumen as additive to foamed concrete with air and water curing.

1.4 Scope of Works

In determining the effect of EAFC compressive strength, flexural strength and its drying shrinkage, comparison was needed to determine whether there are improvements of the result. Three types of samples were compared, which first sample is 1% EAFC, second is 5% EAFC, and third is 100% FC. The samples dimension for compression strength test are 150mm x 150mm x 150mm (length x width x height) while samples dimension for flexural strength are 500mm x 100mm x 100mm (length x width x height). Figure 1.1 and Figure 1.2 show the dimensions of the samples. The density of 1400kg/m³ was used for the entire FC samples in which the density was controlled by the amount of foam used in the mortar.

The water-cement ratio for the specimens were cast using mix ratio of 1:2:0.5 (cement: sand: water) with water-cement ratio of 0.5 and sand-cement ratio of 2. As stated by Hassoun, M. N., and Al-Manaseer, A. (2005) "for complete hydration of a given amount of cement, a water-cement ratio (by weight) equal to 0.25 is needed. A water-cement ratio of about 0.35 or higher is needed for the concrete to be reasonably workable without additives". Total of 54 cubes and 54 prisms were casted which six cubes and six prisms for each type of the sample were tested for its compression strength and flexural strength on 7th, 14th, 28th days after the foamed concrete has been cast. The six cubes or prisms were consisting of three cubes or prisms of air curing and three cubes or prisms of water curing. Drying shrinkage of three types of prism samples were tested every day after the sample being cast using drying shrinkage dial gauge.

All the cubes and prisms were tested at Faculty of Civil Engineering and Earth Resources of Universiti Malaysia Pahang laboratory using Compression Testing Machine, Flexural Testing Machine and drying shrinkage dial gauge. For compression test, load with flat surface was increased on the cube until the cube failed. For flexural strength test, the prisms were supported by two supports with one loading point acting on the middle of the prism. The load was increased until the prism failed. Figure 1.3 shows the flow chart of this study.

These tests have their own standards which are available in British Standard (BS), Eurocode Standard (EC), American Standard Testing Method (ASTM), Malaysian Standard (MS), and other countries standard code of practice. The example of standard code of practice for compression strength test and the dimension of the cube are referred to BS 1881: Part 115:1986 and BS 1881: Part 116:1983 while flexural strength test and the dimension of the prism are referred to BS 1881: Part 118:1983.

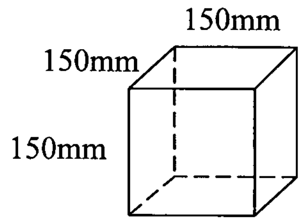


Figure 1.1: Dimension of cubes

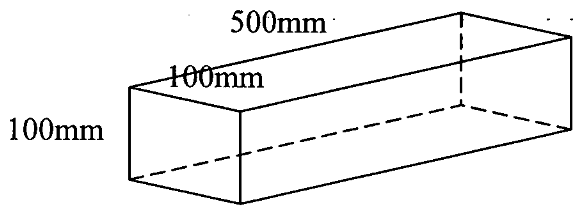
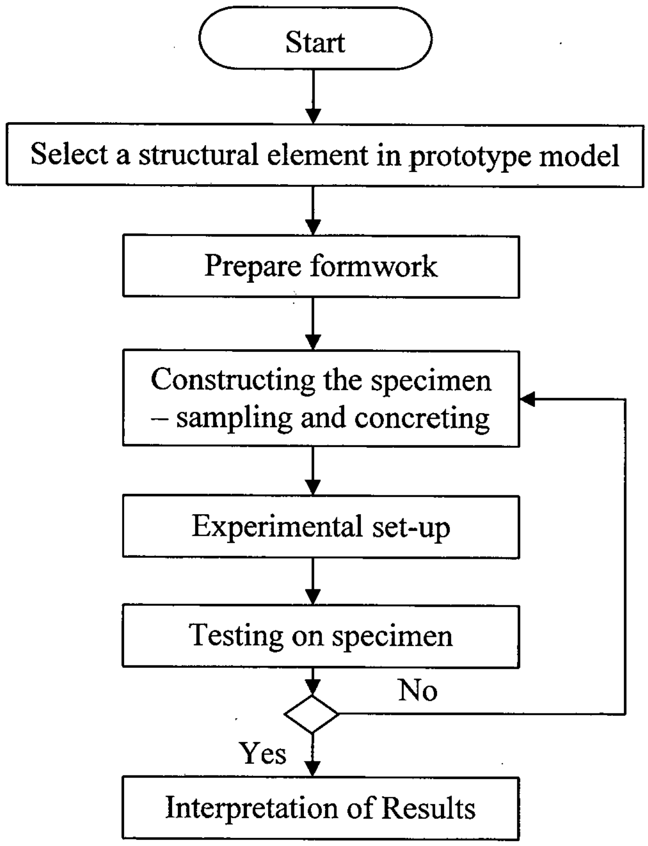


Figure 1.2: Dimension of prisms



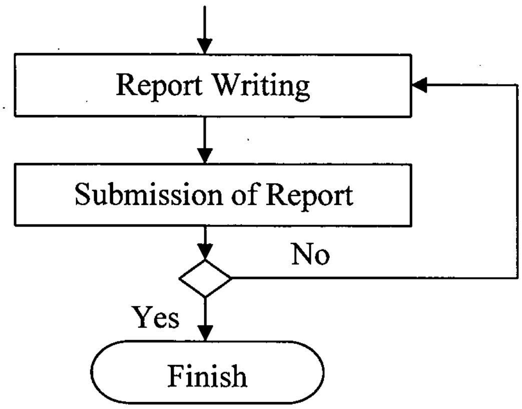


Figure 1.3: Flow Chart of Study

1.5 Significance of Study

Concrete is important in construction industry. So, different types of method are use to produce a new product and improve its quality. In Malaysia, the usage of environmental friendly concrete or green concrete is consider low and this study provide a new method in producing a lightweight concrete with waste material which is more environment friendly concrete and improved properties. This method is still new in which the testing is important to see the increasing of flexural strength in foamed concrete and its drying shrinkage after it is mixed with egg albumen. It could be a new product that can be commercial in the future if the study is successful. Other than that, cost of the project can also be reduce in the future with better strength and more environmental friendly product.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, concrete demand is increasing in the construction industry depending on the development of the country. A lot of research and methods are tried to improve the quality of the concrete. Different types of concrete need to be determine and use it in suitable construction to gain cost-saving advantages and maintain the quality of the construction. The concrete weight is one of the factors that affect the cost of the project. So, foaming agent is use to mix with concrete mixture to reduce the density of the concrete which proportionally reduce its weight. Lightweight foamed concrete is very light but its strength is reducing due to the density which is reduced. Ban, S. C., and Newman, J. (2003) stated that foamed concrete is classified as having an air content of more than 25 per cent.

Hamidah, M. S. et al. (2005) stated that foamed concrete is cement-based slurry into which stable and homogeneous foam is mechanically blended, either by mixing or by injecting. The dry density of the foamed concrete ranges from 300kg/m^3 to 1700kg/m^3 as stated by Aldridge, D. (2005). Several characteristic in using foamed are high strength to weight ratio, lower water absorption, thermal insulating properties, shock absorbing qualities and others.

The idea of using waste materials as an additive in concrete was not new. This innovative idea not only helps to reduce the wastes of materials which will cause pollution to the environment but also reuse the material as benefits to the society with the waste to wealth concept. Other than that, the production of concrete that is environmental friendly is also important which lead to the use of agricultural wastes.

Egg albumen is considered one of the agriculture wastes because of the primary usage of egg yolk only to make mayonnaise, custard, cake or others. The egg albumen is approximately 2/3 of the egg's weight without its shell with nearly 90% of that weight is from water. The remaining weight of egg albumen comes from protein, trace mineral, fatty material, vitamins, and glucose. This constituent such as protein may contribute to some effect in the properties of foamed concrete. In Malaysia, the application of egg albumen in foamed concrete (EAFC) is low and it can be consider as new research in foamed concrete (FC). This research is focus on the effect of EAFC compressive strength, flexural strength and its drying shrinkage.

2.2 Historical of Foamed Concrete

According to Beningfield, N., Gaimster, R., and Griffin, P. (2005), foamed concrete was used nearly century ago in the special precast application of autoclaved aerated concrete, with the first reported applications being apparently independent initiatives in 1923, one in Denmark other in Sweden. The air now was introduced in two ways which is by addition of large amounts of powerful air entraining agents or addition of foam that is prepared in a special generator or mix and then added into the mix. Foamed concrete based on this concept began to be adopted in 1980's.

Typical applications are for general backfilling, filling of redundant sewers, ducts, tunnels, underground tanks and the largest was backfilling of utility trenches.

The use of air entrained and foamed concrete was grown rapidly in recent years. Adridge, D. (2005) stated that two thousand years ago, the Romans were making a primitive concrete mix consisting of small gravel and coarse sands mixed together with hot lime and water. Soon, they discovered by adding animal blood into the mix and agitating it, small air bubble were created which makes the mix more workable and durable. They even add horse hair into mixes to reduce shrinkage which is similar to the fibres nowadays. There is also evidence that Egyptians was using this type of technology over 5000 years ago with similar results. Two thousand years ago, there were no controls over air content in air entrained concretes. In early 1900's, air entrained materials began commercially explore in Sweden with the workings of Axel Eriksson. Until today, Sweden still was the biggest user of lightweight foamed concrete's which it was extremely thermally efficient building materials.

2.2.1 Application of Foamed Concrete

Lightweight foamed concrete is widely used not only in foreign country, but also in Malaysia with its variety of aspects. Foamed concrete can be applied to building/constructions, houses/low cost houses, highway constructions, blinding, void filling, footing, tunnel lining, trench reinstatement, roof insulation and others.

Foamed concrete with its lightweight and excellent thermal properties were an advantageous in housing applications. In the Middle East and South Africa, foamed concrete has been used as roofing insulation material while its low density and resulting high thixotropicity enables the creation of roof slopes as stated by Jones, M. R., and McCarthy, A. (2005).

The first major application of Lightweight Construction Method (LCM) foamed concrete in Malaysia is at the SMART tunnel project in Kuala Lumpur. The foamed concrete specified was of density 1800kg/m^3 which achieved compressive strength of 3 N/mm^3 at the age of 28 days. Foamed concrete block of size 17m x 17m x 6m was cast in three stages in order to allow a maximum height of 2m per cast. The completed foamed concrete block serves to protect the diaphragm wall when the tunneling machine is coming out into the junction box (Lee, Y. L., and Hung, Y. T., 2005).

Table 2.1: Application of Foamed Concrete

Density (kg/m³)	**Applications**
≤ 300	Insulation boards similar to mineral-based and other man-made insulation boards such as polystyrene, polyurethane or mineral wool with no hazardous threat to health, environment or fire.
350-550	Thermal insulation or fire protection, block filling, roof-decking and void filling materials.
600-800	Void filling, such as in landscaping (above/ underground construction), behind archways and refurbishing damaged sewerage systems, as well as producing masonry units.
800-1000	Production of blocks, other non-load bearing building elements such as balcony railings, partitions, parapets, etc.
1100-1400	Prefabricated and cast in place walls, either load bearing or non-load bearing. It can be successfully used as floor screeds.
1500-1800	Recommended for slabs, foundations and other load-bearing building element where higher strength is obligatory.

Source: Lightweight Construction Methods, (2000)

2.3 Advantage of Foamed Concrete

The main advantage of foamed concrete is it consists of lighter weight compare to others concrete. It reduces the dead load of the structures which indirectly reduce the cost of the project and make the design of foundation or supporting structures more economic. It is also economical in terms of transportation as well as manpower.

Foamed concrete can be manufactured to precise specifications of strength and densities depending on the mix ratio which also possesses excellent workability, thermal and sound insulation properties. Workability properties provide self-compaction and flowing capability of the lightweight concrete which is suitable in void filling and others. Foamed concrete has the ability to resist the heat and sound from flowing through.

Other than that, foamed concrete can be nailed, planed, drilled and sawn which is user friendly. It can be finished with all traditional surface finishes ‘C paint, tiles, carpets, and others which increase the types of design of the building. It also provides moisture and fire resistant which is important in fire protection.

2.4 Physical Properties of Foamed Concrete

Aldridge, D. (2005) stated that foam concrete is a cement-based slurry in which a stable, homogeneous foam is mechanically blended, either by mixing or by injecting. Its physical characteristics are determined by various mix designs of cements, fly ash, aggregates, fillers, and volume of entrained foam. The typical foam concrete properties are summarized in Table 2.2.

Table 2.2: Typical properties of foamed concrete

Dry Density, Kg/m^3	**Compressive Strength, N/mm^2**	**Thermal Conductivity, W/mk**	**Modulus of Elasticity, kN/mm^2**	**Drying Shrinkage, %**
400	0.5-1.0	0.1	0.8-1.0	0.3-0.35
600	1.0-1.5	0.11	1.0-1.5	0.22-0.25
800	1.5-2.0	0.17-0.23	2.0-2.5	0.20-0.22
1000	2.5-3.0	0.23-0.30	2.5-3.0	0.18-0.15
1200	4.5-5.5	0.38-0.40	3.5-4.0	0.11-0.09
1400	6.0-8.0	0.50-0.55	5.0-6.0	0.09-0.07
1600	7.5-10.0	0.62-0.66	10.0-12.0	0.07-0.06

Source: Aldridge, D. (2005)

2.5 Mechanical Properties of Foamed Concrete

Mechanical properties of foamed concrete depend on the mix design and there are a number of general properties which are constant across a range of mix design.

2.5.1 Thermal Insulation

Thermal insulation property of a material is the ability to resist the flow of heat and is given as landau or k value. A typical sand cement screed would have a k value of 1.8w/mk which compares to 0.3w/mk for a 1000kg/m^3 density foamed concrete, making the foamed concrete six times more thermally efficient as stated by Aldridge, D. (2005).