PERFORMANCE AND APPLICATIONS OF LIGHTWEIGHT FOAMED CONCRETE WITH VARIOUS DENSITY

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ABSTRACT

Lightweight foamed concrete (LFC) has become an innovative product for the construction field. It is made by mixing the mortar with stable foam. Studies showed that lightweight foamed concrete using fine sand gains higher strength compared to coarse sand. Thus, an experimental work is conducted to produce lightweight foamed concrete incorporated sieved sand (100% passing 0.6mm sieve opening) as filler with target density of 800kg/m^3, 1000kg/m^3, 1300kg/m^3, 1500kg/m^3 and 1700kg/m^3. This study aims to determine the compressive strength-density ratio (performance index) of lightweight foamed concrete. Besides, a guideline about the lightweight foamed concrete's preparation and casting as well as application of lightweight foamed concrete also delivered in this paper. Total nine cubes have been casted for various densities of lightweight foamed concrete and all specimens were cured under water until testing ages (7, 14 and 28 days). The results revealed that high density foamed concrete gained higher compressive strength and performance index compared to low density foamed concrete. Besides, the compressive strength of foamed concrete displayed a continuous increase with concrete age. The lightweight foamed concrete's preparation and casting had been developed as a guideline and discussed step by step. For the application, only LFC-1700 specimen can be proposing for structural purpose as its compressive strength is more than 17MPa while other specimens are proposing for non-structural purpose except LFC-800 specimen.

ABSTRAK

Konkrit ringan berbuih (LFC) telah menjadi salah satu inovatif produk untuk bidang pembinaan. Perbuatan LFC ialah mencampurkan mortar dengan buih yang stabil. Kajian menunjukkan bahawa pengunaan pasir halus dalam konkrit ringan berbuih menghasilkan kekuatan yang lebih tinggi berbanding dengan pasir kasar. Oleh itu, kerja-kerja eksperimen dijalankan untuk menghasilkan konkrit ringan berbuih diperbadankan pasir disaring (100% melepaskan 0.6 mm ayak pembukaan) sebagai pengisi dengan kepadatan sasaran 800kg/m^3, 1000kg/m^3, 1300kg/m^3, 1500kg/m^3 dan 1700kg/m^3. Kajian ini bertujuan untuk menentukan *compressive strength-density ratio* (*performance index*). Selain itu, garis panduan mengenai penyediaan and pemutus konkrit ringan berbuih serta aplikasi konkrit ringan berbuih juga disampaikan dalam kajian ini. Jumlah sembilan kiub telah dibuatkan untuk pelbagai ketumpatan konkrit ringan berbuih dan semua spesimen telah disembuhkan dalam air sehingga umur ujian (7, 14 dan 28 hari). Hasil kajian menunjukkan bahawa ketumpatan konkrit ringan berbuih yang tinggi mendapat kekuatan mampatan dan *performance index* yang lebih tinggi berbanding dengan ketumpatan konkrit ringan berbuih yang rendah. Selain itu, kekuatan mampatan konkrit berbuih memaparkan peningkatan yang berterusan dengan umur konkrit. Dalam kajian ini, penyediaan dan pemutus konkrit ringan berbuih telah dihasilkan sebagai panduan dan dibincangkan langkah demi langkah. Bagi aplikasi LFC dalam kajian ini, hanya spesimen LFC-1700 boleh dicadangkan untuk tujuan struktur kerana kekuatan mampatan adalah lebih daripada 17MPa manakala spesimen lain kecuali spesimen LFC-800 dicadangkan untuk tujuan bukan struktur.

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LIST OF ABBREVIATIONS

ACI	-	American Concrete Institute
ASTM	-	American Society for Testing and Materials
BSI	-	British Standard Institution
CLFC	-	Cement based lightweight foamed concrete
FA_{coarse}	-	Coarse fly ash
GGBFS	-	Ground granulated burst furnace slag
HAUC	-	Highway Authorities & Utilities Committee
ISF	-	Incinerated sugarcan filter cake
LFC	-	Lightweight foamed concrete
LFC-CM	-	LFC with 100% sand filler as control mix
LFC-PF10	-	LFC with 10% POFA replacement as a part of filler
LFC-PF20	-	LFC with 20% POFA replacement as a part of filler
MC	-	Mortar
OPC	-	Ordinary Portland cement
PI	-	Performance Index
POFA	-	Palm oil fuel ash
S.G	-	Specific gravity
s/c ratio	-	Sand-to-cement ratio
SEM	-	Scanning Electron Microscopy
TRL	-	Transport Research Laboratory
w/c ratio	-	Water-to-cement ratio

LIST OF SYMBOLS

A_c	-	Cross-section area of the specimen
Al_2O_3	-	Aluminium oxide
$Ca(OH)_2$	-	Calcium hydroxide
CaO	-	Calcium oxide
f_c	-	Compressive strength
Fe_2O_3	-	Iron oxide
K_2O	-	Potassium oxide
MgO	-	Magnesium oxide
Na_2O	-	Sodium oxide
P	-	Maximum load carried by the specimen
SiO_2	-	Silicon dioxide
SO_3	-	Sulfur trioxide

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is a material that used widely in the construction field, from basic work to multi-storey building. The basic materials that used to manufacture concrete are cement, water and aggregate (coarse and fine). The cement known as the binder reacts with water to form cementitious paste and fill the void between the aggregate particles and glue them together to produce concrete or mortar (Mindess *et al.*, 2003). Besides, admixture sometimes added/replaced during the mixing to modify the concrete properties such as strength, durability and workability. Table 1.1 had showed the definitions of concrete.

Table 1.1: Definitions of concrete (Mindess *et al.*, 2003)

Concrete	=	Filler	+	Binder
Portland cement concrete	=	Aggregate (fine and coarse)	+	Portland cement paste
Mortar	=	Fine aggregate	+	Paste
Paste	=	Cement	+	Water

With the advancement of technology, the development of concrete has attracted great interest and focused by the researchers or contractors. One of the innovative concrete product that is popular nowadays is foamed concrete which had been used in both structural and non-structural purpose. Foamed concrete is classified as lightweight concrete, where stabilized bubble foam created by foaming agent is added into the mortar with appropriate proportions to produce low density concrete (400 to 1800kg/m^3) (Amran *et al.,* 2015). The differences between foamed concrete and conventional concrete are the elimination of coarse aggregate and existence of artificial air bubbles trapped in mortar. Besides that, no compaction is needed as foamed concrete does not settle easily and it is free flowing, self-leveling, thus, spreads to fill all voids and reduce the strain on manpower as well as faster construction work. Aldridge (2005) had reported that the characteristic of foamed concrete is normally depending on its mix design but there are several properties which are general across a range of mix designs such as:

- 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
- Shock absorbing qualities
- Not susceptible to breakdown due to hydrocarbons, bacteria or fungi

In this study, an experimental work on lightweight foamed concrete incorporated with sieved sand as filler is conducted to determine the engineering properties in term of compressive strength. Besides, a guideline on foamed concrete's preparation and casting is also developed. The application of lightweight foamed concrete based on the compressive strength is proposed and discussed in this study.

1.2 Problem Statement

Sand (fine aggregate) is one of the filler materials contribute to the strength of lightweight foamed concrete. The sand used in the mix can reduce the material cost and produce cheaper mix of foamed concrete compare to that fully cement paste is used (Hamidah *et al.*, 2005). The study on different gradations of sand had reported that the lightweight foamed concrete using fine sand gains higher strength compare to coarse sand (Lim *et al.*, 2015). This is owing to more hydrated cement paste are required to bond the larger total surface area of the finer sand particles together and made the microstructure more solid. Therefore, an experimental work is conducted to investigate the performance of lightweight foamed concrete incorporated with sieved sand at various densities.

1.3 Objectives

There are three objectives in this study:

i. To determine the performance index of lightweight foamed concrete incorporated with sieved sand as filler with various densities.
ii. To developed a guideline on lightweight foamed concrete's preparation and casting.
iii. To propose the application of lightweight foamed concrete in accordance to compressive strength results.

1.4 Scope of Study

In this study, the lightweight foamed concrete is produced by mixing ordinary Portland cement, sand, water and synthetic-based foaming agent. The density of the lightweight foamed concrete is designed and targeted in 800, 1000, 1300, 1500 and 1700kg/m^3 respectively. The mix proportion for cement-sand ratio is set as 1:1 while the water-cement ratio (w/c) is depending on the flow table test of base mix (mortar) which the range value is set within 22cm to 23cm in diameter. The sand is sieved to obtain the particles size passing through 600μm sieve opening and oven dried at 105°C ± 5°C for 24 hours to remove the total moisture content before casting. Total nine cubes (100 x 100 x 100mm in dimension) in accordance with BS EN 12390-1 (BSI, 2000) are casted for each density. The foamed concrete cubes are cured in water after unmoulded and tested for compressive strength at 7,14 and 28 days. For the fresh properties, flow table test in accordance with ASTM C1437 (ASTM, 2007) is conducted to determine the workability of fresh base mix while inverted slump test in accordance with ASTM C1611 (ASTM, 2014) is carried out to obtain the consistency of fresh foamed concrete. For the mechanical properties, compressive strength test in accordance with BS EN 12390-3 (BSI, 2001) is conducted to obtain the compressive strength of concrete specimens. The strength performance index (PI) indicates proportion of the compressive strength corresponding to a unit density is determined and discussed. From the experimental, a guideline on lightweight foamed concrete's preparation and casting is developed. Lastly, the lightweight foamed concrete is proposed and discussed for their applications based on the compressive strength results.

1.5 Significance of Study

Through the experimental work, the mix proportion to manufacture the lightweight foamed concrete using sieved sand as filler at various density is obtained and the engineering properties of lightweight foamed concrete in term of compressive strength can be determined. Besides that, in this study, a guideline is also developed in order to provide the procedures of preparation and casting lightweight foamed concrete from beginning of preparation of base mix and foam until the mixture of base mix and foam to produce lightweight foamed concrete. Based on the compressive strength, the applications of lightweight foamed concrete with various density are proposed in civil and structure engineering areas.

1.6 Outline of Thesis

This project report contains 6 chapters. The general information of the research subject including background of the study, problem statement, objectives of the study, scope of work and significance of study are mentioned in Chapter 1. Chapter 2 is the literature review which review the detailed background of the foamed concrete and the research done by previous researchers. Chapter 3 discusses on the experimental works of lightweight foamed concrete incorporated sieved sand as filler. In the chapter, the fresh properties and mechanical properties of lightweight foamed concrete as well as the results and discussion on the mix design are discussed and delivered. From the experimental works, the guideline on lightweight foamed concrete's preparation and casting is observed, recorded, studied and discussed in Chapter 5. In Chapter 6, the application of lightweight foamed concrete incorporated sieved sand as filler at various density is proposed in accordance to their compressive strength requirement. The research works are summarized and concluded in Chapter 7. Moreover, the recommendation for future works also discussed in this chapter.

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