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By YULIUS RIEF ALKHALY

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DEVELOPMENT OF LIGHTWEIGHT CONCRETE USING HOLLOW SPHERES

YULIUS RIEF ALKHALY

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structures)

Faculty of Civil Engineering
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I declare that this project report entitled "*Development of Lightweight Concrete Using Hollow Spheres*" is the result of my own research except as cited in references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Specially for my beloved wife,
Dewi Andriana

To my children,
Siti Iffat Tabriza
Muhammad Rayyan Syauqy

To Brothers and Sisters

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ABSTRACT

A new type lightweight concrete was produce using plastic and glass spheres, as a replacement to coarse aggregate. The new concrete was tested to determine compressive strength, density, water absorption, and stress-strain relationship. Twenty five samples of concrete specimen were prepared, nine of which were mix of normal concrete and cement mortar. The size of spheres of plastic were used of 6 mm, 14.5 mm and glass spheres were of 16 mm, 25 mm. In order to improve the interfacial strength between spheres and cement matrix, the surface of spheres was coated with sand using epoxy adhesive SIKADUR 330. It was found that by using plastic spheres as aggregate the density of the concrete was lowered significantly, while by using glass spheres the density of concrete was not reduced as low as that using plastic spheres. The strength of the concrete using both types of spheres was reduced compared to the concrete using natural coarse aggregate. The strength of concrete using sand coated plastic spheres was increased compared to that without sand coating. Due to insufficient bond strength of SIKADUR 330 on the surface of glass spheres, the concrete using sand coated glass sphere did not gain additional compressive strength. The capability of concrete using glass or plastic spheres to resist water absorption was as good as normal concrete. However, overall performance of concrete using plastic and glass spheres showed good result. The Compressive strength rages between 24 MPa to 29 MPa which is 66% - 77% of normal concrete strength, which indicate that the strength is sufficiently strong for use in structural element. The results of this study indicate that plastic and glass spheres may provide as a suitable alternative to produce structural lightweight concrete.

ABSTRAK

Suatu konkrit ringan jenis baru telah dihasilkan menggunakan sfera plastik dan kaca, sebagai pengganti batu baur kasar. Konkrit jenis baru ini telah diujikaji dengan ujian kekuatan mampatan, ujian kepadatan, ujian penyerapan air dan ujian tegasan-tarikan. Dua puluh lima buah konkrit spesimen telah diujikaji, termasuk didalamya enam siri daripada konkrit biasa dan motar simen sebagai pembanding. Saiz sfera plastic dan sfera kaca yang digunakan masing-masing iaitu 6 mm, 14.5 mm dan 16 mm, 25 mm. Untuk menaikkan kekuatan cengkraman antara permukaan sfera dan konkrit, penyapuan pasir dengan gam epoxy SIKADUR 330 digunakan. Penggunaan sfera plastik sebagai pengganti batu baur kasar menunjukkan penurunan pada kepadatan konkrit secara nyata, sedangkan dengan menggunakan sfera kaca tidak menunjukkan penurunan kepadatan seperti pada sfera plastik. Kedua-dua jenis sfera itu juga memberikan penurunan pada kekuatan mampatan konkrit. Kekuatan mampatan konkrit yang menggunakan sfera dengan sapuan pasir lebih baik dibandingkan dengan konkrit yang menggunakan sfera tanpa sapuan pasir. Oleh kerana lemahnya kekuatan cengkaraman gam SIKADUR 330 pada permukaan sfera kaca, cara ini tidak memberikan tambahan pada kekuatan mamapatan konkrit yang menggunakan sfera kaca. Kemampuan konkrit yang berisi sfera kaca atau palstik untuk mengawal penyerapan air adalah sama serperti konkrit biasa. Walaubagaimanapun, kebolehkerjaan konkrit yang menggunakan sfera kaca dan sfera plastik menunjukkan hasil yang baik. Kekuatan mampatan boleh mencapai 24 MPa hingga 29 MPa atau sebesar 66% - 77% daripada kekuatan mampatan konkrit biasa dan layak digunakan pada unsur struktur. Keputusan ujikaji menunjukkan bahawa sfera plastik dan sfera kaca boleh dipakai sebagai pilihan untuk mewujudkan konkrit ringan pada unsur struktur.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	-	Cross section of the specimen
AAC	-	Autoclaved aerated concrete
ACI	-	American Concrete Institute
Al	-	Aluminium
ASTM	-	American Standard Testing Materials
BS	-	British Standard
CEB	-	Comite'Euro-International du Beton
E	-	Experimental static modulus of elasticity
Ec	-	Theoretical static modulus of elasticity
ε	-	Longitudinal strain of specimen
ε_h	-	Circumferential strain of specimen
f_c	-	Compressive strength of concrete
H_2	-	Hydrogen
H_2O_2	-	Hydrogen Peroxide
γad	-	Air dry density
γd	-	Oven dry density
Ma	-	Mass of the test specimen in air
Mi		Immersion mass of the test specimen
Mo		Oven dry mass of the test specimen
Mw	-	Mass of the test specimen in water
NAAC	-	Non autoclaved aerated concrete
O_2	-	Oxygen
P	-	The maximum load applied
ρ	-	Concrete density of cube specimen
ρw	-	density of water

s	-	Stress of specimen
V	-	Volume of the test specimen
ν	-	Poisson’s ratio
WO	-	Water absorption of the test specimen
Zn	-	Zink

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CHAPTER 1

INTRODUCTION

1.1 Background

The use of lightweight concrete in the construction industry has become popular in the past few decades due to its some benefits. The benefits of using lightweight concrete include: reduce dead load, improved resistance to cyclic loading, longer spans, better fire ratings, thinner structural members, less reinforcing steel, and lower foundation costs (Short and Kinniburgh, 1978).

There are four establish method that can be used to produce lightweight concrete: using air bubble; using hollow or porous aggregate; using solid lightweight material as coarse aggregate; and using coarse aggregates only to produce 'no-fines' concrete (Short and Kinniburgh, 1978; Teo, et al., 2006; and Ravindrarajah, et. al., 1993). Using these methods, lightweight concrete of wide range of density and strength have been produced for use in many civil work purposes.

Classification of lightweight concrete can be based on the density of the concrete. Generally, a low density concrete has low strength and a high density often has high strength. Hence, the major problems of lightweight concrete are its low strength and high rate of water absorption due to its low density. However, if hollow spheres were to be used to replace the ordinary aggregate, the strength of concrete could be maintained as compared to lightweight concrete with air bubble. Agni Vickmeshwaran, (2007), reported that by inclusions of large hollow sphere, the original strength of concrete can be retained but density can be reduced. Thereby, there is possible to use spheres to replace coarse aggregate.

In this study a new method to produce lightweight concrete is proposed. The method uses hollow spheres to replace coarse aggregate or air bubbles. Spherical manufactured aggregate of different sizes of solid plastic and glass are used to produce concrete cube. The concrete with a particular of sphere that produces the highest strength is studied further to investigate stress-strain behaviour. It is expected that by replacing aggregate with hollows spheres, the density of concrete can be reduced and a new type of lightweight concrete can be developed.

1.2 Problem Statement

The lightweight concrete produced by using air bubble or porous/hollow aggregate method absorbs high amount of water. High air content results in lower densities and higher porosity hence consequently lower compressive strength (Kearsley, et. al, 2002; and Lo, et. al., 2004).

Highly permeable concrete either by using porous aggregate or large amount of air bubbles permit easy entry and ingress of water into concrete matrix which results in durability problems. Water is known to be a cause of many types of physical processes of degradation. As a transportation vehicle for aggressive ions, water can also be a source of chemical processes of degradation, such as sulphate and chloride attack. Sulphate attack can result in the loss of strength and even cracking of concrete, while chloride can lower the pH value of concrete and consequently induce corrosion of reinforcement (Mehta and Monteiro, 2006).

Theoretically, the introduction of low-permeability aggregate particles in a high-permeability cement paste is expected to reduce the permeability of the system because the aggregate particles should intercept the channels of flow within the cement paste matrix (Mehta and Monteiro, 2006). Concrete made with non-absorbent material such as plastic and glass spheres as coarse aggregate can be used to produce a lightweight concrete to yield a better performance such as better compressive strength and low permeability. Thus the problem of air bubble or hollow and porous aggregate method can be solved.

1.3 Aims And Objectivities of Study

The aim of this research is to produce lightweight concrete using hollows spheres. In order to achieve this aim, several objectives are set out:

1. To develop a new method for producing lightweight concrete which maybe sufficiently strong for use in structural element.

2. To study the mechanical properties of new developed lightweight concrete in term of compressive strength, density, and water absorption. Type of sphere that produces the highest strength is studied further to investigate the stress-strain behaviour.

1.4 Scope of Study

This study concentrates mainly on the compressive strength of the concrete comprises plastic and glass spheres as coarse aggregate. Due to unavailability of strong hollow spheres in market, solid plastic balls of 6 mm diameter and solid plastic of 14.5 mm diameter with hole/core; and solid glass marbles of 16 and 25 mm diameter were used. The use of solid spheres may not produce the lightweight concrete as intended for. In this study, solid spheres were used merely to test the viability of concept of producing lightweight concrete using hollow spheres.

It has been observed that a concrete mixture containing a rough-textured or crushed aggregate would show somewhat higher strength than a corresponding concrete containing smooth or naturally weathered aggregate of similar mineralogy (Mehta and Monteiro, 2006). Thus, In order to improve bonding with cement matrix, epoxy adhesive was used to coat sand on the surface of spheres but its influence on stated properties will not be considered in this research. Comparison between the proposed lightweight concrete and normal concrete and cement mortar was also made in terms of compressive strength, density and water absorption.

1.5 Layout of Thesis

This thesis consists of 5 chapters. Following current chapter the comprehensive information on available literature of lightweight concrete are presented in chapter 2. Chapter 3 discusses the adoptive methodology used in this study, including design of mix proportion and design as well as preparation and casting of test specimens and detail of testing method .The results are presented in chapter 4 which consist of result of compressive strength, water adsorption and density of new lightweight concrete. Finally chapter 5 presents conclusions and recommendation for current and future experimental work.