MECHANICAL PROPERTIES OF CONCRETE USING SYNTHETIC LIGHTWEIGHT COARSE AGGREGATE (SYLCAG)

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ABSTRACT

The concrete consisting of a hard, chemically inert particulate substance known as an aggregate (usually made from different types of sand and gravel), that is bonded together by cement and water. Aggregate can produced from any materials such as mining sand, offshore sand, pumice, scoria and etc. Offshore sand is a one of alternative for river sand usage in concrete. In this study, the coarse aggregates will be replaced with the synthetic lightweight coarse aggregate using offshore sand (SYLCAG) in concrete. The SYLCAG was produced with density of 1600 kg/m^3which are 66.67% from density of normal aggregate. LA abrasion and aggregate crushing value (ACV) to determine the strength of SLYCAG. Concrete that produced using SYLCAG were test to obtain the mechanical properties that includes compressive strength, flexural strength and water absorption test. The offshore sand have potential to be produced as SYLCAG because there is very less lightweight aggregate such as pumice, scoria, etc. available in Malaysia.

ABSTRAK

Konkrit yang terdiri daripada , bahan zarah lengai secara kimia keras yang dikenali sebagai batu baur (biasanya diperbuat daripada pelbagai jenis pasir dan batu) yang terikat bersama oleh simen dan air. Batu baur boleh dihasilkan daripada apa-apa bahan seperti pasir perlombongan , pasir luar pesisir, pumis, scoria dan sebagainya. Pasir luar pesisir adalah salah satu alternatif kegunaan selain pasir sungai di dalam konkrit . Dalam kajian ini, batu baur kasar akan digantikan dengan batu baur kasar ringan sintetik menggunakan pasir luar pesisir (SYLCAG) dalam konkrit. SYLCAG ini dihasilkan dengan kepadatan 1600 kg/m3 adalah 66.67 % daripada ketumpatan batu baur biasa. LA abrasion dan aggragate crushing value test (ACV) dijalankan untuk menentukan kekuatan SLYCAG . Konkrit yang dihasilkan menggunakan SYLCAG adalah untuk mendapatkan sifat-sifat mekanikal yang merangkumi kekuatan mampatan, kekuatan lenturan dan ujian penyerapan air. Pasir luar pesisir berpotensi untuk dihasilkan sebagai SYLCAG kerana batu baur ringan seperti pumis, scoria , dan lain-lain tidak terdapat terdapat di Malaysia.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF ABBREVIATION

ASTM	American Society for Testing and Materials
BS	British Standard
LWA	Lightweight Aggregate
LWAC	Lightweight Aggregate Concrete
OPC	Ordinary Portland Cement
SYLCAG	Synthetic Lightweight Coarse Aggregate
UMP	University Malaysia Pahang

LIST OF EQUATIONS

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete is a material used in building construction. The concrete consisting of a hard, chemically inert particulate substance known as an aggregate (usually made from different types of sand and gravel), that is bonded together by cement and water. Concrete must be made with low permeability, workable, resistance to freezing, chemicals resistance, water resistance and economy (Metha & Menteiro, 2006). There are many type of concrete that include lightweight concrete. Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that increase the volume of the mixture while giving additional qualities such as nailbility and lessened the dead weight (Kamsiah et al, 2003).

Aggregate is another major part of concrete besides the cement. This study, the coarse aggregates will be replaced with the synthetic lightweight coarse aggregate in concrete. Offshore sand is a one of alternative for river sand usage in concrete. Offshore sand should extract from 15 m ocean depth (Dias, 2007). The offshore sand has low chloride content compare the beach sand. The beach sand has high chloride content due to wetting and drying cycles of sea water. Then, the offshore sand must be washed by rain over a period of time to reduce the chlorides content. After that, this study determines the compressive strength, flexural strength and water absorption of concrete using synthetic lightweight coarse aggregate.

1.2 PROBLEM STATEMENT

Currently, there are many construction purposes such as house, office, shop and other building to improve the infrastructure of populations. In this case, when there are many developments, the usage of the concrete must increase to build the building. The over-exploitation of river sand for construction purposes has led to various harmful consequences. There are many suggestions for various river sand alternatives such as offshore sand, dune sand, quarry dust and washed soil has been made (Dias, 1999). In this study, offshore was considered the most viable of the alternatives for river sand with respect to availability, environmental impact, ease of extraction and cost. But it is important first to check the properties of this material for its compatibility for replacement in concrete.

1.3 OBJECTIVES

i. To evaluate the properties of produced synthetic lightweight coarse aggregate (mention as SLYCAG onward this report) with density of 1600 kg/m^3.

ii. To determine the compressive strength and flexural strength concrete using synthetic lightweight coarse aggregate (SLYCAG).

iii. To determine water absorption of concrete using synthetic lightweight coarse aggregate (SYLCAG).

1.4 SCOPE OF STUDY

This research has the aim to determine the compressive strength and water absorption of concrete using SLYCAG. For this research, the sample of offshore sand is taken from surface reclamation project at Pantai Klebang in Melaka. Then, the size of SYLCAG is 20 mm, 10 mm and 5 mm. This research includes lab works and lab testing on the sample concrete such as compression test, flexural test and water absorption test.

Then, hardened specimens such as 150 mm x 150 mm x 150 mm for cube, 150 mm x 150 mm x 750 mm for beam. The research is focus on the compressive strength and tensile strength concrete using SLYCAG.

1.4 EXPECTED OUTCOME

The expected outcome for this research is to obtain compressive strength and tensile strength of concrete using SLYCAG and compare with conventional concrete. The conventional concrete will be a guide to the determined the strength of lightweight concrete using artificial offshore coarse aggregate. It is also expected that concrete using SLYCAG should be lighter density than conventional concrete. As SYLCAG itself, the mechanical properties as aggregate should be weak compared to normal coarse aggregate.

1.5 CONCLUSION

In this chapter, the general outline of study was finalized base on the topic. This chapter discussedthe background of study related to offshore sand, concrete and lightweight coarse aggregate. There are 3 objective of this study related to the problem statement for this study that is compatibility of SYLCAG. In the next chapter, the reviews of previous study related to the research such as type of lightweight concrete, properties of lightweight coarse aggregate concrete, compressive strength, density, workability, strength of aggregate, lightweight aggregate and offshore sand.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Generally, concrete is product of reaction between hydraulic cement and water but these days, the definition would cover a wide range of product. Today, concrete is made with several types of cement and also containing pozzolan, fly ash, blash-furnance slag, micro-silica, additives, recycled concrete aggregate, admixtures, polymers, fibers, and etc. These concrete can be heated, steam-cured, autoclaved, vacuum-treated, hydraulic pressure, shock-virated, extruded, and sprayed (Neville & Brooks, 2010). There are many research about the concrete is made to fallibility and lessened the dead weight.

In the previous chapter, the outline of this study that isthe objective, problem statement, scope of study and expected outcome has been discussed. This chapter will review of previous study related to chapter 1. It will include review in lightweight concrete, mechanical properties of concrete and offshore sand.

Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increased the volume of the mixture while giving addition qualities such as nailbility and lessened the dead weight. It is lighter than the conventional concrete with a dry density of 300 kg/m3 up to 1840 kg/m3 about 87 %-23% lighter *(Kamsiah et al, 2003).*it was first introduced by the Romans in the second century where " The Pantheon" has been constructed using pumice, the most common type of aggregate used in that particular year (Roji,1997).

The lightweight concrete is low density and thermal conductivity. It is advantages are that there is a reduction of dead load, fasting building rates in construction and lower haulage and handling costs.

2.2 LIGHTWEIGHT CONCRETE

Lightweight concrete can be prepared either by air in its composition or it can be achieved by omitting the finer sizes of the aggregate or even replacing them by a hollow, cellular or porous aggregate. Then, lightweight concrete can divided by three groups such as no fines concrete, lightweight aggregate concrete and aerated/ foamed concrete. For this study, lightweight aggregate concrete type used because the coarse aggregate replaced with artificial offshore coarse aggregate to make the lightweight concrete. Table 2.1 shows the advantages and disadvantage of lightweight concrete.

Table 2.1 Advantages and disadvantage of lightweight concrete

Advantages	Disadvantages
Significant reduction of overall weight results in saving structural frames, footing or piles.	Very sensitive with water content
Economical in term of transportation as well as reduction in manpower.	Difficult to place and finish because of the porosity and angularity of the aggregate.
Rapid and relatively simple construction	Mixing time is longer than conventional concrete to assure proper mixing.

The differences between the types of lightweight concrete are very mush related to its aggregate grading used in the mixes. Table 2.2 shows the types and grading of aggregate suitable for the different type of lightweight concrete (Roji,1997). In this study, structural lightweight aggregate concrete is use and continues grading from either 20 mm or 14 mm down to dust, with a increased fines content (5mm and fines) to produce a workable and dense concrete.

Table 2.2: Types and grading of aggregate suitable for the different type of lightweight concrete

Types Of Lightweight Concrete	**Type Of Aggregate**	**Grading of Aggregate**
No-fines concrete	-Natural aggregate -Blast-furnace slag -Clinker	Nominal single-sized material between 20mm and 10mm BS sieve
Partially compacted lightweight aggregate concrete	-Clinker -Foamed slag. -Expanded Clay, shale, slate, vermiculite and perlite. -Sintered pulverized-fuel ash and pumice.	May be of smaller nominal single sizes of combined coarse and fines (5mm and fines) materials to produce a continues but harsh grading to make a porous concrete.
Structural lightweight aggregate concrete	-Foamed slag - Expanded Clay, shale, slate, and sintered pulverized fuel ash	Continues grading from either 20 mm or 14 mm down to dust, with a increased fines content (5mm and fines) to produce a workable and dense concrete.
Aerated concrete	-Natural fine aggregate -Fine lightweight aggregate -Raw pulverized-fuel ash -ground slag and burnt shales	The aggregate are generally ground down to finer powder, passing a 75 m BS sieve, but sometime fine aggregate (5mm and fines) is also incorporated.

Sources: Roji(1997)

2.2.1 No Fines Concrete

No fines concrete can be defined as a lightweight concrete composed of cement and fine aggregate. The uniformly distributed voids are formed throughout it mass. The main characteristics of this type of lightweight concrete is it maintains its large voids and not forming laitance layers or cement film when placed on the wall (Kamsiah et al, 2003). In this no fines concrete does not contain coarse aggregate

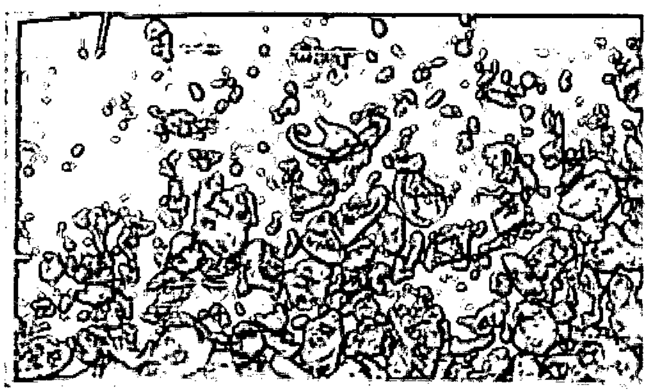

Figure 2.1: No fines concrete

Sources: Kamsiah et al (2003)

2.2.2 Lightweight Coarse Aggregate Concrete

The lightweight aggregate concrete can be divided into two types such as partially compacted lightweight aggregate concrete and structural lightweight aggregate concrete. The partially compacted lightweight aggregate concrete is mainly used for two purposes that are for precast concrete blocks or panels and cast in-situ roofs and walls. Structurally lightweight aggregate concrete is fully compacted similar to that of the normal reinforcement concrete of dense aggregate. It can be used with steel reinforcement as to have a good bond between the steel and the concrete. The concrete should provide adequate protection against the corrosion of the steel. The shape and the texture of the aggregate particles and the coarse nature of the fine aggregate tend to produce harsh concrete mixer (Kamsiah et al, 2003).

The lightweight aggregate can be natural aggregate such as pumice, scoria and the artificial aggregate such as expanded blast-furnace slag, vermiculite and clinker aggregate. In this study, we use artificial offshore sand coarse aggregate replaced the natural coarse aggregate. Figure 1 shows the picture of lightweight aggregate concrete.

FIGURE 2.2: Lightweight Aggregate Concrete

Sources: Kamsiah et al, (2003)

2.2.2.1 Properties of Lightweight Coarse Aggregate Concrete

Neville & Brooks stated there are various type of lightweight aggregate available allow the density of concrete to range from 300 kg/m^3 until 1850 kg/m^3 with a corresponding strength range of 0.3 Mpa until 40 Mpa and sometimes even higher. Then, properties which have to be considered for lightweight coarse aggregate concrete are workability, absorption, drying shrinkage, and moisture movement. For equal workability, lightweight aggregate concrete registers a lower slump and lower compacting factor than normal weight concrete because the work done by gravity is smaller in case of the lighter material (Neville & Brooks, 2010). According to Neville & Brooks (2010), the porous nature of lightweight aggregates means that they have high and rapid water absorption. For example, if the aggregate is dry at the time of mixing, it will rapidly absorb water and the workability will quickly decrease. For this study, we will produce semi - lightweight concrete because only replaced coarse aggregate.

Typically, for the same workability, semi- lightweight aggregate concrete will require 12 to 14 per cent less mixing than lightweight aggregate concrete (Neville & Brooks, 2010). After that, Neville & Brooks stated partial replacement of fine aggregate by normal weight fines is also possible. In any case, replacement should be on an equal volume basis.

2.2.3 Aerated Concrete

The other type lightweight concrete is aerated concrete. Aerated concrete does not contain coarse aggregate and can be regarded as aerated mortar. Typically, aerated concrete is made by introducing air or other gas into a cement slurry and fine sand. In commercial practices, the sand is replaced by pulverized- fuel ash or other siliceous material and lime maybe used instead of cement (Roji,1997).

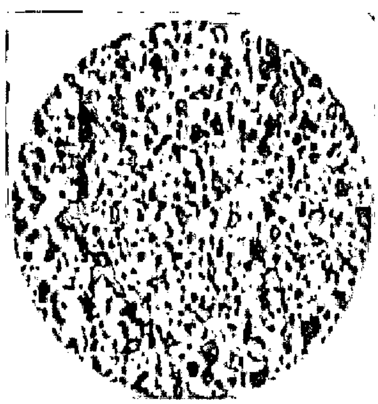

Figure2.3: Aerated Concrete

Sources: Kamsiah et al (2003)

2.3 COMPRESSIVE STRENGTH

Compressive strength is the primary property of concrete (other are generally defined from it) and is the one most used in design. It is one of the fundamental properties used for quality control for lightweight concrete (Kamsiah et al, 2003).

Compression strength of the foam concrete decreases exponentially with a reduction in density of the foam concrete (Kearsley et al ,1996). In this study, we compare the compressive strength of the concrete between using artificial offshore sand coarse aggregate and natural coarse aggregate.

2.4 DENSITY

The density of both fresh and hardened concrete is of interest to the parties involved for numerous reasons including its effect on durability, strength and resistance to permeability. Table 2.3 shows the density of hardened concrete and compressive strength at 28 days (Kamsiah et al, 2003). The dry density of lightweight concrete is 300 kg/m^3 up to 1840 kg/m^3 lighter than the conventional concrete. Lightweight concrete can reduce the dead weight of the structure up to 15 % or more. Then, BS E 206-1 defines lightweight aggregate concrete as concrete produced using lightweight aggregate for all or part of the total aggregate. The aggregate compression about 70 % of the volume of concrete, reduction in density is more easily achieved by replacing all or part of the normal weight aggregates where having a density about 2300 kg/m^3.

Table 2.3: Density of hardened concrete and compressive strength at 28 days

Density (Kg/m^3)	**Compressive strength (KN/m^3)**	**Density (Kg/m^3)**	**Compressive strength (KN/m^3)**
1470	2.52	1840	16.78
1720	5.50	1920	16.73
1770	10.34	1990	16.58
1780	9.19	2040	17.27
1810	13.12	2040	12.18
1820	11.87	2050	9.35
1840	13.21	2060	22.99

Sources: Kamsiah et al (2003)

2.5 WORKABILITY

Workability depend on a number of interacting factors such as water content, aggregate type and grading, cement ration, presence of admixture and fineness of cement. The main factor is the water content of the mix since by simply adding water the inter particle lubrication is increase. Lightweight aggregate tend to lower the workability and a lower compacting factor than normal weight concrete because the work done by gravity is smaller in the case of the lighter material (Neville &Broocks, 2010). The slump for lightweight aggregate concrete will tend to be lower than that of normal concrete of the same workability about 25 mm for lower slump concrete.

2.6 AGGREGATE

Aggregate is one part of three elements in concrete. At least three-quarters of the volume of concrete is occupied by aggregate. After that, not only may the aggregate limit the strength of concrete, but the properties of aggregate can affect the durability and structural performance of concrete. Usually, aggregate only viewed as an inert material dispersed throughout the cement paste largely for economic reasons because aggregate can reduce cement content and it can affect the cost. But, the opposite view aggregate as a building material connected into a cohesive whole by means of the cement paste. In fact, aggregate is not truly inert and its physical, thermal, and sometimes also chemical properties influence the performance of concrete.

2.6.1 Strength of Aggregate

Neville stated compressive strength of concrete usually not significantly exceeded that of the major part of the aggregate contained in concrete. Additional, the required information has to be obtained usually from indirect test, crushing value of bulk density, force required to compact bulk density aggregate and performance of aggregate in concrete (Neville, 2012). According to Neville (2012), if the aggregate under test leads to lower compressive strength of concrete, and in particular if numerous individual aggregate particles appear fractured after the concrete specimen has been crushed.

The strength of the aggregate is lower than the nominal compressive strength of the concrete mix in which the aggregate was incorporated. Then, Neville also stated the strength of aggregate represents a limiting case because the physical properties of aggregate have some influence on the even strength of concrete even when the aggregate by itself is strong enough not to fracture prematurely.

A good average value of the crushing strength of aggregate is about 200 Mpa but many excellent aggregates range in strength down to 80 Mpa. For these study, granite is usually type of rock used for make concrete sample. Table 2.4 shows compressive strength of America rocks commonly used as concrete aggregates.

Table 2.4: Compressive strength of America rocks commonly used as concrete aggregate

		Compressive strength					
		Average		**After deletion of extremes**			
				Maximum		**Minimum**	
Type of rock	**Number of sample**	**Mpa**	**psi**	**Mpa**	**psi**	**Mpa**	**psi**
Granite	278	181	26 200	257	37 300	114	16 600
Felsite	12	324	47 000	526	76 300	120	17 400
Trap	59	283	41 100	377	54 700	201	29 200
Limestone	241	159	23 000	241	34 900	93	13 500
Sandstone	79	131	19 000	240	34 800	44	6 400
Marble	4	117	16 900	244	25 400	51	7 400
Quartzite	26	252	36 500	423	61 200	124	18 000
Gneiss	36	147	21 300	235	34 100	94	13 600
Schist	31	170	24 600	297	43 100	91	13 200

Sources: Neville (2012)

- For most samples, the compressive strength is an average of 3 to 15 specimens.
- Average of all samples.
- 10 per cent of all samples tested with highest or lowest values have been deleted as not typical of the material.

After that, there are several mechanical properties of aggregate are of interest to determine the strength of aggregate such as Aggregate Impact Value Test, LA Abrasion Test, Aggregate Crushing Value Test and Ten Percent Fines. According to Neville (2012), attempts to develop a test for lightweight aggregate, similar to the crushing value test, have been made but no test has been standardized. Table 2.5 show average value of crushing strength, aggregate crushing value, and abrasion, impact and attrition value for the different rock group of BS 812: Part 1 : 1975.

Table 2.5: Show average value of crushing strength, aggregate crushing value, and abrasion value, impact and attrition value for the different rock group.

Rock group	Crushing value		Aggregate crushing value	Abrison value	Impact value	Attrition Value +		Specific gravity
	Mpa	KPsi				Dry	Wet	
Basalt	200	29	12	17.6	16	3.3	5.5	2.85
Flint	205	30	17	17	17	3.1	2.5	2.55
Gabbro	195	8.5	-	19	19	2.5	3.2	2.95
Granite	185	7	20	13	13	2.9	3.2	2.69
Gritsone	220	2	12	15	15	3.0	5.3	2.67
Hornfels	340	9.5	11	17	17	2.7	3.8	2.88
Limestone	165	4	24	9	9	4.3	7.8	2.69
Porphyry	230	3.5	12	20	20	2.6	2.6	2.66
Quartzite	330	7.5	16	16	16	3.0	3.0	2.62
Schist	245	5.5	-	13	13	4.3	4.3	2.76

Sources: Neville (2012)

2.6.2 Lightweight Aggregate

Lightweight aggregate can be made between aggregates occurring in nature and manufactured. The main natural lightweight aggregates are diatomite, pumice, scoria, volcanic cinders and tuff (Neville & Brooks, 2010). For this study, artificial aggregate made from offshore sand was used to replacement the normal aggregate in concrete.