SYNTHETIC LIGHTWEIGHT COARSE AGGREGATE (SYLCAG) CONCRETE USING ARTIFICIAL OFFSHORE SAND

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ABSTRACT

Concrete is a rough building material that are made from a mixture of aggregate, sand, cement and water, that can be spread or poured into molds and that forms a mass on hardening. Aggregate is a granular mineral material such as sand, gravel, crushed stone that be used with a bonding medium It will undergo substantial wear and tear throughout life. In general, it should be hard and tough enough to resist crushing, degradation and disintegration from any activities. Currently, there are increasing demand on coarse aggregate. So, one alternative are taken which is produce artificial coarse aggregate and some of them is lightweight. This research, is about the production of artificial lightweight coarse aggregate (SYLCAG) by using artificial offshore sand with 1300 kg/m^3 of density which is 54% lighter than normal aggregate. That SYLCAG was be used in concrete to replace fully function of normal aggregate and also make the concrete more lightly. The SYLCAG will be tested by LA abrasion test and crushing value test. Then, that SYLCAG is used to produce SYLCAG concrete with 75% density compared to normal concrete density and will be test by compressive strength test and flexural test to get it properties. As conclusion, this aggregate produced have a potential to further use in construction industry for part that have experience less forces like wall or partition.

ABSTRAK

Konkrit merupakan bahan binaan kasar yang diperbuat daripada campuran batu baur atau batu kelikir, pasir, simen dan air yang di letakkan kedalam acuan atau kotak bentuk untuk yang membentuk sesuatu jisim apabila mengeras. Batu baur akan diguna dan berada didalam konkrit sepanjang hayatnya. Secara umum, batu baur hendaklah keras dan kuat bagi mengelakkan ianya hancur dan pecah daripada tekanan dan beban yang dikenakan. Pada masa ini, terdapat peningkatan permintaan terhadap batu baur kasar. Jadi, salah satu alternatif yang diambil untuk menghasilkan batu baur kasar buatan dan ianya adalah ringan berbanding batu baur biasa. Dalam kajian ini, ia memfokuskan kepada pengeluaran batu baur kasar yang ringan dengan menggunakan pasir luar pesisir laut dengan ketumpatan 1300 kg/m3 dimana ianya adalah 54 peratus lebih ringan daripada agregat biasa. Dari batu baur kasar, ia akan digunakan di dalam konkrit untuk menggantikan sepenuhnya fungsi batu baur kasar biasa bagi menghasilkan konkrit yang lebih ringan. Bagi tujuan ujikaji, batu baur ringan akan diuji dengan ujian LA ujian lelasan dan menghancurkan ujian nilai. Agregat ringan akan diuji oleh ujian LA Abrasion dan ujian Crushing Value. Kemudian, batu baur ringan tersebut akan digunakan untuk menghasilkan konkrit ringan dengan ketumpatan 75 peratus daripada ketumpatan konkrit biasa dan akan diuji dengan terhadap ujian kekuatan mampatan dan ujian lenturan untuk mengetahui sifatnya. Kesimpulannya, batu baur yang dihasilkan ini mempunyai potensi untuk terus digunakan dalam industri pembinaan bagi sebahagian tujuan seperti dinding dan partisyen kerana kurang terdedah kepada daya yang tinggi

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In the local construction industries currently, there are buildings that have been constructed by using lightweight concrete. Lightweight concrete also known as foam concrete which is widely used in modern constructions because it is mortar less and can be produced with different densities. Foamed concrete is a concrete consisting of foaming agent that entrapped air voids in mortar that cause the concrete to be lightweight in range of densities between 400 – 2000 kg/m3. It have a high flow ability, low self weight, minimum consumption of aggregates, controlled low strength, and good thermal insulation properties (R.C. Valore, 1954).

Other than lightweight concrete, light to medium weight concrete also can be produced by using lightweight aggregate. Porous lightweight aggregate of low specific gravity is used in this kind of concrete that will be mention as lightweight concrete in this report. It is not a new material. It has been known since the early days of the Roman Empire which they partly constructed structure with materials that can be characterised as lightweight aggregate concrete. As the rapid technology improvement, there have been a lot of lightweight aggregates produced. Some of them can be identified as clay, river sand, fly ash, blast-furnace slag and many more. European Union (2000) stated that some characteristics of lightweight aggregates concrete that can be notified are the lower density and higher insulating capacity by which it distinguishes itself from Normal Weight Concrete.

Offshore sand is a new material that used in the process of mixing in order to produce a lightweight aggregate. Dias (2007) stated that offshore sand is the sand that sucked up from 15m of ocean depth. Some researchers at Sri Lanka found that offshore sand was the suitable choice to replace river sand with minimal impact to cost and environment. Dias (2007) in his paper mentioned that the beach sand have a high chloride content than the offshore sand due to wetting and drying cycles of sea water.

1.2 PROBLEM STATEMENT

Construction project is one of the activities that widely get focus nowadays. In construction project, many materials are used. The increase of construction project activities will lead to increase of material usage. One of the materials used is coarse aggregate. The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and it is influence the concrete mixed and hardened properties, mixture proportions, and economy. Usually, coarse aggregate are production of crushed stone or gravel. Because of increasing demand on coarse aggregate, one alternative are taken which is produce artificial coarse aggregate and some of them is lightweight. Such as by using fly ash, pumice, slag, sand, crushed lava and many more. It will became other sources for the coarse aggregate.

In this study, the focus is more on the production of synthetic lightweight coarse aggregate (SYLCAG). From that SYLCAG, it will be used in concrete to replace fully function of normal aggregate and also make the concrete more lighter.

Foaming agent has that characteristic that will lead to produce lightweight structure. It is used as a void filling. Due to lightweight, the application as a concrete block for wall or partition may reduce the load bearing on beam. It may contribute to the reduction of size or number of reinforcement bars needed for structure. This would help for any given company to minimise the construction costs.

In this study, offshore was considered to be use because it is an alternative to replace river sand with respect to availability, environmental impact, ease of extraction and cost.

1.3 RESEARCH OBJECTIVE

i. To produce synthetic lightweight coarse aggregate (SYLCAG) with density 1300 kg/m^3 using offshore sand and determine mechanical properties in term of toughness and resistance.

ii. To determine chloride content in offshore sand and the produced SYLCAG.

iii. To determine mechanical properties of lightweight concrete that used SYLCAG in term of compressive strength and flexural stress.

1.4 SCOPE OF STUDY

The offshore sand is taken from reclamation project at Pantai Klebang, Melaka. A lightweight aggregate will be produced from offshore sand by mixing it with the foaming agent using suitable ratio to get density 1300 kg/m^3. In this research, there are 3 type of size of lightweight aggregates that will be produce. Which is 5mm, 10mm and 20mm.

The properties are being considered for the lightweight coarse aggregate will be tested and compared with conventional aggregate as a control. For the lightweight aggregates will test by using LA Abrasion test and Aggregate Crushing Value test to get their toughness and resistant value while compression test will be conducted to 150mm cube to get the its compressive strength.

Then, SLYCAG concrete will be produce by using those SLYCAG. Specimen size that will use is 150 mm x 150 mm x 150 mm for cube, 150 mm x 150 mm x 750 mm for beam. Those sample will test in laboratory in term to get their mechanical properties. This research is focus more on the compressive strength and tensile strength of the concrete that produce by using offshore lightweight aggregate with few different ratio.

1.5 EXPECTED OUTCOME

The expected outcome for this research is to achieve the suitable design of lightweight coarse aggregates by using offshore sand and use it to make a concrete. The result of mechanical properties that has been considered in this study will be compared with the properties of conventional aggregate and normal concrete. The SYLCAG concrete should be lighter.

On the other hand, this SYLCAG that was produced using offshore sand also can be used as alternative sources to reduce the usage of the normal aggregate. This study also is also expecting the chloride contain in offshore sand is lesser than the beach sand and river sand because of SYLCAG was produced with curing method.

1.6 CONCLUSION

This chapter has discuss the background of study, problem statement, objectives, scope of study and expected outcome for this research that related to SYLCAG concrete. In this chapter, it is a general knowledge of the research and there 3 objectives that have been decide which is related to the SYLCAG and SYLCAG concrete mechanical properties. Also, the scope that will be considered for this research such as materials, specimen size and testing also have discussed. The expected outcome for this research is to produce a lightweight aggregate that can be used in construction industry. In the next chapter, the review of previous paper related to this study were discussed. It is based on objectives and scope that already finalized for this study.

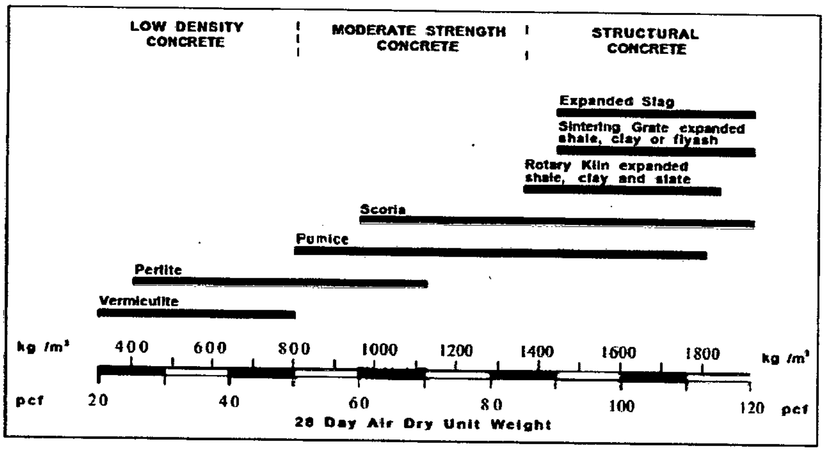

Figure 2.1 : Concrete aggregate spectrum

This diagram indicates the approximate 28-days of curing age, air dry unit weight range of three types of lightweight aggregate concretes. The larger size of lightweight aggregates are composed by processed or naturally occurring cellular materials of mineral origin.

Raw materials used in commercial production of structural lightweight aggregates are generally suitable natural deposits of shale, clays, or slates. The lightweight aggregate to be used is importance to the designer and user of structural lightweight concrete. One of several materials used are decrease the unit weight of concrete also reducing the structural load and the cost of the building.

The lightweight aggregate can be industry by products such as furnace bottom ash and furnace clinker. Natural lightweight aggregate can be define as pumice, wood particle and artificial lightweight aggregate such as foamed slag expand shale aggregate and expand clay aggregate, sintered pulverized-fuel ash aggregate, perlite and vermiculite. The aggregate used in this paper is artificial aggregates.

2.3.2 Properties of Lightweight Aggregate

In general, the strength of lightweight aggregate can be related to the concrete strength that will produced. Other than that, result in a concrete mix which is 20 % lighter in weight when lightweight aggregate are used compared to use natural gravel concrete.

The internal structure in the lightweight concrete is a honeycomb that one of generally interconnected voids of varying size and shape that amounting to 40 % of the volume. Lightweight aggregates are made by a thermal process using natural materual like clay, shale, slate, perlite, sand and vermiculite. Chandra and Berntsson (2008) claims, that the process of making lightweight aggregate is influence by raw materials used. Avery material have their owh way to conduct it. Especially for the material that mixing with other material such as foaming agent. More over, the lightweight aggregate will be mix with foaming agent in this study.

In the report of ACI Committee 213, state that lightweight aggregates from different sources or produced by different methods may have different considerably in particle shape and texture. Shape may be cubic and regular, rounded, angular or irregular while the texture is depend on the material used. Such as, fly ash, pumice, foaming agent and bottom ash.

More, the specific gravity of lightweight aggregates should be lower than that the normal weight aggregates. Also, the bulk specific gravity of lightweight aggregate also varies with particle size.

2.3.3 Strength and Toughness

In general, the strength of lightweight aggregate that produce can be related to the resulting concrete strength. The strength of aggregate particles varies with type and source and is measurable only in a qualitative way. Some particles may be strong and hard, and others weak and friable.

Saha (1999) has stated that the strength of lightweight aggregates can be related to the concrete strength and ceiling strength. Others, Thorsten et. al. (2009) also claimed that the particle tensile strength increase along with increasing of particle density. Then, it show that the increasing fracture energy is increasing with particle density. Figure 2.2 below show the relation of the strength.

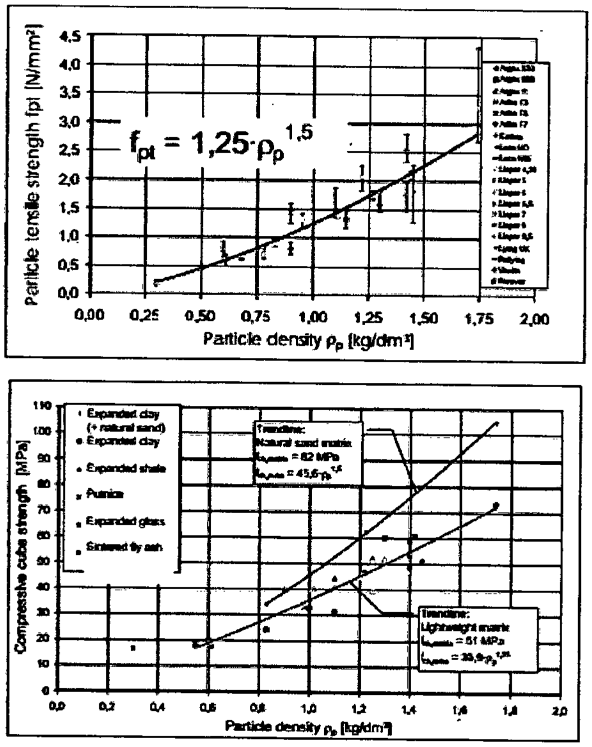

Figure 2.2 : The relation of particle size and density

Source : Thorsen et all 2009

2.4 LIGHTWEIGHT CONCRETE

2.4.1 Definition of Lightweight Concrete

Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as nailibility and lessened the dead weight.

The main specialties of lightweight concrete are its low density and thermal conductivity. Its advantages are the reduction of dead load, faster building rates in construction and lower haulage or handling costs.

2.4.2 Type of Lightweight Concrete

Lightweight concrete can be prepared by injecting air in the composition or can be achieved by omitting the finer aggregate sizes or replacing them by a hollow, cellular or porous aggregate. In fact, there are four method can produce lightweight concrete which is using air bubble, porous aggregate, lightweight material such as coarse aggregate and using coarse aggregates only to produce no-fines concrete (Ravindararajah et. al., 1993). Table 2.1 shows the type of the lightweight concrete such as aerated concrete, no-fine concrete, lightweight concrete and foam concrete.

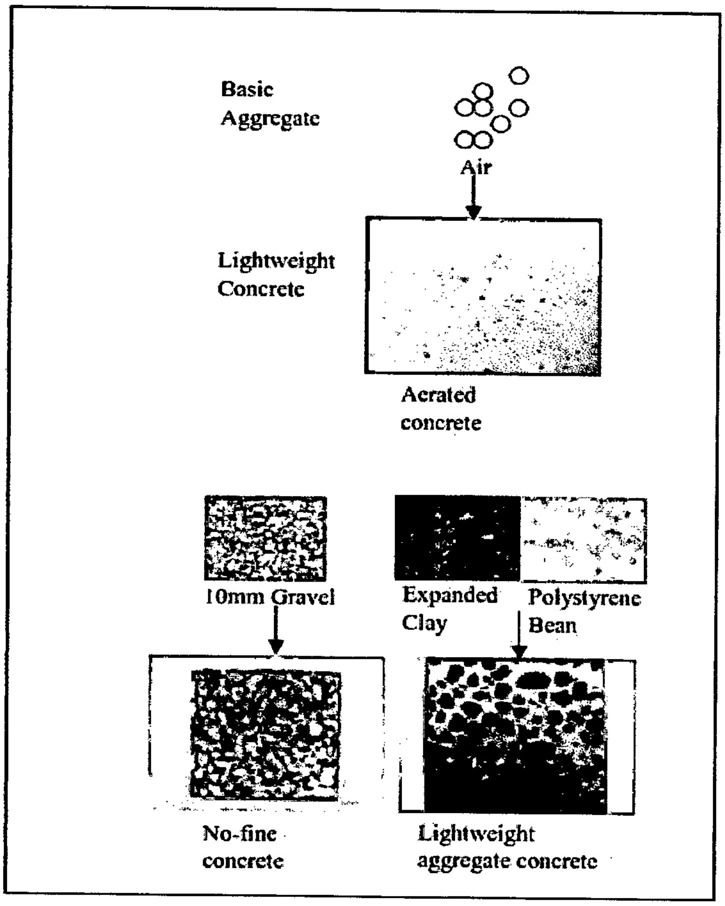

Figure 2.3 : Types of lightweight concrete

Source: Ravindararajah 1993

Table 2.1 : Types of concrete grade lightweight

Type Of Lightweight Concrete	Type Of Aggregate	Grading of Aggregate (Range of Particle Size)
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 fine (5mm and fines) material to produce a continues but harsh grading to make a porous concrete
Structural lightweight aggregate concrete	Foamed slag Expanded clay, shale or slate and sintered pulverized fuel ash	Continues grading from either 20mm or 14mm down to dust, with an 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 μm BS sieves, but sometimes fine aggregate (5mm and fines) is also incorporated

2.4.3 Characteristic of Lightweight Concrete

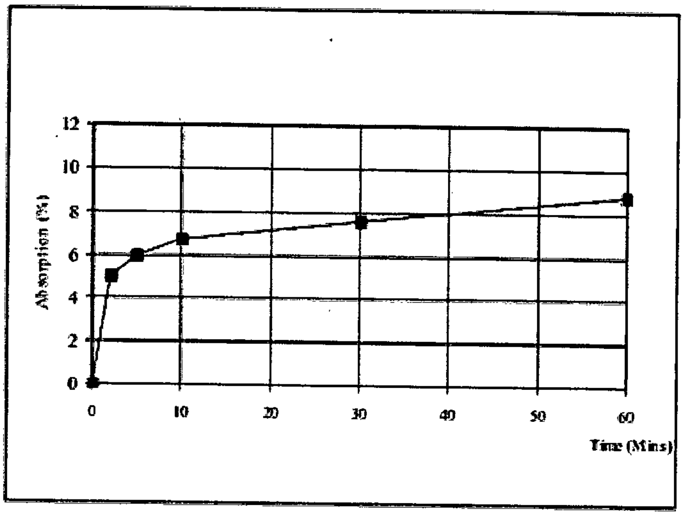

Figure 2.4 : Water absorption of lightweight aggregate

In term of structural, lightweight aggregate concrete (LWAC) and natural sand with oven dry densities have density around 1750 kg/m3 and strengths up to 70 N/mm (Andrew, 2008). With some admixtures, it is fairly straightforward to produce LWAC with dry densities in the region of 1450 kg/m and strengths in excess of 40 N/mm2 using both coarse and fine LWA. In conclusion, we can say that lightweight aggregate densities are around 240 to 1440 kg/m. usually, this concrete is normally used for the insulation purpose.

2.4.4 Advantage and Disadvantages

There are some advantages and disadvantages of using a lightweight aggregate in the concrete design. Andrew (2008) stated that by using lightweight aggregates in place of dense aggregates can also reduce the concrete weight. The lighter weight of concrete will also make the density of the concrete is reduce. Moreover, Table 2.2 below shows the advantages and disadvantages of using lightweight concrete in structure purpose as stated by kamsiah et. al. (2008).

Table 2.2 : Advantages and disadvantages of lightweight concrete

Advantages	Disadvantages
i) Rapid and relatively simple construction ii) Economical in terms of transportation as well as reduction in manpower. iii) Significant reduction of overall weight results in saving structural frames, footing or piles. iv) Most of lightweight concrete have better nailing and sawing properties than heavier and stronger conventional concrete	i) Very sensitive with water content in the mixtures. ii) Difficult to place and finish because of the porosity and angularity of the aggregate. In some mixes the cement mortar may separate the aggregate and float towards the surface. iii) Mixing time is longer than conventional concrete to assure proper mixing

2.5 FOAMING CONCRETE

2.5.1 Definition of Foaming Concrete

Lightweight foamed concrete is a kind of lightweight concrete, which is less heavy than a plain concrete by combining foam into cement slurry as explain by Watson et al. (1978).

From the meaning, the combining of foaming agent such as aluminium powder and zinc powder within the concrete slurry is the reason for the concrete to be less heavy than the conventional concrete.

Foamed concrete also known as cellular lightweight concrete which is produced by the mixing of ordinary Portland cement, sand with or without pozzolanic material as a cement replacement, water and a foam that is produced by the foaming agent.

Other definition by R.C. Valore (1954) a foamed concrete is a [illegible]

2.6 OFFSHORE SAND

2.6.1 Definition of Offshore Sand

Abdullah (1992) have claimed that offshore sand is a sand that should be taken 1.5 km away from beach with the depth is greater than 10m below. This offshore sand is widely used in some country. Moreover, Dias (2007) also stated that offshore sand extracted from below around 15 m of ocean depth.

Researcher from University of Moratuwa has claimed that the environmental and ecological impact from extracting the sand from 15 meters below sea level is minuscule while using beach sand is not a viable solution. It is because the impacts it has such coastal erosion and salt water intrusion.

This offshore sand is widely used in some country as coastal restoration and land reclamation project such as in Dubai, Malaysia, Singapore and many more. The nearest project of reclamation land in Malaysia is at Pantai Klebang, Malacca and it still on progress.

2.6.2 Chloride Content

Chloride is one of the aspects for consideration when the durability of concrete is important. Chloride is not good for material that will used in concrete mix because it will give some effect like speeding time of corrosion and will make concrete less strength. Dias (2007) claimed that the chloride content in offshore sand will depend on the chloride content in sea water and the moisture content of the sand. Usually, sea water has a Cl^- content of 1.98%, although there would be local fluctuations.

Figure 2.4 below show the chloride content in the offshore sand after being washed and drainage for the four type of samples. The chloride content on the materials are shows in percent.

Table 3. Results of sand column test

Sampling level (Fig. 1)	Set 1 – sea water; 5 days' drainage		Set 2 – sea water; 27 days' drainage		Set 3 – 80 mm rain water; 5 days drainage		Set 4 – additional 240 mm rain water; 5 days drain	
	Moisture (%)	Cl^- (%)	Moisture (%)	Cl^- (%)	Moisture (%)	Cl^- (%)	Moisture (%)	Cl^- (%)
A	2.10	0.044	1.37	0.115	2.22	0.008	2.37	0.0003
B	3.94	0.088	2.38	0.054	3.44	0.007	3.58	0.0002
C	3.20	0.061	2.79	0.069	2.96	0.030	2.99	0.0016
D	15.69	0.387	12.39	0.314	8.88	0.075	9.97	0.0459

Figure 2.5 : Chloride level

Source : Dias 2007

The most commonly used limit for total chlorides is the 0.4% limit (by weight of cement) specified in BS 5328: Part 1: 1997 for reinforced concrete. It should be noted that the limit for pre stressed concrete is 0.1% and that for reinforced concrete made with sulphate-resisting Portland cement (SRPC) is 0.2%.

2.6.3 Advantage and Disadvantages

Dolage et. al. (2013) state in their research, that using offshore sand may have given some advantages and disadvantages to the concrete. Table 2.3 below show the advantages and disadvantages of the offshore sand :

Table 2.3 : Advantages and disadvantages of offshore sand

Advantages	Disadvantages
It is the cheapest form of fine aggregate.	it may lead to efflorescence and corrosion of reinforcement
As it is found in natural deposits grading of offshore sand sand is generally good.	If washing is necessary, it may be an additional burden.
	Restrictions on mining offshore sand, to prevent sea erosion.