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Synthetic Lightweight Coarse Aggregate Using Offshore Sand

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Abstract –*Offshore sand is a capable alternative replacement for land aggregate in concrete. It is necessity for some country or regional where land aggregate is scarce and sometimes unavailable to be used for development but offshore sand is accessible for replacement. This paper reports about the production and usage of synthetic lightweight coarse aggregate produced using offshore sand (SYLCAG). It was produced with density of 1300 kg/m*^{3} *which is nearly 60% lighter than normal aggregate. This SYLCAG was used as a full replacement for coarse aggregate in concrete which then produced as a concrete with density almost 1900 kg/m3. The produced concrete did not have a good strength with design of 25 MPa concrete. However, it still has the potential to be develop with higher design and later used as structural concrete.*

Keywords: Synthetic Aggregate, Offshore Sand, Lightweight Aggregate

1.0 INTRODUCTION

The utilization of land resources as the prime source for construction materials has always been a rising issue for certain country that include Malaysia. In 2008 it was reported that there was almost 2% reduction toward granite and limestone aggregate production which led to importing aggregate where it was 6.3 times higher than the previous year [1]. According to [2], Malaysia consumed 2.76 billion metric tons of natural aggregate in 2010 which most of it came from land resources. This shows that exploration toward other source is essential not with the aim to further exploit natural resource but for reservation of future development.

Offshore sand is one of available natural resource that has potential to be use in construction industries. In Sri Lanka for example, due to limited source of river sand, explorative usage of offshore sand has been progressed [3]. In Malaysia, offshore sand mining have already started to progress in south of Johore to cater the need of sand for development mostly in embankment activities [4]. In the concrete industries of Malaysia there is no record shows application of offshore sand in structural concrete yet. There is too little investigation toward such application.

One of the reason that hinder the use offshore sand in concrete is because the properties of the materials itself is not suitable for concrete. The chloride level of offshore sand is high and will enhance the possibility of corrosion in reinforced concrete. However, [5] found that offshore sand can be treated with gravity drain so that the content of Cl^- ions could be reduced to an acceptable level for OPC concrete mix. They stated that a conservative limit for allowable Cl^-

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ions in o□shore sand for OPC based reinforced concrete is 0.075% by weight of the sand. [5] also found that the concrete mix using offshore sand (Cl^- content of 0.075%) and designed as grade 20, showed the satisfactory and similar corrosion performance in embedded steel to a chloride free control mix. It shows that offshore sand is capable to replace washed sand in any conventional OPC concrete mix that should include foamed concrete.

This paper presents an explorative study which produced offshore sand foam concrete later crushed to synthetic lightweight coarse aggregate (SYLCAG). It was mention by [6] that using crushed concrete as aggregate can produce a concrete with similar bulk engineering and durability properties as the corresponding natural aggregate concretes, providing they can be designed to have equal strength. The idea of making it as the synthetic coarse lightweight aggregate using offshore sand has the possibility to help in reducing the usage of natural raw rocks and decrease the bulk weight of a concrete mix.

2.0 METHODOLOGY

2.1 Materials

The offshore sand was taken from reclamation project at Pantai Klebang, Melaka. Melaka land reclamation has been done in decades and most of the sand was pump from the states offshore itself. A large quantity of sand was taken from a single area of reclamation to control the properties of this sand. This offshore sand was never treated but was already exposed to land weather for more than 3 years or higher. Although it has been exposed for a long time to rain and sun for a long time, the chloride content of this sand was high compared to river sand. This sand was used as it was taken to produce a foam concrete.

With ability to control the density of foam concrete, offshore sand with the size lower than 2 mm was used as the fine aggregate in a design with density of 1300 kg/m^3. After water curing for more than 28 days, the foam concrete was crushed. With a sieving process, it was produced into SYLCAG with size of 2.36 – 20 mm. This SYLCAG have gone through several test to determine the important properties required for application as a coarse aggregate.

2.2 Tests

The test of this study was divided into two phase. The first phase was the test to study the physical properties of the produced SYLCAG. The tests include chloride content test, abrasion test, crushing value test and compressive strength test. The second phase of the study was to conduct compression and flexural test on concrete that were produced by using SYLCAG.

Table 1: Detail of mix design

Sample Mix	Fine aggregate (kg)	Coarse Aggregate (kg)
G25	660	1174
SYLCAG*1	660	635.92
G35	637.2	1115.08
SYLCAG*2	637.2	604

The mix designs for concrete using SYLCAG were based on the standard design of 25 MPa (G25) and 35 MPa (G35). The replacements were based on volume replacement of those

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designs and were named SYLCAG*1 and SYLCAG*2 respectively. The aim was to achieve concrete with the same volume but lower densities. Detail of the mix design for 1 m^3 is shown in Table 1. All designs use the same weight of cement and water that was 420 kg and 210 kg respectively. Samples for compression test were produced with the size of 150 mm while for flexural test with the size of 750 x 150 x 150 mm. All samples were cured for 7 days, 14 days, and 28 days.

3.0 RESULTS AND DISCUSSION

3.1 Chloride Content

Table 2 shows the chloride content in three type of sample. Chloride content test verify that the offshore sand obtained still have high content of chloride ion even after exposed for a long time on land. From result, offshore sand that used as a sample have chloride content as 133 mg/L which is higher than river sand that only have 48 mg/L. After SYLCAG from offshore sand have been produced, it was tested again to measure its chloride content. From this study, SYLCAG that produced with density of 1300 kg/m^3 have a lower chloride content which is 7 mg/L.

Table 2: Detail of mix design

Sample	Chloride Content (mg/L)
Sand	48
Offshore Sand	133
SYLCAG	7

The main reason was due effect from producing with foaming agent and the curing process before. The cube sample was soaked in the water for 28 days. This result show that processed offshore sand can have lower chloride content. With this lower chloride content, SYLCAG can be used in concrete as it achieved a lower value compared to normal river sand that was used for concrete mix. It was highlighted by many that higher chloride content may speed the corrosion process happen. Specify in British Standard that the most commonly used limit for total chlorides is the 0.4% limit by weight of cement. With the weight of 650 kg of SYLCAG, the chloride weight was only 3.5 gram which was very low compared to weight of cement.

3.2 Abrasion Resistance and Aggregate Crushing Value

Coarse aggregate before being used normally subjected wearing due to many process including transporting and stockpiling. Abrasion resistant was important to be determine to examine the suitability of SYLCAG for application. Table 3 shows the comparison between normal aggregate and SYLCAG abrasion resistant. The test was conduct for the size of aggregate between 10 to 19 mm. The initial weight was divided to 2500 g for size from 10 to 14 mm and another half for size from 14 to 19 mm.

From the results, SYLCAG with density of 1300kg/m^3 was verified with low abrasion resistance. American Society for Testing and Materials (ASTM) provide that allowable abrasion value that can be used for concrete should be less than 45%. For this mix, some modification can be done to achieve that limit because the percentage of loss was not too far from the limit. The surfaces of SYLCAG basically are full of voids which produced unsmooth surface of the aggregate itself. If the number of surface voids can be reduce there are high possibility to increase the abrasion resistance.

Table 3: Abrasion resistance of aggregates

Sample	Weight of sample (after) (g)	Weight loss (g)	Loss
Normal aggregate	3610	1390	27.8 %
SYLCAG	2270	2730	47.4 %

The aggregate crushing value also one of important properties of aggregate that need to be determine. It provides a relative measure of resistance toward crushing under gradually applied load. Normally the allowable crushing value for aggregate is between 25% and 35 % which depend on the application of the aggregate. Table 4 shows the comparison between normal aggregate and SYLCAG crushing value. With limit of 30 % for crushing value, SYLCAG was recorded to reach only 33.10% which was not far greater than 30%. Its show that there is promising possibility for the mix to be modified to achieve the limit of 30%.

Table 4: Aggregates crushing value

Sample	Aggregate Size (mm)	Weight of Sample (g)			Loss
		Before	After	Loss	
Normal aggregate	14-10mm	2680	2050	630	23.51%
SYLCAG		1580	1057	523	33.10%

3.4 Aggregate Compressive Strength

Aggregate compressive strength was determine in order to verify the self-strength of SYLCAG before incorporate in the concrete mix design. The normal nature coarse aggregate like granite have the strength that is more than 100 MPa which is very high toward the end only used to produce normal concrete with strength that is less 60 MPa.

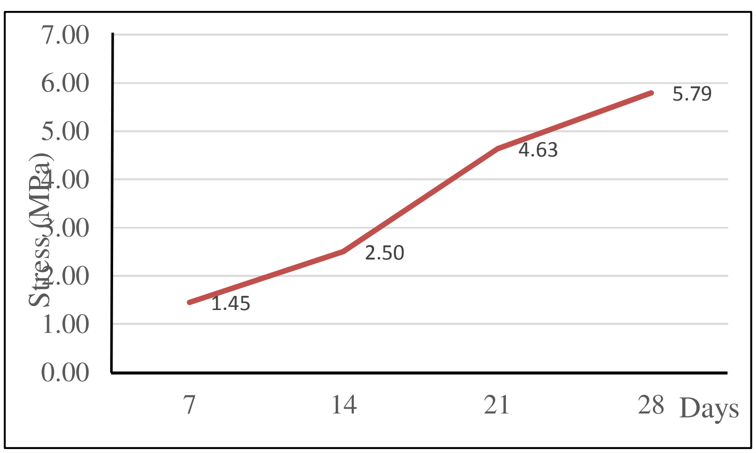

Figure 1: Compressive strength of SYLCAG 1300 kg/m^3

Figure 1 shows the relation between compressive strength and curing age. From the graph, the compressive strength increase is proportional to curing age. For this mix design of foam concrete, the compressive strength keeps increased until 28-days. The result for compressive strength for SYLCAG achieved expectation which is 5.78 MPa for 28-days. The minimum compressive strength that has been setup was 5.0 MPa. The study proceeds with this mix design to produce lightweight aggregate. Compressive strength of foam concrete influenced by many factor such as age, curing method, density and mix proportion. Other parameters that affect the strength of the foam concrete are cement sand and water cement ratio, curing regime, size and type of sand and type of foaming agent used [7,8].

3.5 Lightweight Concrete Using SYLCAG

The most important properties of hardened concrete that need to be apprehended is a good compressive strength. Normally the minimum strength that are used in structured is more than 20 MPa. As mention in method, for group of sample were produced to determine the compressive strength. The test is carried out on cube samples which undergone curing for 28 days. Generally, the compressive strength of all concrete increased with the curing age.

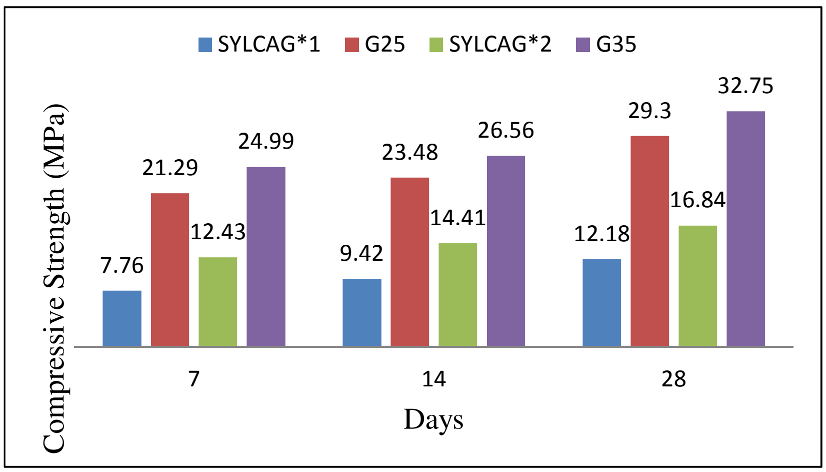

Figure 1: Schematic for the leading edge

Figure 2 shows the chart of compressive strength between normal concrete G25 and G35 with modified design using SLYCAG. From the chart, we can see the huge different between normal concretes with SYLCAG concretes. For three set of days, normal concretes far higher compressive strength compare SYLCAG concretes. The minimum compressive strength that was aim for this two mix was 20 MPa. However, with a design of G35 nearly 17 MPa was achieved by SYLCAG*2. It is expected that if a design with strength of 45 to 55 MPa is used, there are promising possibility that 20 MPa strength can be achieved by using SYLCAG with density of 1300 kg/m^3.

While having a low strength compare to normal concrete design, SYCAG concretes has the advantage with its much lighter and lower density as recorded in Table 5. Highlighted in this study also is that even when SYLCAG was produced with a very low strength as shown in Figure 1, SYLCAG was able to be used to produce concrete with strength that is more than 15 MPa in this study.

Table 5: Properties of concrete achieved at 28 days

Sample	Density (kg/m^3)	Compressive strength (MPa)	Flexural strength (MPa)
G25	2281.48	29.30	3.58
SYLCAG*1	1906.17	12.18	1.2
G35	2296.30	32.75	4.21
SYLCAG*2	1930.86	16.84	1.54

It is a fact for foam concrete, the strength will be reduces because of high number of void developed in the concrete itself. But by producing initial aggregate with void (SYLCAG), the void was controlled in the coarse aggregate only. With this void, it was also same with flexural stress capacity that was reduced as shown in Table 5. But this property of concrete is normally replaced with reinforcement if the concrete are used in structure application. With more study the compressive and flexural strength at 28 days for SYLCAG concrete can be improved with the aim to keep the density below 2000 kg/m^3.

4.0 CONCLUSSION

The study on lightweight coarse aggregate using offshore sand (SYLCAG) has open opportunity to apply offshore sand in the concrete industry. However, based on the finding of this study, there are some improvements need to be achieved to validate its usage for concrete. It is important first to achieve a good compressive strength design which have strength that is more than 20 MPa but have low density. If this design is available, this SYLCAG have high potential for usage in countries that have low natural aggregate storage. There works that prove that foam concrete can be used to produced high strength concrete [9].

SYLCAG also have been produced with prove that the chloride content is no concern anymore toward application in reinforced concrete. Nevertheless, it is required to certify this with more study with long term effect toward corrosion potential if SYLCAG is used to produce reinforced concrete structure. It is because even with low chloride content, the void in the aggregate can contribute toward reinforced concrete deteriorations.

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