FLEXURAL BEHAV[illegible]ETIC LIGHTWEIGHT COARSE AGGREGATE (SYLCAG) CONCRETE

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ABSTRACT

The use of offshore sand is an alternative to replace normal weight aggregate where they are over exploited nowadays. The development of this study were experimentally to determine the capabilities of the researched materials (offshore sand) used in structural reinforced concrete. Flexural strength test were carried out with increasing load using third point load test method until the designed reinforced beam fails. The load and deflection were recorded in timely manner. Experimental ultimate moment capacity and deflection were compared with theoretical calculations and the cracks occurred are visualized to determine mode of failures. Even at early stage sample beam shows some potentials until first cracks occurred due to shear failure, the study found that sample beam deflection was higher than predicted and the ultimate moment capacity only achieves 40% compared to control sample.

ABSTRAK

Penggunaan pasir laut dalam adalah alternatif bagi menggantikan aggregat biasa dimana aggregat biasa dilihat digunakan secara berleluasa. Justeru, pembangunan kajian ini adalah menilai kemampuan pasir laut dalam untuk digunakan dalam struktur konkrit bertetulang. Kajian berkenaan momen lentur akan dijalankan dengan pertambahan beban secara berperingkat sehingga rasuk yang direkabentuk mengalami kegagalan. Dalam pada itu pesongan turut direkodkan. Seterusnya data momen lentur dan pesongan ini dianalisis untuk dibandingkan dengan teori kajian. Manakala keretakan pada rasuk akan dianalisis untuk menentukan keadaan kegagalan yg dialami. Kajian mendapati momen lentur yang berlaku bagi sampel rasuk yang konkrit diuji adalah tinggi daripada jangkaan dan hanya mampu mencapai 40% daya lentur sampel konkrit biasa.

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LIST OF ABBREVIATION

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
B.S.	British Standard
HWC	Heavy Weight Concrete
LVDT	Linear Voltage Displacement Transducers
LWA	Lightweight Aggregate
LWAC	Lightweight Aggregate Concrete
LWC	Lightweight Concrete
NWA	Normal Weight Aggregate
NWC	Normal Weight Concrete
NWCA	Normal Weight Coarse Aggregate
OPC	Ordinary Portland Cement
SLWAC	Structural Lightweight Aggregate Concrete
SLWC	Structural Lightweight Concrete

SYLCAG	Synthetic Lightweight Coarse Aggregate
UMP	University Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Reinforced concrete is well known as versatile, economical and successful construction material over the world. Concrete is a composite material of cement, fine aggregate, coarse aggregate and water. The use of lightweight concrete in construction industry nowadays has been gaining popularity. Many researchers are trying to produce a lightweight concrete (LWC) with a significant strength depends on the applications. Concrete has high compression strength but low tensile strength, about 10% of the compressive strength. Providing reinforcement in concrete is to strengthen the concrete in term of tension force. However, in large-scale structural, applications of lightweight concrete are not popular comparing to normal weight concrete (NWC).

According to ACI 213, structural lightweight concrete (SLWC) applicable for multistory building frames and floors, curtain walls, shell roofs folded plates, bridges, prestressed or precast elements and also use in marine structures. Development of the suitability of the materials is important to provide many options producing concrete especially for the application as structural lightweight concrete (SLWC).

Offshore sand refers to sea sand but it is not beach sand. The term offshore refers to under sea level and the material is not available to be obtaining easily. Very different from river sand, offshore sand contains shells in its composition. It can be seen just by normal visualization inspection and the color also brighter than river sand. Figure 1.1 shows offshore sand at its location the sample taken.

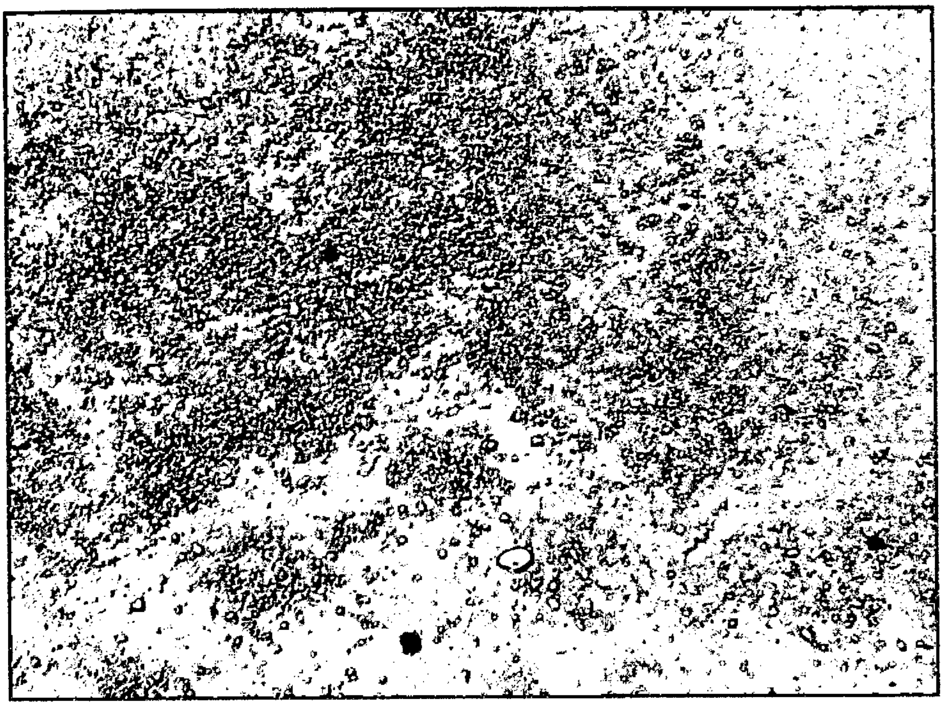

Figure 1.1: offshore sand

Therefore, this research presents the study of the simple structure behaviour utilizing synthetic lightweight coarse aggregate (SYLCAG) using offshore sand as replacement in concrete mix. This report presents in 5 chapters that are introduction, literature review, methodology, result and analysis and conclusion respectively. In this chapter, the section divided to background of the study, problem statement, research objective, scope of study, significance of study and conclusion.

1.2 BACKGROUND OF THE STUDY

Currently, reinforced concrete use normal weight coarse aggregate as a largest part of the materials. Due to fast developments, this normal weight aggregate is over exploited in construction. There is an alternative suggestion by many researchers that is using offshore sand to replace fully or partially river sand in concrete. A researcher at Sri Lanka found that offshore sand was the suitable choice to replace river sand with minimal impact to cost and environment. However, offshore sand should extract from 15m of ocean depth (Dias, 2007). Comparing to beach sand, the offshore sand have lower chloride content. Dias (2007) in his paper mention that the beach sand have a high chloride content due to wetting and drying cycles of sea water. Beside that it also contributes to beach erosion. Even it has chloride content; it shouldn't be a problem since chloride content can be reduced by repeated wash and drain using rain water, beach sand take longer time. The use of offshore sand then will provide alternative to land aggregate. In this study, the offshore sand is use as a material to produce lightweight coarse aggregate to replace normal weight aggregate in concrete.

1.3 STATEMENT OF PROBLEM

Construction industries in over the worlds now are highest demand on raw material of concrete especially aggregate. In concrete the largest part of concrete are normal weight coarse aggregate (NWCA). With the developments over the world keep increasing, the demand will also increase even nowadays the production of normal weight aggregate (NWA) is slowing down. Normal weight aggregate (NWA) is natural resources. In his research Lo (2004) has mentioned most of normal weight aggregate (NWA) is a natural stone such as limestone and granite. With the amount of concrete keep increasing, natural environment and resources are excessively over exploited. According to that issue offshore sand can be an alternative to replace either the use of river sand or the use of aggregate.

In large-scale structural applications lightweight concrete is not popular comparing to normal weight concrete. Lim (2006) indicate that two main reason lightweight concrete not popular as normal weight concrete. Firstly, it requires greater skills and technology backup in-term of lack of understanding on the production technique of this material. Secondly, there is insufficient information available locally on the structural performance to provide guidance to the designers. In other research (Muda, 2012) stated that lightweight concrete problems is low flexural strength. So, the contents of this research hopefully contribute to future development of structural lightweight concrete (SLWC). It deals with flexural behaviour and failure characteristics of reinforced lightweight artificial offshore aggregate.

It is important to study whether concrete using SYLCAG can behave similar as normal concrete in structure system. This research investigates especially whether simple beam using SYLCAG concrete can behave similar to beam using normal concrete. So, this study is to provide more reference either the use lightweight aggregate concrete (LWC) or the use offshore sand in structural applications for the construction industry in the future.

1.4 OBJECTIVE OF RESEARCH

The objective of the research shown below:

(i) To compare theoretical and experimental the ultimate moment of reinforced concrete beam using SYLCAG.

(ii) To determine the mid-span deflection of reinforced SYLCAG concrete beam.

(iii) To visualize the failure mode and crack pattern of reinforced lightweight artificial offshore aggregate concrete.

1.5 SCOPE OF STUDY

The scope of study for this research basically to study the flexural behaviour and failure characteristics of reinforced SYLCAG concrete beam. The aggregate will follow ASTM C33 grading requirements. The reinforced SYLCAG concrete beam to be research is lightweight aggregate concrete made from offshore sand. The offshore sand was taken from reclamation project at Pantai Klebang, Melaka. The sand will be washed by rain before it will be use as material in making a lightweight aggregate to replace 100% aggregate function before the aggregate used for making a concrete samples. The curing must be done by provide enough moisture to the sample before testing conducted. Testing is being done in the laboratory at 28-days age of samples. The numbers of samples to be prepared is 2 concrete beams including control sample labeled beam CL and beam 1300 as the researched sample. The size of each beam is 150 mm x 200 mm x 1500 mm. After testing the samples, the result is being analyzed and will come out with significant conclusion.

1.6 SIGNIFICANCE OF THE STUDY

The test structure in this study was structural simple concrete beam reinforced with steel bar using lightweight coarse aggregate concrete. This study hopefully will help construction industry in the future on development offshore sand as alternative to normal weight aggregate (NWC). More than that, researchers have more references related to this area of study.

1.7 CONCLUSION

The construction industries need alternative materials in the business. The use of offshore sand will provide alternative such as replacing sand with fly ash, laterite soil, pumice etc. In this chapter, the general outline of the study was finalized. It is base on the topic of this research. The topic discussed in this chapter including problem statement, three objectives, scope and significance of the study. The next chapter consist five section shows the review published information related to this study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will discuss in detail about the theory research, raw materials, lightweight concrete, characteristic of reinforced concrete beam, design strength of materials, theory of design reinforced concrete beam and the use of offshore sand. In the previous chapter stated a background, problem statement, objective, scope and significance of the study to make sure and to be a guideline for the review to be on track.

Reinforced concrete is a composite material that consists of cement, fine aggregates, coarse aggregate and embedded with reinforced steel bar (Nawy, 2003). However, water is a key ingredient to manufacture concrete. According to unit weights, concrete divided into 3 groups (Asik, 2006):

(i) Heavy-weight concrete, HWC (Unit weight is in the range of 3200 kg/m^3 - 4000 kg/m^3)

(ii) Normal-weight concrete, NWC (Unit weight is in the range of 2400 kg/m^3 - 2600 kg/m^3)

(iii) Lightweight concrete, LWC (Unit weight is less than 2000 kg/m^3)

This study is using lightweight concrete (LWC) as method producing concrete. There is many type of lightweight concrete (LWC) and in this study offshore sand is use as a raw material to produce lightweight aggregate (LWA) before producing the lightweight concrete (LWC). Current researchers are directly replaced the use of river sand with offshore sand. So, literature contains limited information on the use of offshore sand as an aggregate in making a reinforced concrete.

2.2 RAW MATERIALS

Normal concrete generally consist a mixture material of cement, water and aggregate. For lightweight concrete these elements also used but the differences are it includes expanding agent or using lightweight aggregate (Shamsuri, 2011). These materials use are discusses in this topic. However, the SYLCAG is artificial lightweight offshore coarse aggregate made from cement, offshore sand, water and foam agent.

2.2.1 Cement

Cement in concrete acting as a binder to all materials in concrete. Cement has a variety accordingly to usage in construction or to solve special problems of concrete. The greatest use of cement is ordinary Portland cement (Mindess et al., 2003). Mixing cement and water provides mixture called cement paste. In concrete, cement paste covers the surfaces of the aggregate particle, fill the spaces between particles and produce a compact mass by binding the aggregates particles (Erdogan, 2002).

2.2.2 Fine Aggregate

Fine aggregate terms is generally refers to sand. Generally, river sand is used in conventional concrete production. Grading fine aggregate is necessary according to BS 882:1992 and. Table 2.1 shows the grading requirements for fine aggregate.

Table 2.1: BS and ASTM grading requirements for fine aggregate.

Sieve size		*Percentage by mass passing sieves*				
BS	*ASTM No.*	*BS 882 : 1992*				*ASTM C 33-08*
		Overall grading	*Coarse grading*	*Medium grading*	*Fine grading*	
10.0 mm	$\frac{3}{18}$ in.	100				100
5.0 mm	$\frac{3}{16}$ in.	89–100				95–100
2.36 mm	8	60–100	60–100	65–100	80–100	80–100
1.18 mm	16	30–100	30–90	45–100	70–100	50–85
600 μm	30	15–100	15–54	25–80	55–100	25–60
300 μm	50	5–70	5–40	5–48	5–70	5–30
150 μm	100	0–15*				0–10

*For crushed stone fine aggregate, the permissible limit is increased to 20 per cent except for heavy duty floors.

Sources: Neville (1995)

2.2.3 Water

Generally water used for hydration process and provide workability to concrete mixture. Water is an important ingredient of concrete. Impurities of water can effect on concrete quality. The impurities contained in the concrete mix also effect setting times, drying shrinkage, durability or may cause efflorescence (Mindess et al., 2003).

2.2.4 Synthetic Lightweight Coarse Aggregate (SYLCAG)

In this study, the SYLCAG is manufacture using offshore sand, Portland cement, foam agent and water. The function of coarse aggregate in concrete will be replaced by this SYLCAG.

Offshore sand is sand obtained from seashore or dredged from the sea. By observation if compared to river sand the major difference is the absence of shells in river sand are not much as offshore sand. According to Seneviratne (2006) normally offshore sand saturated with sea water had chloride content around 0.3%. However, it can be reduced around 0.075% when the sea water is gravity drained.

Offshore sand had been used widely as beach or coastal restoration and land reclamation project for example reclamation project at Melaka. Abdullah (1992) stated that offshore sand is feasible and financially viable option for reclamation project but suggested offshore sand should taken from 1.5 km away with depth greater than 10m. This evidence shows the use of offshore sand in Malaysia. However, the use offshore sand in reinforced concrete in Malaysia has no related information even it has some advantages to be consider.

A study by Chandrakeerthy (n.d) as cite in Dolage (2013) list the advantages and disadvantages as follows:

Table 2.2: Advantages and Disadvantages of offshore sand

Advantages	**Disadvantages**
It is cheapest form of fine aggregate It is more rounded and cubical likely to river sand. Price fluctuations are small throughout the year. As t is found in natural deposits, grading of offshore sand is generally good. It contains no organic contamination, silt or weak small gravel particles The chloride can be reduces to acceptance level	Efflorescence possibilities and corrosion of steel bar. If washing is necessary, it may be an additional burden Offshore sand facility will require a large capital investment

Sources : Chandrakeerthy (n.d) as cite in Dolage (2013)

In this research SYLCAG is used to replaces normal weight aggregate (NWA) in term of it density. The synthetic term refers to it manufactured aggregate. The laboratory process making this aggregate discuss in chapter 3. Table 2.3 from BS 882:1992 will be used as guidance producing this aggregate.

Table 2.3: BS grading requirements for coarse aggregate.

Sieve size		*Percentage by mass passing BS sieves*						
mm	*in.*	*Nominal size of graded aggregate*			*Nominal size of single-sized aggregate*			
		40 to 5 mm *1½ in. to 3/16 in.*	*20 to 5 mm* *¾ in. to 3/16 in.*	*14 to 5 mm* *½ in. to 3/16 in.*	*40 mm* *1½ in.*	*20 mm* *¾ in.*	*14 mm* *½ in.*	*10 mm* *3/8 in.*
50.0	2	100	—	—	100	—	—	—
37.5	1½	90–100	100	—	85–100	100	—	—
20.0	¾	35–70	90–100	100	0–25	85–100	100	—
14.0	½	25–55	40–80	90–100	—	0–70	85–100	100
10.0	3/8	10–40	30–60	50–85	0–5	0–25	0–50	85–100
5.0	3/16	0–5	0–10	0–10	—	0–5	0–10	0–25
2.36	No. 8	—	—	—	—	—	—	0–5

Sources: Neville (1995)

2.2.5 Foam

Foam agent in this study is use in manufacturing SYLCAG. Foam agent provides air bubbles in concrete mixture (Shamsuri, 2011). Applying this foamed agent in manufacturing SYLCAG creates a lightweight aggregate (LWA).

2.2.6 Reinforcement Steel Bar

Flexural behaviour in this study depends to the reinforcement steel bars embedded in reinforced concrete structures. According to Eurocode 2 design should be base on characteristic strength of the reinforcement (f_{yk}). Two types of characteristic strength present in Table 2.4. The advantages of using reinforcement in concrete is to overcome weakness of concrete in term of tensile strength while it has a good ability to bond with concrete however may lose strength due to corrosion (Waller, 2005). So, if lightweight concrete has a good bond with steel reinforcement similar to normal weight concrete, then the result should be close to each other. Next topic will discuss about the lightweight concrete (LWC).

Table 2.4 : Eurocode 2 characteristic strength of reinforcement

Reinforcement type	Characteristic strength, F_y (N/mm^2)
Hot rolled mild steel	250
High yield steel (hot rolled)	500

2.3 LIGHTWEIGHT CONCRETE

Lightweight concrete (LWC) has been applied over 2000 years. A building during the early Roman Empire such the Port of Cosa, the Pantheon Dome and the Colliseum were the several example lightweight concrete structures (ACI, 2003). The used of structural lightweight concrete (SLWC) reduce the selfweight of a structure and permits larger precast units to be handled (Sivakumar and Gomathi, 2012). According to American Standard (2003) as cite in Shamsuri (2011), lightweight concrete (LWC) is a concrete that can achieve minimum 17 Mpa of compressive strength in 28 days with density less than 1850 kg/m^3. According to Chia and Zhang (2002), lightweight concrete density typically range from 1400 kg/m^3 to 2000 kg/m^3 compared to 2400 kg/m^3 for normal weight concrete (NWC). But, According to Asik (2006) ultra- lightweight concrete can be higher voids with lower density for non-structural purposes.

Lightweight concrete categories based on no-fines concrete, aerated cellular concrete and lightweight aggregate concrete (Sivakumar and Gomathi, 2012). Lightweight concrete mixtures can be designed with the same procedure as normal weight concrete but lightweight concrete has a lower compressive strength than normal weight concrete. The production of lightweight concrete may often complicated than normal weight concrete in term of water absorption (Asik, (2006).

2.3.1 Types of Lightweight Concrete

There are many method producing lightweight concrete (LWC) either by provide more air void in its composition or replacing the aggregate with hollow, cellular or porous aggregate (Newman et al., 2003). Sivakuamar and Gomathi (2012) categorized lightweight concrete into 3 groups:

(i) No-fines concrete

(ii) Aerated/Foamed concrete

(iii) Lightweight aggregate concrete

No-fines are a concrete that only contains cement and rough aggregates which provide more voids in concrete. It is used for construct outside bearing wall, non-bearing wall and plaster wall for structure and slab (Neville, 1995). Aerated or foamed concrete made by mixing concrete with small amount of aerated agent that create air bubbles in concrete to reduce density and provide good thermal-acoustic insulation. However, it has low compressive strength and high rate of water absorption (Arreshvina, 2002).

Lightweight aggregate concrete (LWAC) is widely used of lightweight concrete (LWC) in building construction since over 2000 years till today. Lightweight aggregate (LWA) can be classified into two categories that is natural aggregate and artificially manufactured aggregate. Lightweight aggregate concrete (LWAC) often called structural lightweight aggregate concrete (SLWAC) with regard to the applications in buildings, bridges and offshore structures. Generally the aim producing lightweight aggregate concrete (LWAC) is increasing the concrete strength while reducing its density. There is wide range of different lightweight aggregate (LWA) which is depends on raw materials, density, shape, outer skin and water absorption (Faust, 1998). In this study, lightweight aggregate (LWA) use for lightweight aggregate concrete (LWAC) contains SYLCAG made from mixing offshore sand, Portlant cement, Foam and water. There are a lot of chemicals which can influence the ability of lightweight concrete (LWC) such as acid, alkali, carbonation and chloride ion (Chandra and Berntsson, 2002).

2.3.2 Applications and Classifications of Lightweight Aggregate Concrete

Nowadays lightweight is widely used for modern construction. Varies applications are using lightweight concrete (LWC) including multistory building frames and floor, curtain walls. Shell roofs, folded plates, bridges, prestressed or element of all types and others (ACI, 1999).

According to ACI committee 213 (1999) many types of aggregates available can be classified as lightweight aggregate (LWA) and their properties cover wide ranges. Figure 2.1 indicates the approximate 28 day air dry unit weight range of three types of lightweight aggregate concrete along with the use to which each type is generally associated.

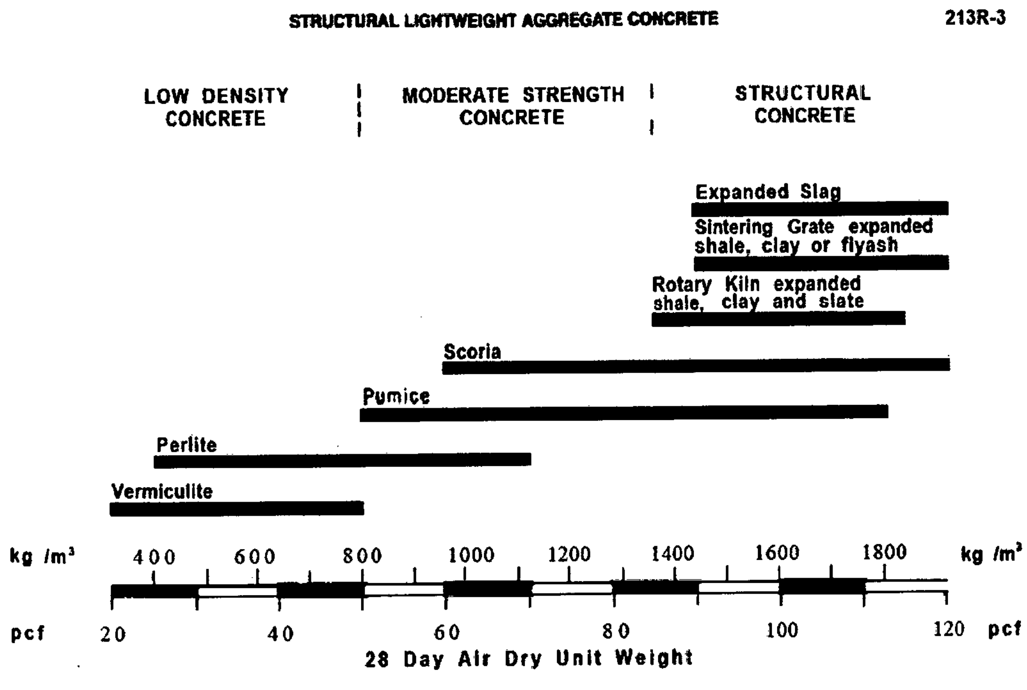

Figure 2.1: Approximate unit weight in 28 days of lightweight aggregate concrete

Sources: Neville (1995)