THE PERFORMANCE OF CONCRETE USING SYNTHETIC LIGHTWEIGHT COARSE AGGREGATE (SYLCAG) ON FLEXURAL BEHAVIOR

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ABSTRACT

Flexural behaviour is one of the element in determine whether the materials involve in the case study can be used as part of the structure. This study reported on the flexural behaviour of reinforced concrete beams construct from synthetic lightweight coarse aggregate (SYLCAG) produced from offshore sand which is used as 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 offshore sand as synthetic lightweight coarse aggregate (SYLCAG) used in structural reinforced concrete. Compressive strength test were carried out to determine the strength of concrete using SYLCAG. Flexural strength test were carried out with increasing load using four point load test method until the designed reinforced beam fails. The load applied and deflection were recorded in timely manner. Experimental ultimate load capacity and deflection were then compared with the theoretical calculations which calculated from Eurocode 2 for the ultimate load capacity and ACI code or the deflection. The cracks occurred are visualised to determine the mode of failures. This study find that concrete made of SYLCAG has low strength. Other than that, for the four point test, SYLCAG reinforced concrete beam has shown lower load capacity can be taken before the beam fail as about 50% of the normal concrete design of the same strength. At early stage, SYLCAG concrete show positive failure mode and as the load apply increased, it tend to have failure mode in shear.

ABSTRAK

Ujian kekuatan lenturan merupakan salah satu elemen dalam menentukan sama ada bahan yang digunakan dalam ujikaji boleh digunakan sebagai sebahagian daripada struktur. Kajian ini melaporkan kelakuan lenturan rasuk konkrit bertetulang sebahagiannya terdiri daripada sintetik ringan agregat kasar (SYLCAG) dihasilkan daripada pasir pantai yang digunakan sebagai alternatif untuk menggantikan agregat normal di mana telah dieksploitasi dengan kerapnya pada masa kini. Perkembangan kajian ini adalah uji kaji untuk menentukan keupayaan pasir luar pesisir sebagai SYLCAG yang digunakan dalam struktur konkrit bertetulang. Ujian kekuatan mampatan dijalankan untuk menentukan kekuatan konkrit menggunakan SYLCAG. Ujian kekuatan lenturan dijalankan dengan penambahan beban menggunakan empat titik kaedah ujian beban sehingga rasuk bertetulang yang direka gagal. Beban dikenakan dan lenturan telah direkodkan dengan cara yang tepat pada masanya. Maksimum kapasiti beban lenturan dari eksperimen yang telah dijalankan kemudiannya dibandingkan dengan pengiraan secara teori yang dikira dari Eurocode 2 untuk maksimum kapasiti beban dan kod ACI untuk lenturan. Keretakan berlaku diperhatikan untuk menentukan mod kegagalan. Kajian ini mendapati konkrit yang diperbuat daripada SYLCAG mempunyai kekuatan yang rendah. Selain daripada itu, bagi ujian empat mata, rasuk konkrit bertetulang SYLCAG telah menunjukkan kapasiti beban lebih rendah dapat ditampung sebelum rasuk gagal di mana kira-kira 50% daripada konkrit biasa pada kekuatan yang hampir sama. Pada peringkat awal, rasuk konkrit bertetulang SYLCAG menunjukkan mod kegagalan positif dan semakin beban yang dikenakan meningkat, ia cenderung mempunyai mod kegagalan ricih.

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LIST OF ABBREVATIONS

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BEM	Board of Engineers Malaysia
BS	British Standard
LVDT	Linear Voltage Displacement Transducer
LWA	Lightweight Aggregate
LWAC	Lightweight Aggregate Concrete
LWC	Lightweight Concrete
NA	Natural Aggregate
NWC	Normal Weight Concrete
OPC	Ordinary Portland Cement
SYLCAG	Synthetic Lightweight Coarse Aggregate
UMP	University Malaysia Pahang

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Nowadays, the world becomes more advanced but the construction industry is highly dependent on conventional materials such as cement, aggregate and sand for concrete production. The increasing of demand has been placed on construction material industry especially in the last decade owing to increasing the human population and country development will cause a chronic shortage of building materials and the increasing of cost materials construction.

To meet with that, the consideration using cheaper and locally available materials to meet desired needs will enhance self-efficiency and for sustainable development. Therefore, the lightweight concrete has been introduced. In lightweight concrete, researcher from Sri Lanka suggested the used of offshore sand as synthetic lightweight coarse aggregate (SYLCAG) to replace the natural coarse aggregate.

In this chapter, the outline of this study will be discussed more. It include the background of study, problem statement, objective, scope of study and significant of study and what is the expected outcome regarding SYLCAG will be discussed. All of the outline will be the base in conducting this study.

1.2 BACKGROUND OF STUDY

Concrete is known as a composite material composed of aggregate or filler (coarse granular material) entrenched in a hard matrix of material called cement or binder which fills the space between the aggregate particles and glues then together. In today's world, concrete as a predominant material compared to steel, timber asphalt and stone has widely used in construction industries for bridges, buildings, dams and highways.

There are many type of concrete and one of them is called lightweight concrete. Lightweight concrete has in place density of 1440 to 1840 kg/m^3 and compared to normal weight concrete with a density in the range of 2240 to 2400 kg/m^3 (NRMCA, 2003). In this study, it will focus more on lightweight aggregate concrete. Lightweight aggregate concrete can be produced by using variety of lightweight aggregates such as natural materials, thermal treatment of natural raw materials, manufacture from industrial by-products and processing of industrial by-product.

Due to high demand of the coarse aggregate, researcher has provide with an alternative of replacing river sand as aggregate by using offshore sand. According to Dias (2007) the offshore sand should be extract from 15m ocean depth. Compare to beach sand, offshore sand has lower chloride content. This offshore sand should be washed by rain for a period of time to reduce its chloride content. In this study, the offshore sand will be used as coarse aggregate to replace the normal weight aggregate to determine the flexural behavior and failure characteristic as a lightweight aggregate concrete.

1.3 PROBLEM STATEMENT

Raw material in construction industries all over the world especially natural aggregates with over-exploitation of it source has led to various harmful consequences including the shortage of the natural aggregates itself. According to BEM (2006), taking example of Selangor is apparent to be rich in potential of aggregate resources but however only 6% has been identified to be the potential one as a large proportion of this potential area is already inaccessible due to development. Therefore to overcome the shortage of natural aggregate source, various suggestion of alternative has been made such as by using offshore sand, dune sand, quarry dust and washed soil. In this study, the offshore sand will be used as a material to produce lightweight coarse aggregate to replace the entire normal weight coarse aggregate in concrete and whether the SYCLAG beam concrete can identically behave as the normal concrete.

1.4 OBJECTIVES

The objectives of this study are shown below:

i. To determine the compressive strength of concrete using SYLCAG.
ii. To compare the behavior of reinforced SYCLAG beam with normal reinforced beam.
iii. To observe the failure mode and crack pattern of reinforced SYCLAG concrete beam.

1.5 SCOPE OF STUDY

The scope of study is basically to study the flexural behavior and failure characteristics of reinforced SYCLAG concrete beam. The aggregate used is the well graded aggregate. The reinforced concrete beam to be study is lightweight aggregate concrete which the coarse aggregate is made up from offshore sand. The offshore sand were taken from reclamation project in Pantai Klebang, Malacca which was constructed in form of concrete and then crushed to be taken as artificial aggregate used for making a concrete samples. The density of SYLCAG will be 1600 kg/m^3.

Testing for both beams will be done in laboratory at 28 days age of curing period. The numbers of beams need to be prepared are 2 concrete beams including one control sample labeled as beam CB and one research sample labeled as beam SB. The size of each beam is 150 mm x 200 mm x 1500 mm. The number of cubes involve altogether will be 24 concrete cube as 6 sample for control cube at each age of 7 days and 28 days of curing period and 6 sample for SYLCAG concrete cube at age of 7 days to 28 days of curing period. The size of each cubes is 150 mm x 150 mm x 150 mm. After testing the samples for compressive and flexural strength test, the result being analyzed and will come out with significant solution.

1.6 SIGNIFICANT OF STUDY

Based on current situation, it is not appropriate to depend only on natural aggregate as main aggregate sources. The increasing in material demand and decreasing in material source will cause serious problem to the construction industry and to the environment. This study will be a significant endeavor in determined the potential of offshore sand to replace the natural aggregate which will help the construction industry in the future. Furthermore, this study will also be beneficial in determine the flexural behavior of SYLCAG concrete beam and give information on failure mode and crack pattern involved. It will also serve as future references related to this area of study.

1.7 EXPECTED OUTCOME

The SYLCAG concrete expected to have strength between 18 to 25 MPa. Flexural strength of SYLCAG beam is expected to be lower than normal beam as the density of SYLCAG as flexural strength related to density. SYLCAG concrete beam expected to show typical structural behavior in flexure as in normal weight concrete beam for mode of failure and crack pattern.

1.8 CONCLUSION

In this chapter, the general outline of study was finalized base on the topic. This chapter discussed the background study related to offshore sand, lightweight coarse aggregate and concrete. The three objective involve in this study related to the problem statement that is the performance of SYLCAG to replace the natural coarse aggregate. In the next chapter, this study will focus more on the previous study related to the research of this SYLCAG concrete.

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 by several types of cement and also containing pozzolan, flys ash, blast-furnance slag, micro-silica, additives, recycle 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 also many research about the concrete is made to fallibility and lessened the dead weight.

In previous chapter the outline of this study that include the objective, problem statement, scope of study, expected outcome and significant of study on lightweight coarse aggregate concrete (SYLCAG) has been discussed. In this chapter, related literature review are from the primary resources of published materials such as books, journal articles, research papers and thesis. The review basically cover the properties of offshore sand and the properties of lightweight concrete and lightweight aggregate with details from previous study.

2.2 OFFSHORE SAND

Offshore sand is feasible and financially viable option for reclamation project but suggested offshore sand taken from 1.5km away with the greater than 10m (Abdullah 1992). In this study offshore sand take from land reclamation project in Pantai Klebang Malacca. Dias (2007) stated that there is study in Sri Lanka beach sands has also shown fairly high chloride content in some samples. The use of sea water for batching or for curing would also promote corrosion. The purpose of using offshore sand is because it is environmental friendly and ecological impact from extracting the sand from 15m below sea level is minuscule. Using sea sand is not a practicable solution due to impacts such as coastal erosion, salt water intrusion into rivers and collapsing of river banks (Dias, 2007). In this study there are new alternatives of using offshore sand as a practical replacement for the river sand.

2.2.1 Chloride Content in Offshore Sand

The chloride content in offshore sand depends on the chloride content in sea water. The offshore contains relatively constant chloride content but more moisture content in sand retains more chloride around particles. In hot climates, through the moisture content is less, due to evaporation of moisture chloride coating will foam around particles (Shantha, 2006). Offshore sand should remove the chloride content until achieve the acceptable level.

According to Seneviratne (2006) normally offshore sand saturated with sea water had chloride content around 0.3% but it can be reduced around 0.075% when sea water is gravity drained.

The 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 (Dias et al, 2007). According to Shanta (2006) and the reference BS812-117:1198 using silver nitrate solution.

Table 2.1: Chloride content by using Silver Nitrate solution

Samples	**CI- content (%)**
Sample from sea shore	0.16
Sample from stock pile	0.03

Source: Shantha (2006)

2.2.2 Impact of Shell and Other Impurities

According to Chapmen and Roeder, shell has no adverse impact on strength but the workability of concrete may decrease if the concrete with aggregate having large shell content. With respect of shell and other impurities, Limeira et al attest that presence of small, normally acceptable percentage of coal, chalk or clay is unlikely to affect workability. By observation if compared to river sand the major difference is the absence of shells in river sand not as much as offshore sand. Table 2.2 listed the advantages and disadvantages discovered by Chandrakeerthy (1994).

Table 2.2: Advantages and disadvantages of sea sand

Advantages	Disadvantages
As a form of fine aggregate, it is the cheapest.	Corrosion of reinforcement and efflorescence may occur
Compare to crushed fine aggregate, sea sand is in more rounded or cubical like river sand which therefore decrease the use for cement and water.	Additional burden if the washing to reduce chloride is necessary.
Grading of sea sand is consider to be good as it is found in natural deposits	As there is restrictions on mining sea shore sand because of the prevention on sea erosion, therefore, just a little potential of sea sand is realized.
It contains no organic contamination, silt or weak small gravel particles.	Large capital investment is required as to build offshore sand facility is not cheap.
The chloride content can be lowered to acceptable limits which by washing even using seawater.	
Grading of sea finer than that of river sand and since local crushed stone coarse aggregate is coarser, it does not show any adverse effects when used in concrete.	

Source: Chandrakeerthy (1994)

2.3 LIGHTWEIGHT CONCRETE

With a suitable lightweight aggregate, a concrete can be produced with densities which are 25-40 per cent lower but the strength is still equal to maximum normally achieve by ordinary concrete. Lightweight aggregate can be divided into structural lightweight concretes and ultra-lightweight concrete used for nonstructural purposes (Mindess, et al. 1996). ACI Committee 213 makes three division on the basis of strength and unit weight : low density, low strength concrete for insulation : moderate-strength lightweight concrete used for concrete block and other applications where some useful strength is desirable and structural lightweight concrete.

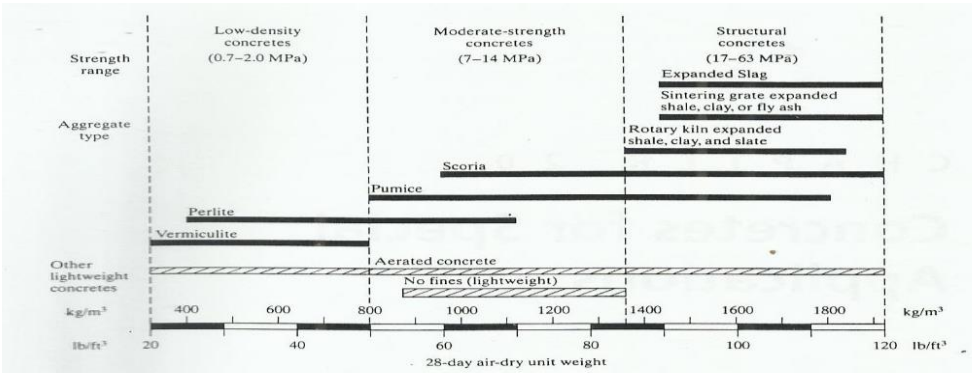

Figure 2.1: Classification of lightweight concrete

Source: ACI (2001)

The main specialties of lightweight concrete are its low density and thermal conductivity. Its advantages are that there is a reduction of dead load, faster building rates in construction and lower haulage and handling costs (Kamsiah, 2004).

A lightweight concrete is slightly different than the normal concrete in terms of its weight and mixture content. Lightweight concrete usage can help to reduce the construction cost and also reduce the overall building weight (Kamsiah Mohd Ismail, 2004). As a lightweight concrete, offshore sand has gained researcher's attention as one of the materials to be used as synthetic lightweight coarse aggregate in lightweight concrete production. However, in this research, offshore sand will be used as a substitute material for coarse aggregate. The strength of SYLCAG concrete will be compared with the control concrete to find a better material for lightweight concrete production.

Table 2.3: Properties of different types of lightweight concrete

Type of Lightweight Concrete	Type of Aggregate	Dry-Rodded Unit Weight of aggregate (kg/m3)[a]	Compressive Strength at 28 Days (MPa)[a]	Unit Weight of Concrete (kg/m3)[a]	Thermal Conductivity (W/m.K)[a]
Aerated concrete	-	-	0.5-24	300-1900	0.05-1.30
Partially compacted	Expanded vermiculite	65-250	04-3.0	300-1120	0.07-0.10
	Pumice	500-900	1.0-3.0	800-1800	0.15-0.30
	Expanded slag	500-1000	1.0-4.5	960-1520	0.16-0.42
	Sintered pulverized-fly ash	600-1000	2.0-5.5	1120-1280	0.17-0.30
	Expanded shale, clay, slate	550-1050	4.5-6.6	960-1200	0.27-0.42
	Clinker	720-1040	1.7-5.5	720-1520	0.22-0.42
No-fines concrete	Natural aggregate	1350-1600	3.0-14	1600-2000	-
	Lightweight aggregate	500-1050	2.0-5.5	880-1360	-
Structural lightweight aggregate concrete	Expanded slag	500-1000	8.0-50	1440-2080[b]	0.34-0.74
	Sintered pulverized-fly ash	600-1000	11-63	1400-1900[b]	0.52-1.10
	Expanded shale, clay, slate	550-1050	11-50	1360-1840[b]	0.51-0.95

[a](kg/m^3) x0.062 $=lb/ft^3$; MPa x 145 = $lb/in.^2$; W/m.K x 0.58 = Btu/ft.h.°F .

The denser concretes are obtained by replacing some of the lightweight fine aggregate with natural sand.

Source: Neville and Brooks (2010)

2.3.1 Engineering Properties of Lightweight Concrete

The engineering properties of lightweight concrete depend to materials used in mix design. Low c/w ratios to achieve higher strength which this would require generally higher cement and mineral admixture content which needed for structural lightweight concrete compare to normal-weight concrete of the same strength. Furthermore, the physical characteristics of lightweight aggregates are such that more paste is often required to provide good workability (Mindess, 1986). Table 2.4 below cementitious material contents of lightweight and normal weight concrete.

Table 2.4 : Cementitious material content of lightweight and normal weight concretes

Compressive strength		**Cementitious Material Content kg/m³ (lb/yd)³**			
MPa	**(lb/in.²)**	**Lightweight**		**Normal weight**	
17	(2500)	210-310	(350-520)	210-250	(350-420)
21	(3000)	240-340	(400-570)	210-300	(350-500)
28	(4000)	300-400	(500-670)	240-340	(400-570)
35	(5000)	360-450	(600-760)	300-400	(500-670)
42	(6000)	410-510	(690-860)	350-460	(590-770)

Source: Mindess (1986)

2.3.2 Advantages and Disadvantages of Lightweight Concrete

According Kamsiah et al, there are several advantages and disadvantages of lightweight concrete. The advantages are including the rapid and relatively simple construction, lightweight concrete is economical in terms transportation as well as the reduction in man power. Lightweight concrete also significant in reduction of overall weight results in saving structural frames, footing and piles. Most of lightweight concrete have better nailing and sawing properties than heavier and stronger conventional concrete. The disadvantages of lightweight concrete is it is very sensitive with water content in the mixture itself. Furthermore, it is also difficult to be placed on finish as the porosity and angularity of the aggregate. For example, in some mixes, the cement mortar may separate the aggregate and float toward the surface. Mixing time also take longer time as it is to make sure the proper mixing. These are the advantages and disdvantages of lightweight concrete.

2.4 COMPRESSIVE STRENGTH

Compressive strength is one of the essential part of concrete which also the most use in design and so much greater than tensile strength (Darwin,2003). According to many researcher, it is one of the fundamental properties used in determine the quality for a lightweight concrete. Figure 2.2 show the strength against the material properties according to EuroLightCon. Because of the water absorption of the lightweight aggregate (LWA), the w/c ratio will increase the more normal weight aggregate (NWA) is replaced by LWA. The lower the w/c -ratio, the higher the strength. The density decreases when more NWA is replaced by LWA. The lower the density, probably the lower the strength. The crushing resistance of LWA is very low compared to NWA. The more NWA is replaced the lower the strength. In this study, we compared the compressive strength of the concrete using artificial offshore sand as coarse aggregate and natural coarse aggregate.

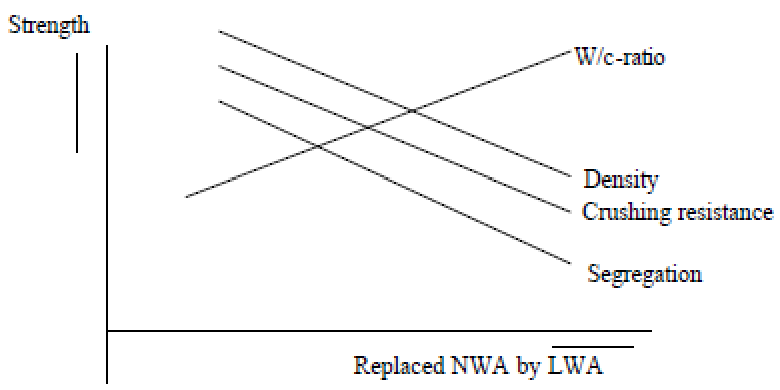

Figure 2.2: Trend curve indicating strength on material properties.

Source: EuroLightCon, (2000)

2.5 LIGHTWEIGHT AGGREGATE

According to Gambhir (1986), lightweight aggregate may be group according to following categories. Firstly, it is naturally occurring materials which require further processing such expanded clay, shale and slate. Secondly, it is industrial by product such as fly ash, foamed or expanded blast furnace. Thirdly, naturally occurring materials such as pumice, foamed lava. volcanic tuff and porous limestone. The lightweight aggregates having unit up to 12 kN/m^3 which is used in manufacturing masonry blocks or the structural concrete for the reduction of the structure's self-weight.

Main requirement of the lightweight aggregate is it has low density which has specification limit the unit weight of 12 kN/m^3 for fine aggregate and approximately 10 kN/m^3 for coarse aggregate. (Gambhir, 2013). Other characteristics of concrete using lightweight aggregate are reduced workability due to the rough texture, lower tensile strength, lower modulus elasticity and higher creep and shrinkage.

According to Neville & Brooks (2010), the use of lightweight fine as well as lightweight coarse aggregate, the problem is low workability. Therefore, it is preferable to use normal weight fine aggregate with lightweight coarse aggregate. By referring as semi-lightweight concrete, modulus of elasticity is higher and shrinkage is lower than all lightweight aggregate is used. Table 2.5 below shows the physical properties of lightweight aggregate according to different type which are aggregate for structural concrete, aggregate for low-medium strength concrete and last but not least, aggregate for low strength concrete.

Table 2.5 : Physcial properties of lightweight aggregate.

Aggregate type	Particle, shape and surface texture	Density (kg/m^3)	Bulk density (kg/m^3)	Typical concrete	
				Compressive strength (MPa)	**Unit weight (kg/m^3)**
A. Aggregate for structural concrete (f_{ck} > 15Mpa)					
Expanded clay	Rounded and slightly rough particles.	Coarse 600 to 1600 Fine 1300 to 1800	300 to 900	10 to 60	1000 to 1700
Expanded shale and slate	Often angular and slightly rounded, smooth surface.	Coarse 800 to 1400 Fine 1600 to 1900	400 to 1200	20 to 50	1300 to 1600
Fly ash	Similar to expanded clay.	1300 to 2100	600 to 1100	30 to 60	1500 to 1600
Foamed-blast-furnace slag	Irregular angular particles with rough and open pored surface.	1000 to 2200	400 to 1100	10 to 45	1800 to 2000
Sintered-colliery waste	Angular with open-pored surface.	1000 to 1900	500 to 1000	10 to 40	1400 to 1600
B. Aggregate for low-medium strength concrete (3.5 to 15 MPa)					
Pumice	Rounded particles with open-textured but rather smooth surface.	550 to 1650	350 to 650	5 to 15	1200 to 1600
C. Aggregate for low strength concrete (0.5 to 3.5 MPa)					
Perlite	Rounded and of angular shape and rough surface.	100 to 400	40 to 200	1.2 to 3.0	400 to 500
Vermiculite	Cubical.	100 to 400	60 to 200	1.2 to 3.0	300 to 700

Source : Neville and Brooks (2010)

2.6 FLEXURAL BEHAVIOR ON LIGHTWGHT BEAM

According to Swamy & Lambert (1984), the flexural strength of lightweight concrete beam for example this experiment was conducted by using fly ash coarse aggregate compare to normal beam with natural aggregate is lower. Beside that, both of them showed typical structure behaviour in flexure which actually quiete the same. Figure 2.3 shows the failure mode in flexure of T-beams made with fly ash aggregate and sand.

Figure 2.3: Failure mode in flexure of T-beams made with fly ash aggregates and sand.

Source : Swamy & Lambertt 1984

2.7 CONCLUSION

In this chapter the general outline of previous study was finalized based on the previous topic. It is discussed about the properties of lightweight concrete, lightweight aggregate and offshore sand. In the next chapter, it will be focused more on methodology involve to achieve the objective of this research.