FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE BEAM USING PARTIAL SYNTHETIC LIGHTWEIGHT COARSE AGGREGATE (SYLCAG)

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ABSTRACT

A vast development in the construction industries indicate the highly demand for the use of concrete. This also effect the depletion problem of natural coarse aggregate such as granite, crushed rock , and stone from the quarries. Thus, as an alternative to replace the natural coarse aggregate, synthetic coarse aggregate is produced to overcome the problem. This research involves the investigation of the flexural behavior of reinforced lightweight concrete beam made from synthetic lightweight coarse aggregate (SYLCAG). The SYLCAG is used to replace partially function of natural coarse aggregate. A reinforced concrete beam was tested in the flexural beam test using the four-point loads test. The compressive strength and the flexural behavior of the lightweight beam were two important parameters examined during the beam tests. The paper compares flexural performance of the lightweight beam and the normal beam in the term of failure modes, load deflection response, and ultimate load with those of the theoretical analysis. The theoretical results for ultimate load and deflection was predicted using equation provided by the ACI 318-05 building code and EC2. From the result, it shows that the SYLCAG concrete has slightly lower compressive strength and lower density than the normal concrete. The strength of SYLCAG concrete that was developed was about 93% from strength of control concrete. However the ultimate load of SYCLAG beam was 116% of the ultimate load of control beam. SYLCAG beam also has achieved 98% deflection of control beam and 79% deflection of the theoretical value. It can be conclude that the SYLCAG beam exhibit similar flexural behavior as that of normal concrete.

ABSTRAK

Perkembangan yang pesat dalam industri pembinaan menunjukkan bahawa permintaan bagi penggunaan konkrit sangat tinggi. Hal ini akan menyebabkan masalah seperti kekurangan bahan mentah seperti batu semulajadi yang digunakan dalam konkrit. Oleh itu, sebagai jalan alternatif untuk menggantikan penggunaan batu semulajadi, penggunaan batu sintetik boleh dipraktikkan untuk mengatasi masalah ini. Tumpuan kajian ini adalah mengenai kelakuan lenturan rasuk yang diperbuat daripada batu sintetik ringan (SYLCAG). SYLCAG ini digunakan untuk menggantikan separuh daripada batu semulajadi Rasuk konkrit bertetulang ini diuji dalam ujian lenturan menggunakan kaedah empat titik beban. Kekuatan mampatan dan kelakuan lenturan rasuk ringan adalah dua parameter penting yang diperiksa semasa ujian lenturan rasuk. Kertas kerja ini membandingkan prestasi lenturan rasuk ringan dan rasuk biasa dalam terma mod kegagalan, respon beban pesongan dan beban maksimum dengan yang analisis teori. Keputusan teori bagi beban maksimum dan pesongan diramalkan dengan menggunakan persamaan yang diberikan oleh ACI 318-05 kod bangunan dan EC2. Daripada keputusan itu, ia menunjukkan bahawa konkrit SYLCAG mempunyai kekuatan mampatan yang lebih rendah sedikit dan kepadatan yang rendah daripada konkrit biasa. Kekuatan konkrit bagi SYLCAG adalah kira-kira 93% daripada kekuatan konkrit kawalan.. Walau bagaimanapun, beban muktamad bagi rasuk SYCLAG adalah 116% daripada beban muktamad bagi rasuk kawalan. Pesongan bagi rasuk SYLCAG juga telah mencapai 98% daripada pesongan rasuk kawalan dan 79% daripada pesongan nilai teori.Daripada keputusan yang diperoleh daripada eksperimen, kesimpulannya adalah rasuk SYLCAG mempamerkan corak retakan dan mod kegagalan yang sama seperti rasuk kawalan.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The highly demand for light and durable concrete has increased in the recent years because of its inbuilt economies and advantages compared with conventional concrete in many structural application. Lightweight concrete is the concrete that have density between 1400 kg/m^3 to 1950 kg/m^3 for structural concrete and 600 kg/m^3 to 1200 kg/m^3 for non-structural concrete. This type of concrete is mainly used for non-load bearing wall in domestic building as well as being used as panels in framed structures. Is also being used for structural applications such as bridges, high rise building , floating structures and building where the soil conditions for the construction of the building is poor and cannot withstand higher load bearing capacity.

When the density of concrete is reduced this in turn leads to reduction of dead load acting in the structure consequently reduced load in the foundation, leading to greater economy in construction. Thus making it possible to construct high rise building in soft soil. This also gives a greater reduction in the weight of precast elements and thus reducing the handling load, which it turn ensure the safety of construction Lightweight concrete has major effect on the improvement of the properties of the concrete especially in term of tensile-compressive ratio, the behavior towards earthquake forces and resistance to fracture toughness and cracking. This chapter will be discussing about the problem statement of the study that explain the reason of lightweight concrete to be used in structural element. The objective of this study will also be stated to clarify the aim of this study, the scope of study, and the expected outcome of this study.

1.2 PROBLEM STATEMENT

Nowadays, a large volume of construction and demolition waste has been the main causes for the environmental problems that have to be faced by construction industry in almost all country in the world. Concrete is the most essential need for any construction industry. Concrete is used nearly about three tonnes per year for each person in the world which then made it to become the second largest consumable material in the world after water consumption. The vast development of construction activities indicate the widely use natural resources such natural aggregate such as sand , gravel , granite , basalt and many more. In concrete production, aggregate occupy about 70 to 80 % of the concrete volume. Coarse aggregate occupy the concrete about 2/3 of the total volumes of aggregate and the rest of it is filled with fine aggregate.

Many of the natural coarse aggregate are formed by crushing the rock that extracted from pits and quarries which come from different geological sources. Due to the vast growth in the construction industry, the demand for coarse and fine aggregate is increase rapidly. For fine aggregate, river sand is commonly used as natural sand. The demand of river sand is escalating rapidly in developing country in order to satisfy the growth of construction industry.

Hence, as an alternative to replace natural sand, offshore sand is considered to be used due to its fineness, price fluctuations throughout the year, and ease of mining operation. For the replacement of natural coarse aggregate, synthetic lightweight coarse aggregate (SYLCAG) is used in concrete. The SYLCAG will be used as partial replacement of natural coarse aggregate as it produced concrete with lighter density than the normal concrete.

1.3 RESEARCH OBJECTIVES

i. To determine the ultimate flexural load and the deflection of reinforced SYLCAG beam
ii. To identify the mode of failure of reinforced SYLCAG beam.
iii. To determine the mechanical properties of lightweight aggregate concrete in term of compressive strength
iv. To make comparison of result from experiment and theoretical based on Eurocode 2 and ACI 318-05 code provision.

1.4 SCOPE OF STUDY

Synthetic lightweight coarse aggregate (SYLCAG) is used to replace partially function of natural coarse aggregate in the concrete. This SYLCAG concrete is considered as foam concrete as its production consist only fine aggregate which used offshore sand in this study with addition of foaming agent. The offshore sand were obtain from the reclamation project located at Pantai Klebang, Melaka. The cube specimen of SYLCAG concrete with size of 150 mm that have been produced will be crushed in order to obtain the synthetic lightweight coarse aggregate.

The synthetic lightweight coarse aggregate with 4 different sizes will be used to produced lightweight aggregate concrete beam . The 4 sizes are 5 mm, 10 mm , 14 mm and 20 mm. 50 % of this SYLCAG is used as a replacement of natural coarse aggregate in the concrete beam. The beam specimen size will be 150 mm x 200 mm x 1500 mm. The tests that will be carried out are compression test and beam flexural test. Compression test will be tested on cube samples at age of 7 days and 28 days. 3 cubes will be tested on each day. For the beam flexural test, the method used for the test is four-point loading The test is conducted to identify the behavior of the beam in term of cracking pattern, deflection at failure, and the ultimate load. All of these parameters will be compared with the control concrete beam.

1.5 EXPECTED OUTCOME

This proposed research is carried out to study the flexural behavior of reinforcement lightweight concrete using synthetic lightweight coarse aggregate as alternative to replace the natural coarse aggregate. Lightweight concrete will be produced so that it can be used in future as structural element in building such as beam and foundation. Apart from having less density compared to the normal concrete, the lightweight concrete is expected to have lower compressive strength and larger deflection than the normal concrete because of the lightweight properties of SYLCAG used to replace the normal aggregates

1.6 CONCLUSION

This chapter has discussed about the problem statement, objectives , the scope of study , and the expected outcome of this research. It have been explained in details the purpose of this research to give clear ideas about the lightweight concrete , lightweight aggregate, and why it is used as alternative to replace the natural coarse aggregate. This chapter also helps student and future researchers to understand the objective, the scope of study and the outcome from this study.

The objectives that have been discussed in this chapter were mostly related to the flexural behavior and mechanical properties of lightweight concrete. The scope of study were covered about materials used , specimen size, and type of testing to be carried out. The expected outcome of this study is to produce lightweight concrete that can be used as structural element in building such as beam. In next chapter, there will be review from previous research related to this study. It is based on the objectives and the scope of study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Coarse aggregate plays an important role in affecting the durability of the concrete, permeability, strength, workability and also the cost of the concrete. The use synthetic lightweight coarse aggregate (SYLCAG) as artificial coarse aggregate will help to conserves natural coarse aggregate such as gravel, basalt rock ,etc. The SYLCAG is produced from the crushed foamed concrete that consist of offshore sand as fine aggregate is considered as crushed coarse aggregate (CCA). SYLCAG used in the production of the lightweight concrete as it will reduce the self weight and dead load of the element structure such as wall, beam , column and slab.

Using the crushed foam concrete as synthetic coarse aggregate will help to reduce the impact on landfills, reduce the energy consumption and can reduce cost of construction. In construction of structural element such as beam, many research have been done to produce different type of reinforced lightweight concrete beam using various types of lightweight aggregates.

In previous study, the flexural behavior of reinforced lightweight concrete beam have been investigate based on its performance toward different parameter like type of lightweight aggregate used, tensile steel ratio, compressive steel ratio, spacing of link in flexural zone, and many more. In this study, the flexural behavior on reinforced concrete beam will be investigated when the concrete beam is made from synthetic lightweight coarse aggregate (SYLCAG).

2.2 LIGHTWEIGHT AGGREGATE (LWA)

2.2.1 Definition

Aggregate is divided into 3 types which are lightweight , normal weight , and heavyweight aggregate. From this 3 types of aggregates, lightweight aggregate (LWA) is used in the production of lightweight aggregate concrete for the structural purpose.

Lightweight aggregate is more porous and lighter than dense aggregate such as gravel, sand, and ground rock. LWA has unit weight of 2/3 or 1/3 of the dense aggregate, thus making it to have low bulk density and easy to be transported and placed. Lightweight aggregate have the ability to absorb large amount of water and can only allow limited entering of fresh mortar into an open surface pores of particle aggregate , usually with the larger ones.

There are 2 types of lightweight aggregate which are natural aggregate and artificial aggregate. Natural aggregate can be obtained from pumice, tuff and clinker aggregate or cinder from the volcanic area , wood particles, and scoria.

This natural aggregate can be used in production of lightweight insulating concrete with the density of 250 kg/m^3 to 1450 kg/m^3. Whereas, artificial aggregate can be obtained from the expanded clay , expanded slate & shale from the natural minerals, fly ash ,and blast furnace slag can be used to make lightweight aggregate of 1350 kg/m^3 to 1850kg/m^3.

2.2.2 Types of Lightweight Aggregates

2.2.2.1 Natural Lightweight Aggregate

Pumice stone is one of the natural lightweight aggregate. It is formed by the rapid cooling of the molten volcanic matters. Pumice is obtained from the volcanic outbreak of viscous magma which consists of mostly siliceous and high content of dissolved volatile constituents like water vapor. It has specific gravity of less than one which will make it to float in water. Pumice is used to make lightweight concrete or low-density of insulative cinder blocks. It is also used as a pozzolanic materials when mixed with lime to produce a smooth, lightweight , and plaster-like concrete.

Figure 2.1: Pumice Stone

Source: Geology.com

Scoria is another one of the natural aggregate. It is an igneous rock with dark-coloured that consist of many bubble-like cavities which is known as vesicles. The colour range from black or grey to reddish brown. The particles of scoria is also called as “cinder” and the scoria that obtained from the eruption of small volcanoes is called “ cinder cones “. It is differs from pumice as it has thicker vesicles walls that make it denser than pumice. It is also more porous and has high strength and surface area. The scoria is used mostly in drainage work and landscaping. It is also used in high-temperature insulation and used on oil well site to overcome the mud problems with the heavy truck traffic.

Figure 2.1: Scoria

Source : en.wikipedia.org

2.2.2.2 Artificial Lightweight Aggregate

Perlite is one of the artificial lightweight aggregate. It is an amorphous volcanic glass which is formed by the hydration of the extrusive igneous rock and has relatively high water content. The process of hydration is occur naturally and it will expand greatly when it is heated sufficiently. When it is crushed and heated to temperature above 15000 F, it will expand to form lightweight, glass-like particle structure, and non-combustible structure. The weight of perlite is about 1/10 weight of gravel and sand with white or grey in color. It is used in lightweight fire retardant for plaster , floor fills, roof, curtain walls , and precast panel, and insulating concrete.

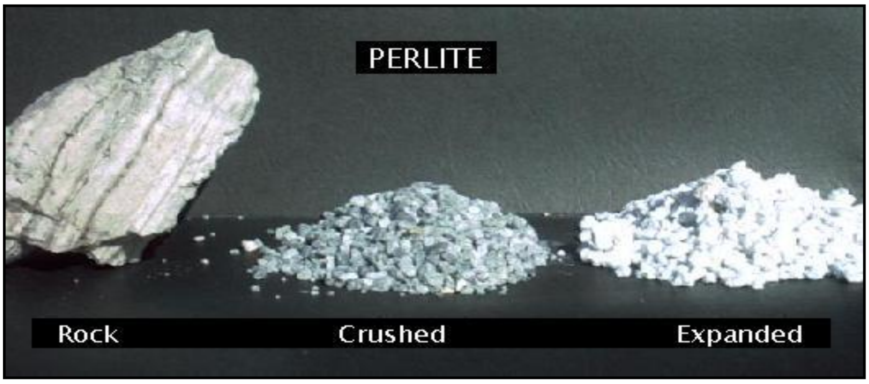

Figure 2.3: The various form of perlite

Source: www.mineralseducation.org

Vermiculite is a silicate and hydrous mineral that expand greatly when subjected to heat. It is formed by hydrothermal and weathering alteration. The vermiculite concrete is about 15 % of the weight of the structural grade concrete. It also has good insulating properties and has fireproofing characteristics. The vermiculite concrete also being used as precast concrete units like structural slabs with core type, channel slab, double tees , and pre-stressed single. The cast-in place vermiculite concrete provides a smooth surface of built up roofing membrane.

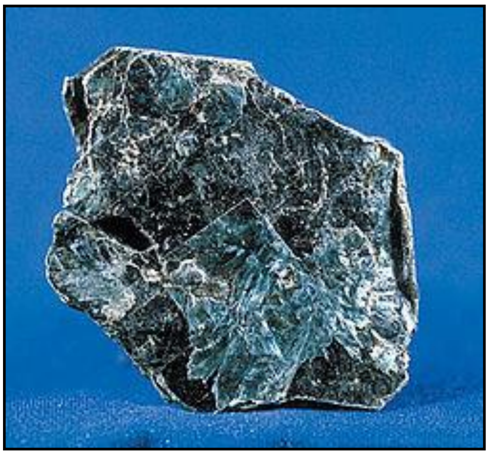

Figure 2.2 : Vermiculite

Source: en.wikipedia.org

Norlite is a porous ceramic material that is formed by expanding the selected shale in a rotary kiln. The product of the process is produce a consistent and high quality of ceramic aggregate which has properties of a strong, durable, physically stable , lightweight , environmentally inert, and good thermal insulation. It is also absorptive aggregates , non-toxic and it will not degrade over time. Norlite has the advantages of reducing dead loads, improving fire rating, and lower the thermal conductivity of element in building.

Figure 2.3: Norlite

Source: www.norliteagg.com

2.2.3 Properties of Lightweight Aggregate

2.2.3.1Bulk Density and Moisture Content

The bulk specific gravity of LWA is varies with particles size of aggregate. The specific gravity is higher for the fine aggregate and lower for the coarse aggregate. The loose and dry bulk density are ranges from 380 kg/m^3 to 870 kg/m^3 for the lightweight coarse aggregate and 700kg/m^3 to 1200kg/m^3 for the lightweight fine aggregate. As for the typical natural/normal aggregate (NWA), the bulk density is about 1400kg/m^3 to 1600kg/m^3 (Lydon , 1972)

2.2.3.2 Specific Gravity

The most lightly coarse aggregate has a specific gravity of 0.5 to 0.6. Generally, the specific gravity of the lightweight coarse aggregate is ranging from 1.2 to 1.5 whereas for the fine aggregate, the specific gravity is 1.3 to 1.7. However, the specific gravity also highly depends on the grading of aggregate. The density is increasing with the decreasing of the particles size of aggregate.

2.2.3.3 Bonding Properties

The bond between the LWA and the surrounding hydrated paste in the mix is considered as good, thus making it to offer an advantage in term of its bonding properties. The factors that contribute to the good bonding properties is due to the rough surface textures of the LWA. The rough surface textures of the LWA are favorable to fine mechanical interlocking that exist between the aggregate and cement paste. The high porosity of the LWA also contributes to some penetration of the cement paste into the opening of the free surface pores in the aggregate particles.

2.2.3.4 Water Absorption

In general, LWA have significantly higher water absorption value than the normal aggregate . The water absorption of LWA is time-dependent and the rate of absorption is depends on the type and the particle size of aggregates. The absorption rate of LWA is vary which starting from being fairly slow, continuing at a steady constant rate for long period, then being rapidly increasing , and finally followed by more slower constant rate for a long period

The early absorption of LWA is ranges from 5% to 15 % of dry weight of concrete after 24 hours .Whereas, for the normal aggregate, the rate of absorption is 0.5 to 2 % after 24 hours absorption. (Lydon, 1972).Thus, from the typical data obtained through the previous test that have been done , the absorption rate of NWA is usually less than 2 % which is much lower than LWA.

2.3 CRUSHED CONCRETE AGGREGATE (CCA)

2.3.1 Definition

Crushed concrete aggregate (CCA) is the recycled and returned concrete aggregate to be used as coarse aggregate for the production of new concrete. The topics that may be concern is whether the CCA have provide the same quality as natural aggregate is still relatively new technique in the application for construction industry. The popularity of using the CCA has become increases from time to time for many reasons. The initiatives to use the CCA have been applied to much country like Australia as it creates more sustainable concrete in future.

2.3.2 Advantages of CCA

Crushed concrete aggregate (CCA) produce a green and environmental friendly type of structural concrete in the construction industry. Because of the vast increases of demand for natural aggregate, there are some major environmental issues that must be taken into account, as stated by Oikonomou (2005) , " the construction industry have takes 50 % of raw materials which are obtained from the natural environment , have consume about 40 % of total energy , and also have creates 50 % of total waste from the construction. Also in New Zealand, the waste from the construction and demolition activity was generated about 27 % of the overall total waste. About 25 % of this construction and demolition waste (C&DW) is ranging from concrete waste which also include 7 % of the total waste.

Thus. the widely use of CCA on large scale will help to reduce the demolition waste , reduce the use of landfill, provide cost and energy saving as well as can helps to conserve the natural aggregate supplies which become slowly depleted around many country in the world. Crushing the concrete to produced coarse aggregate also takes less energy consuming compare with the natural aggregate which obtained through mining process. Besides that, the aggregate obtained from the crushed concrete will lead to the production of lightweight concrete (LWC) because it is more lighter than natural aggregate.

2.3.3 Properties of CCA

2.3.3.1 Density

Crushed Concrete Aggregate is more porous that natural aggregate. The fresh density of CCA is 5 % to 10 % lower that natural aggregate due to its porosity and the presence of cement paste in the concrete. The presence of cement paste in the concrete is less dense than the underlying rock ,thus making the concrete density to have light density than the natural aggregate.

Because it is lighter than mineral aggregate , thus making it more easy to be place and strike off. Apart from that, the new concrete which result from the use of CCA has same shrinkage properties as a normal concrete when it is properly proportioned. The air void and entrapped air content in the CCA is commonly higher than natural mineral aggregate. To maintain an adequate amount of air content in the concrete, the use of air entraining admixture should be limited and properly controlled.

2.3.3.2 Workability

Crushed Concrete Aggregate may required increase in water demand because of its harsh texture and rough surface which result from the crushing process of the aggregate. However, the increase in water demand will depend on the source of the concrete aggregate and it mechanical and physical properties.

Thus, an adjustment of cement content must be made in order to compensate the higher water demand. The cohesiveness and fluidity of the concrete mixes also reduced, and problem such as bleeding may be occur. To solve this problem, it is necessary to increase the cement content in the concrete mix.

The addition of admixtures such as air entraining and super plasticizer can also increase the cohesiveness and the workability of the mix in order to minimize the increase of cement content and water demand. Another option that can be made to overcome this problem is to stored the crushed concrete aggregate for atleast 24 hours at saturated surface dry (SSD) moisture state. In general, to achieve the same water-cement ratio , workability and slump value as in normal concrete , the cement paste and water content have to be increased.

2.4 OFFSHORE SAND

2.4.1 Definition

Offshore sand is one of the alternatives to replace river sand as fine aggregates. Previous studies has discovered that offshore sand extracted from European and American coast was suitable to be used as construction materials in the application for the base and sub base of pavement. The cost of the offshore sand also is much cheaper which is about 50 % to 70 % of the river sand. Recently, most of the extraction of aggregate in marine have been carried out in areas such as North Sea, Baltic Sea , English Channel , North Atlantic Sea and Irish Sea. Countries like United Kingdom, France and Denmark is also known as the main countries for the extraction of these marine aggregate. A comprehensive study have been carried out by Dias (2006) using sample of offshore sand obtain from the stockpile dredged in 2002 to prove that offshore sand can be used for reinforced concreting work.

2.4.2 Advantages

The shape of the offshore sand is more cubical and rounded than the crushed fine aggregate, thus making it to have low demand for cement and water. It is also cheaper than other types of fine aggregates hence the price variation is small throughout the year. High chloride content in the offshore sand can be reduced to adequate limits by washing it with rain water, of sea water , or freshwater.

2.4.3 Disadvantages

High chloride content of the offshore sand may contribute to efflorescence and corrosion of the steel imbedded in the concrete. Washing the offshore sand to remove the chloride content from the sand is not very practical to be applied because it required additional burden , energy , and time consuming. The mining of the offshore sand may be restricted due to environment factors such as sea erosion. The facility of the mining operation required special mechanized equipment and plant , thus require expensive capital investment for this operation.

2.4.4 Properties

2.4.4.1 Shell Content

Offshore sand contains a large amount of shells. According to Chapmen and Roeder (1987), the workability of the concrete is reduced when using fine aggregate with high amount of shell , but it does not cause any bad effect on the strength of the concrete.

2.4.4.2 Limits on Chloride Content

Penetration of chloride ions into the concrete is one of the common aspects to be taken into account because it can affect the durability of the concrete. Thus, the application of offshore sand in the concrete structure has high potential in affecting the durability of the concrete. However, Neville (2000) have stated that offshore sand