PENGESAHAN PENYELIA

'Saya akui bahawa telah membaca
karya ini dan pada pandangan saya karya ini
adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan
Ijazah Sarjana Muda Kejuruteraan Mekanikal (Struktur dan Bahan)'

Tandatangan : ....
Nama Penyelia : AHMAD FUAD AB GHANI
Tarikh : 11/05/09

STUDY OF APPLICATION OF LIGHTWEIGHT CONCRETE

MOHAMAD AMIRUDDIN BIN NOR AZIZAN

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This report is dedicated to my beloved parents Nor Azizan bin Mustapha Kamal and Siti Noridah Bte Ujang for their endless love and support.

“Saya akui laporan ini adalah hasil kerja saya sendii kecuali ringkasan dan petikan yang tiap–tiapsatunya saya telah jelaskan sumbernya”

Tandatangan:……………………………………
Nama penulis:…MOHAMAD AMIRUDDIN BIN NOR AZIZAN…
Tarikh:……11/05/09……………………………

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ABSTRACT

Structural lightweight concrete is still in the early age of its usage in Malaysia. It advantages and application also haven't been exploit yet to the level it should be. The study were conducted to emphasis on the advantages of using structural lightweight concrete compare to the normal weight concrete. Information such as the physical and material properties were included and a few test that will be carried out in the study were explained in details. Through out the history structural lightweight concrete had been applied in many occasions especially in the construction industry. Its applications varies to multistory building frames and floors, curtain wall, shell roofs, bridges , marine structures and others.

One of the example of light weight concrete is the Autoclaved Aerated Concrete AAC. Autoclaved Aerated Concrete (AAC) is an ultra-light concrete. It is formed by thousands of homogeneous and totally independent air cells that provide AAC its superior properties such as thermal insulation and fire resistance, which can only be achieved in traditional systems through the combination of different materials.

ABSTRAK

Struktur konkrit ringan masih dalam peringkat awal penggunaannya di Malaysia. Kelebihan dan penggunaannya masih belum di eksploitasi. Kajian telah dijalankan untuk penekanan pada kebaikan menggunakan struktur konkrit ringan berbandingan konkrit berat normal. Maklumat seperti ciri-ciri bahan dan fizikal diuji. Melalui sejarah struktur konkrit ringan telah digunakan dalam banyak peristiwa terutama sekali dalam industri pembinaan. Penggunaannya berbeza-beza untuk bingkai-bingkai dan tingkat, dinding tirai, petala menutup, jambatan-jambatan , struktur-struktur laut dan lain-lain.

Satu daripada contoh konkrit berat ringan merupakan Autoclaved Aerated Concrete AAC. Autoclaved Konkrit Berongga (AAC) adalah satu ultra ringan konkrit. Ia diperbuat daripada beribu-ribu homogen dan seluruhnya sel-sel udara bebas yang memberi sifat penebatan terma dan ketahanan api, yang hanya boleh menjadi dicapai dalam sistem-sistem tradisional melalui bahan kombinasi perbezaan.

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T = splitting tensile strength, psi [MPa]
P = maximum applied load indicated by the testing machine
l = length in [mm]
d =diameter in [mm]

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CHAPTER 1

INTRODUCTION

1.1 Background

The primary use of structural lightweight concrete is to reduce the dead load of a concrete structure, which then allows the structural designer to reduce the size of columns, footings and other load bearing elements. Structural lightweight concrete mixtures can be designed to achieve similar strengths as normal weight concrete. The same is true for other mechanical and durability performance requirements. Structural lightweight concrete provides a more efficient strength-to-weight ratio in structural elements. In most cases, the marginally higher cost of the lightweight concrete is offset by size reduction of structural elements, less reinforcing steel and reduced volume of concrete, resulting in lower overall cost. In buildings, structural lightweight concrete provides a higher fire-rated concrete structure. Structural lightweight concrete also benefits from energy conservation considerations as it provides higher R-values of wall elements for improved insulation properties. The porosity of lightweight aggregate provides a source of water for internal curing of the concrete that provides continued enhancement of concrete strength and durability. This does not preclude the need for external curing. Structural lightweight concrete has been used for bridge decks, piers and beams, slabs and wall elements in steel and concrete frame buildings, parking structures, tilt-up walls, topping slabs and composite slabs on metal deck.

Structural lightweight concrete has an in-place density (unit weight) on the order of 1440 to 1840 kg/m^3 compared to normal weight concrete with a density in the range of 2240 to 2400 kg/m^3. For structural applications the concrete strength should be greater than 2500 psi (17.0 MPa). The concrete mixture is made with a lightweight coarse aggregate. In some cases a portion or the entire fine aggregate may be a lightweight product. Lightweight aggregates used in structural lightweight concrete are typically expanded shale, clay ,slate and organic materials that have been fired in a rotary kiln to develop a porous structure. Other products such as air-cooled blast furnace slag are also used.

Lightweight concrete can be manufactured with a combination of fine and coarse lightweight aggregate or coarse lightweight aggregate and normal weight fine aggregate. Complete replacement of normalweight fine aggregate with a lightweight aggregate will decrease the concrete density by approximately 160 kg/m^3. Structural lightweight concrete will not typically serve in an oven-dry environment. Therefore, structural design of structural lightweight concrete generally relies on an ***equilibrium*** density (sometimes referred to as *air-dry* density); the condition in which some moisture is retained within the lightweight concrete. Equilibrium density is a standardized value intended to represent the approximate density of the in- place concrete when it is in service. Project specifications should indicate the required equilibrium density of the lightweight concrete. Equilibrium density is defined in ASTM C 567, and can be calculated from the concrete mixture proportions. Field acceptance is based on measured density of fresh concrete in accordance with ASTM C 138. Equilibrium density will be approximately 3 to 50 to 130 kg/m^3 less than the fresh density and a correlation should be agreed upon prior to delivery of concrete. The tolerance for acceptance on fresh density is typically ±50 kg/m^3 from the target value. Lightweight aggregates must comply with the requirements of ASTM Specification C 330. Due to the cellular nature of lightweight aggregate particles absorption typically is in the range of 5% to 20% by weight of dry aggregate. Lightweight aggregates generally require wetting prior to use to achieve a high degree of saturation. Some concrete producers may not have the capability of prewetting lightweight aggregates in cold weather if temperature controlled storage is not available. Some lightweight aggregate suppliers furnish vacuum saturated aggregate. With the exception of bridges and marine structures, specifications for

structural lightweight concrete do not typically have a requirement for maximum water-to-cementitious materials (w/cm) ratio. The w/cm ratio of structural lightweight concrete cannot be precisely determined because of the difficulty in determining the absorption of lightweight aggregate. Air content of structural lightweight concrete must be closely
monitored and controlled to ensure that the density requirements are being achieved. Testing for air content must be according to the volumetric method, ASTM C 173,
or calculated using the gravimetric method described in ASTM C 138. Virtually all lightweight concrete is air- entrained. Finishing lightweight concrete requires proper attention to detail. Excessive amounts of water or excessive slump will cause the lightweight aggregate to segregate from the mortar. Bull floating will generally provide an adequate finish. If the surface for an interior floor is to receive a hard troweled finish, use precautions to minimize the formation of blisters or delaminations. Due to the inherent higher total moisture content of lightweight concrete it typically takes a longer time than normal weight concrete to dry to levels that might be considered adequate for application of floor covering materials. The splitting tensile strength of lightweight concrete is used in structural design criteria.. The splitting tensile strength corresponding to the specified compressive strength is determined in laboratory evaluations. Splitting tensile strength testing is not used as a basis for field acceptance of concrete.

1.2 Objectives

The objective of the study is to determine the advantage of using the structural lightweight concrete in construction industry, the physical and material property used in producing the structural lightweight concrete using static analysis and destructive analysis methods.

1.3 Scopes

1. To do literature study or the structural lightweight concrete
2. To emphasis on the advantage of using structural lightweight concrete compared to normal weight concrete
3. To study the physical and material properties of structural lightweight concrete
4. To determine the functions and applications of lightweight concrete

1.4 Problem Statement

The use of structural lightweight concrete in our country is still at minimal usage due to the lack or very little exposure to the advantage of using structural light weight concrete in construction industry. This research is carried out to emphasis on the stated advantages of using the structural lightweight concrete and its functions and applications. Supposedly, the usage of structural lightweight concrete which have better mechanical and durability performance will give much advantage compared to the normal weight concrete as structural lightweight concrete provides a more efficient strength-to-weight ratio in structural elements and in most cases, the marginally higher cost of the lightweight concrete is offset by size reduction of structural elements, less reinforcing steel and reduced volume of concrete, resulting in lower overall cost and also, in buildings, structural lightweight concrete provides a higher fire-rated concrete structure .

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter two will describe about literature review on structural lightweight concrete. Some information focusing about the properties of lightweight concrete and aggregates will be discussed and the standard method that was used by international standard organization for this composite will be mention in this chapter.

2.2 Structural lightweight concrete

Structural lightweight aggregate concrete is an important and versatile material in modern construction. It has many and varied applications including multistory building frames and floors, bridges, offshore oil platforms, and pre-stressed or pre-cast elements of all types. Many architects, engineers, and contractors recognize the inherent economies and advantages offered by this material, as evidenced by the many impressive lightweight concrete structures found today throughout the world .Structural lightweight aggregate concrete solves weight and durability problems in buildings and exposed structures. Lightweight concrete has strengths comparable to normal weight concrete, yet is typically 25% to 35% lighter. Structural lightweight concrete offers design flexibility and substantial cost savings by providing: less dead load, improved seismic structural response, longer spans, better fire ratings, thinner sections, decreased story height, smaller size structural members, less reinforcing steel, and lower foundation costs. Lightweight concrete precast elements offer reduced transportation and placement costs. Minimum compressive strength of structural-grade lightweight aggregate concrete has, in effect, been established by the ASTM specification for lightweight aggregates or structural concrete (c330) as in the table below.

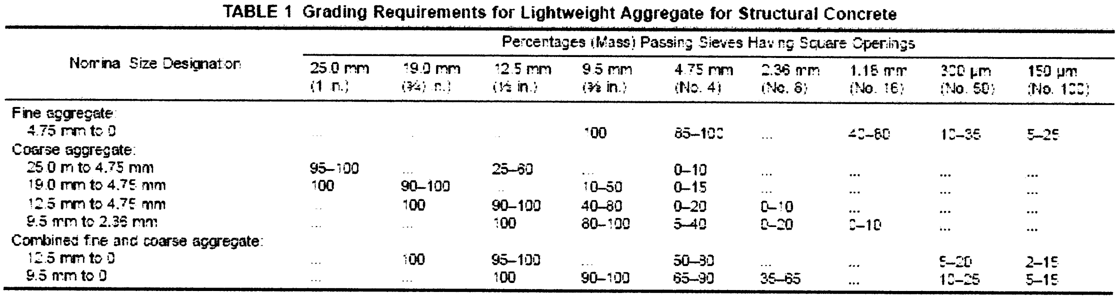

TABLE 1 Grading Requirements for Lightweight Aggregate for Structural Concrete

Nominal Size Designation	Percentages (Mass) Passing Sieves Having Square Openings								
	25.0 mm (1 in.)	19.0 mm (¾ in.)	12.5 mm (½ in.)	9.5 mm (⅜ in.)	4.75 mm (No. 4)	2.36 mm (No. 8)	1.18 mm (No. 16)	300 µm (No. 50)	150 µm (No. 100)
Fine aggregate:									
4.75 mm to 0	...	...	...	100	85–100	...	40–80	10–35	5–25
Coarse aggregate:									
25.0 m to 4.75 mm	95–100	...	25–60	...	0–10	...	...	...	...
19.0 mm to 4.75 mm	100	90–100	...	10–50	0–15	...	...	...	...
12.5 mm to 4.75 mm	...	100	90–100	40–80	0–20	0–10	...	...	...
9.5 mm to 2.36 mm	...	...	100	80–100	5–40	0–20	0–10	...	...
Combined fine and coarse aggregate:									
12.5 mm to 0	...	100	95–100	...	50–80	...	...	5–20	2–15
9.5 mm to 0	...	...	100	90–100	65–90	35–65	...	10–25	5–15

Table 2.1

2.2.1 Topcu [1] and Al-Khaiat and Haque [2]

Reported that structural lightweight concrete has its obvious advantages of higher strength/weight ratio, better tensile strain capacity, lower coefficient of thermal expansion, and superior heat and sound insulation characteristics due to air voids of the lightweight aggregate. Furthermore, Topcu [1] also reported that the reduction in the dead weight of a construction by the use of lightweight aggregates in concrete could result in a decrease in the cross-section of steelreinforced columns, beams, plates, and foundations. It is also possible to reduce steel reinforcement. Alduaij et al. [3] studied lightweight concrete in coastal areas by using different unit weight aggregates including lightweight crushed bricks, lightweight expanded clay, and normal-weight gravel without the use of natural fine aggregates (no-fines concrete). They obtained a lightweight concrete with 22 MPa cylinder compressive strength and 1520 kg/m3 dry unit weight at 28 days.

2.2.2 Altun and Haktanir [4]

They suggested the use of structural lightweight concrete (SLWC) and normal-weight concrete (NWC) together in composite reinforced concrete members. The composite reinforced concrete consists of two layers—the lower being cast as normal weight concrete(NWC) and the upper as a layer of structural light weight concrete(SLWC), both of which are placed in the fresh phase, the SLWC overlying the NWC. They reported that the composite reinforced concrete elements behave similarly to normal reinforced concrete elements with the advantage of reduction in dead weight. There are vast amounts of studies on use of lightweight aggregates either in SLWC production or lightweight concrete block. However, there are only few published studies on the use of scoria in SLWC. Also, there are few published materials on SLWC made with fly ash

2.2.3 Shideler (1957) [70]

Shideler presented one of the first comprehensive studies on lightweight concrete. He tested both normal strength and high strength concrete. The high strength concrete had f_c>7000psi. He tested for compressive strength, modulus of elasticity, creep, drying shrinkage, bond, and flexural strength. Eight lightweight aggregates were used in the testing. Shideler found he could produce concrete with f_c> 8000psi using an expanded clay. He was able to exceed 3500 psi at 2 days using this aggregate. Also, he found the modulus of elasticity to be between 2,000,000 psi and 3,000,000 psi for high strength concrete using expanded clay depending on whether the test specimens were wet or dry.

Modulus of rupture was 600 psi at 28 days for the expanded clay aggregate. He also found that creep of the various lightweight concrete was greater than creep for comparable normal weight concrete. Overall, Shideler found that performance of the lightweight concrete was good and structural grade concrete could be produced with each of the aggregates he tested.

2.2.4 Nilsen and Aïtcen (1992) [59]

Nilsen and Aïtcen looked at the properties of high-strength concrete containing various types of aggregates. This report will focus on the results for concrete with lightweight aggregate. The lightweight concrete was made with expanded shale coarse aggregate and natural sand fine aggregate. Silica fume was used as an admixture. Also, Type III Portland cement was used. The two mixes produced concrete with compressive strengths of 13,100 and 10,700 psi, respectively at 28 days of age. Also, the concretes attained 8500 psi and 7000 psi at one day of age, well above the 3500 psi needed for the current project.. They found that the AASHTO code Equation 8.7.1 [1] (Equation 2.2 in this report) for lightweight concrete modulus of elasticity underestimated the modulus of elasticity, a finding that agrees with the previous research by Slate, Nilson, and Martinez.

Drying shrinkage of the lightweight concrete was similar to that of normal weight concrete.

2.2.5 Zhang and Gjørv (1993) [81]

Lightweight aggregate has often been used in Norway in offshore oil platforms. Zhang and Gjørv studied some of this lightweight concrete. They developed nine lightweight concrete mixes using silica fume as a pozzolanic admixture. The worst performing concrete achieved a compressive strength of 8310 psi at 28 days. All mixes were 6000 psi by 3 days. Zhang and Gjørv hypothesized that the lightweight aggregate strength would control the maximum strength of the mix. The cement content, silica fume, and sand have lesser effects.

2.2.6 Zhang and Gjørv (1991) [80]

Zhang and Gjørv produced a later paper dealing with the properties of high-strength lightweight concrete.The conclusions of interest were:

a) The ratio of tensile strength to compressive strength in lightweight concrete is less than the same ratio in normalweight concrete.
b) The strength of the lightweight aggregate is the primary factor controlling the strength of highstrength lightweight concrete.

2.2.7 Mircea, Ioani, Filip, and Pepenar (1994) [53]

The authors tested 260 reinforced and pre-stressed beams under different aggressive environments for durability. Beams were made of lightweight and of normal weight concrete and were pre-cracked. The beams were then placed in various environments and allowed to sit for ten years. After ten years, the beams were analyzed and loaded to failure to see if they maintained their strength. The conclusions were that the lightweight concrete performed as well as the normal weight concrete. The density of the lightweight concrete beams decreased 2.2% while the normal weight companion beams decreased 2.0%. Also, both types of concrete increased in modulus of elasticity with the lightweight gaining 12% while the normal weight gained 25%. Compressive strength of the lightweight concrete increased 17-25% while the normal weight gained 7-15%. Overall, the results were similar with neither concrete performing poorly. Also, higher cement contents generally proved to reduce the size of the cracking inside the beams. Since high cement contents generally portend higher strength concrete, this means that the higher strength beams were better able to resist crack growth.

2.2.8 Laamanen (1993) [45]

Laamanen discusses the Sundbru bridge in Eidsvoll, Norway which used high-strength lightweight concrete. The bridge, built in 1991-1992, utilized natural sand and lightweight aggregate Leca, an expanded clay. Overall performance of the concrete in the bridge was excellent. The compressive strength of the concrete averaged 9700 psi at 28 days, achieved with the use of silica fume as an admixture.

The modulus of elasticity was 3,080,000 psi at 28 days. The equilibrium unit weight of the concrete averaged between 115 pounds per cubic foot (pcf) and 118 pcf. Measured chloride and freeze-thaw resistance indicated that the lightweight concrete performed as well as comparable normalweight concrete. Overall, the performance of this bridge was a success.

2.2.9 Hanson [32]

Hanson wrote an early paper discussing the use of lightweight concrete for prestressed concrete construction. He focused on the expanded shale aggregate that was available in the Rocky Mountain area.The main advantages of lightweight concrete, Hanson concluded, were the ability to produce smaller sections due to the decrease in weight othe concrete. Also, another advantage was the decreased transportation cost, as a lower weight will allow more units to be placed on a truck for transfer. However, substantial attention was focused on the strength of the concrete. Due to the desire of precast manufacturers to release their forms in one day, a concrete mix must be developed which has sufficient one day release strength. Also, Hanson suggests that a lightweight concrete mix must also have an adequate modulus of elasticity, as this will help reduce camber of the unit, a significant problem with lightweight concrete pre-stressed members.

2.3 Material

Structural lightweight concrete is composed of several components, including cement, water, admixtures, fine aggregates, and coarse aggregates. The use of lightweight coarse aggregates can lead to significant reductions in the self weight of the concrete. Materials used as lightweight aggregate include slate, slag, palletized fly ash, and expanded clays and shales. The clays and shales are mined from the ground and then placed in a kiln as well as the organic material such as palm oil waste and rice husk. As they are heated, gases are introduced and the materials