FOAM CONCRET ... LOW SECTION

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ABSTRACT

A normal concrete with a density range in between 2400 kg/m^3 to 2500 kg/m^3 proved to be heavy to hoisted to a height in turn the needs of heavy lifting machinery are required especially in precast concrete structures construction. Foam concrete can be categorized as lightweight concrete as the density is less than 2000 kg/m^3 around 1600 kg/m^3 to 1800 kg/m^3 where this could reduce overall weight of the structures. Another idea of reducing the weight is by forming hollows along the structures such as precast hollow-core slab provided the hollow is formed not at critical location such as where the compression is the highest. Many parameters may influence the overall hollow column response such as the shape of the section, the amount of the longitudinal and transverse reinforcement, the cross section thickness, the axial load ratio and finally the material strength of concrete and reinforcement. This study program focus on the types of failure of circular hollow cross sections beam and plot the crack pattern of the beam under bending . Four simply supported beam with difference circular hollow section and one rectangular solid beam will be tested of effective span of 3 m subjected to four point loadings. The strain gauge are uses to measures the strain while the deflection were measured using LVDT. All beams in this study are rectangular beams with dimension of 200mm x 150mm for width and height. This result were compare with rectangular solid beam. The results show that the longitudinal opening affected the initial crack and deflection of the beam due to the decreasing of second moment of inertia. Initial crack which observed was appeared at the support . So this beam failed due to shear. The results shows that the increasing size hollow section will increasing the deflection and initial crack of the beam.

ABSTRAK

Ketumpatan konkrit biasa adalah diantara 2400 kg/m^3 hingga 2500 kg/m^3 adalah sangat berat dan susah diangkat ke tempat yang tinggi dan memerlukan pengunaan jentera berat terutamanya untuk pemasangan konkrit pratuang di dalam tapak bina. Konkrit berudara boleh dikategorikan sebagai konkrit ringan kerana ketumpatan adalah kurang daripada 2000 kg/m^3 sekitar 1600 kg/m^3 hingga 1800 kg/m^3 di mana ini dapat mengurangkan berat badan keseluruhan struktur. Satu lagi idea untuk mengurangkan berat badan struktur adalah dengan membentuk ruang rongga di sepanjang struktur. Banyak parameter yang boleh mempengaruhi tindak balas ruangan berongga keseluruhan seperti bentuk ruang rongga itu, jumlah tetulang membujur dan melintang, keratan rentas ketebalan, nisbah beban paksi dan akhirnya kekuatan bahan konkrit dan tetulang. Kajian ini memberi tumpuan kepada jenis kegagalan rasuk yang berongga bulat dan plot corak retak rasuk di bawah lenturan. Empat rasuk dengan panjang 3 meter akan disokong mudah dengan perbezaan seksyen berongga bulat dan satu rasuk pepejal segi empat tepat akan diuji tertakluk kepada empat beban titik. Strain gauge adalah kegunaan kepada langkah-langkah ketegangan manakala pesongan akan diukur dengan menggunakan LVDT. Semua rasuk dalam kajian ini ialah rasuk segi empat tepat dengan dimensi 200mm x 150mm untuk lebar dan ketinggian. Keputusan ini akan membandingkan dengan rasuk pepejal segi empat tepat. Keputusan menunjukkan bahawa pembukaan membujur terjejas retak awal dan lenturan rasuk disebabkan penurunan momen kedua inersia. Retak awal yang diperhatikan telah muncul di penyokong. Jadi rasuk ini gagal kerana terputus. Keputusan menunjukkan bahawa seksyen berongga saiz yang lebih akan meningkatkan lenturan dan retakan awal rasuk.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

PVC	Polyvinyl chloride
LVDT	Linear Variable Displacement Transducer
UMP	University Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The Industrial Building System (IBS) used widely in other country such as Europe and United State. Since that, the IBS method is used into the construction field in Malaysia. IBS method simplified the construction work as a well as it reduced time consuming also reducing the cost for the construction. In IBS construction method, precast solid beam is commonly used by the contractor in order to reduce time consume.

But Normal concrete proved to be heavy to hoist to a height in turn the needs of heavy lifting machinery are required especially in precast concrete structures construction. To make the beam is easy to lift up the reducing the weight use foamed concrete and by forming hollows along the structures such as precast hollow-core slab.

Concrete beams that are used in buildings as horizontal supporting pieces above doors and windows. These are called lintels. These lintels are reinforced with steel rods cast in the concrete. The steel rods are normally placed below the neutral axis. The combination of more than one material makes the reinforced concrete a composite material. The steel enhances the strength of the concrete when stretched under tension. Concrete is very strong in compression but weak in tension. This is one of the properties of concrete. Beams used in buildings may vary in cross sectional shape.

Some may be solid or hollow. For hollow section is often adopted in order to increase flexural rigidity and reduce the selft-weight of piers. However, there possibility that reincorcement concrete members with a hollow section may not have enough plastic deformation capacity and energy dissipation since it is generally difficult to ensure effective confinement of the thinner web causes the deterioration of shear resistance of the members.

1.2 PROBLEM STATEMENT

Concrete is the most popular and conventional construction material used and the combination with steel reinforcement enhanced the properties in-terms of bending or tension as concrete is good in compression but weak in tension. However, a normal concrete with a density range in between 2400 kg/m^3 to 2500 kg/m^3 proved to be heavy to hoisted to a height in turn the needs of heavy lifting machinery are required especially in precast concrete structures construction. Foam concrete can be categorized as lightweight concrete as the density is less than 2000 kg/m^3 around 1600 kg/m^3 to 1800 kg/m^3 where this could reduce overall weight of the structures. Another idea of reducing the weight is by forming hollows along the structures such as precast hollow-core slab provided the hollow is formed not at critical location such as where the compression is the highest. In the case of reinforced concrete beam, theoretically the compression part is about 0.9 from the top compression fiber where the bottom is in tension and the resistance to tension is resisted by steel reinforcement. Therefore, the concrete at the bottom part of the beam is not effectively used but only contributes to shear resistance yet still not entirely as the shear also is resisted by shear reinforcements along the beam. With regards to that, the section below 0.9x of the compression fiber section, the concrete theoretically can be removed but not all, just enough to encased and cover the shear reinforcement for fire and the environment as well as to hold it in place. Thus, this will create a hollow along the beam section where this could contribute to weight reduction but at the same time able to resist the design loading. However, as part of the beam cross-section is hollow, the second moment of area,I of the section is reduced thus will affect the deflection as the I is proportionally inverse to the deflection. Due to that, it is important to evaluate the performance of foam concrete beam with hollow under bending test.

1.3 OBJECTIVE

To carry out this research, a few objectives have been determined to evaluate the finished product after it is produced. The objective of this study is: -

a) To investigate the performance deflection, cracking, strain, and strength of circular hollow foam concrete beam under four point bending test.
b) To determine the types of failure and plot the crack pattern of the beam under bending.

1.4 SCOPE OF STUDY

The scope of research has determined to make the research could be done more effectively and not diverted to the outside of the study. In producing the beam, the study has determined the scope of the following research: -

a) This test for simply supported beam that the both of support for this beam is use roller support
b) To identify the behavior of beam foamed concrete with circular hollow section
c) To measures the strain , (stress cannot be measured but calculated form the measured strain) and deflection of foamed concrete beam with circular hollow section
d) To the analysis and design of such beams under the most commonly
e) To check and analysis cracking pattern for hollow beam
f) The experimental setup is based on four point bending test
g) Four simply supported beam with difference circular hollow section (which diameter for hollow section is 25mm, 32mm, 50mm and 80mm) and one rectangular solid beam will be tested of effective span of 3 m subjected to four point loadings

1.5 RESEARCH SIGNIFICANCE

Some building have to withstand high levels of torsion forces. As a consequence, hollow beams are often the obvious solution. It could be possible that the balance of transversal to longitudinal torsion reinforcement is not fully reached. If the transversal reinforcement is somehow underestimated, the hollow beam needs to be transversally strengthened. The hollow beam is use to saving in weight, which affects especially the cost of transport, handling and erection for pre-cast cross sections.

CHAPTER 2

LITERATURE REVIEW

2.1 LIGHTWEIGHT CONCRETE

There are many advantages of introducing lightweight concrete in construction industry however there are also drawback and limitation of using lightweight concrete. Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as nailibility and lessened the dead weight . It is lighter than the conventional concrete with a dry density of 300 kg/m^3 up to 1840 kg/m^3 and 87 to 23% lighter. It was first introduced by the Romans in the second century where 'The Pantheon' has been constructed using pumice, the most common type of aggregate used in that particular year . From there on, the use of lightweight concrete has been widely spread across other countries such as USA, United Kingdom and Sweden. 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. The building of 'The Pantheon' of lightweight concrete material is still standing eminently in Rome until now for about 18 centuries.

2.1.1 Types Of Lightweight Concrete

Lightweight concrete can be prepared either by injecting air in its composition or it can be achieved by omitting the finer sizes of the aggregate or even replacing them by a hollow, cellular or porous aggregate. Particularly, lightweight concrete can be categorized into three groups:

i) No-fines concrete

ii) Lightweight aggregate concrete

iii) Foamed concrete

2.1.2 No-Fines Concrete

No-fines concrete can be defined as a lightweight concrete composed of cement and fine aggregate. Uniformly distributed voids are formed throughout its mass. The main characteristics of this type of lightweight concrete is it maintains its large voids and not forming laitance layers or cement film when placed on the wall. Figure 2.1 shows one example of No-fines concrete. No-fines concrete usually used for both load bearing and non-load bearing for external walls and partitions. The strength of no-fines concrete increases as the cement content is increased. However, it is sensitive to the water composition. Insufficient water can cause lack of cohesion between the particles and therefore, subsequent loss in strength of the concrete. Likewise too much water can cause cement film to run off the aggregate to form laitance layers, leaving the bulk of the concrete deficient in cement and thus weakens the strength.

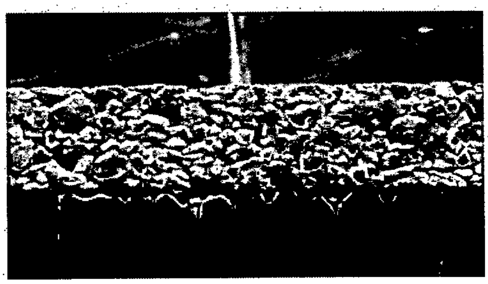


Figure 2.1 : No-fines concrete

2.1.3 Lightweight Aggregate Concrete

Porous lightweight aggregate of low specific gravity is used in this lightweight concrete instead of ordinary concrete. The lightweight aggregate can be natural aggregate such as pumice, scoria and all of those of volcanic origin and the artificial aggregate such as expanded blast-furnace slag, vermiculite and clinker aggregate. The main characteristic of this lightweight aggregate is its high porosity which results in a low specific gravity. The lightweight aggregate concrete can be divided into two types according to its application. One is partially compacted lightweight aggregate concrete and the other is the structural lightweight aggregate concrete.

The partially compacted lightweight aggregate concrete is mainly used for two purposes that is for precast concrete blocks or panels and cast in-situ roofs and walls. The main requirement for this type of concrete is that it should have adequate strength and a low density to obtain the best thermal insulation and a low drying shrinkage to avoid cracking . Structurally lightweight aggregate concrete is fully compacted similar to that of the normal reinforced concrete of dense aggregate. It can be used with steel reinforcement as to have a good bond between the steel and the concrete. The concrete should provide adequate protection against the corrosion of the steel. The shape and the texture of the aggregate particles and the coarse nature of the fine aggregate tend to produce harsh concrete mixes.

2.1.4 Lightweight Foamed

Numerous researchers had focused on mechanical and physical properties of foamed concrete. Hamidah *et. al.* (2005) had conducted an experiment on compressive strength of series of foamed concrete with varying sand to cement ratio, water to cement ratio and particle size distribution of sand while Narayanan and Ramamurthy (2000) had studied on the physical, chemical, mechanical and functional characteristic of foamed concrete. In addition, Aldridge (2005) summarized the typical foamed concrete properties. Very limited work has been done on structure behaviour of aerated reinforced concrete structures. Cividini (1981) studied the behaviour of long-term deflection of aerated reinforced concrete slabs. Before that, Regan (1990) had investigated two series reinforced aerated concrete members under shear tests. In general, lightweight concrete are related with the density which the density is lesser than density of normal concrete. Andrew and William (1978) reveal that lightweight concrete is a concrete which has been made lighter than ordinary concrete.

Normally, lightweight foamed concrete do not used coarse aggregate but it will replace with lightweight aggregate. Zhang (1990) mentioned that concrete which achieved 1120 kg/m3 of density can be considered as a lightweight concrete meanwhile British Standards, BS 8110: Part 2: 1985 classifies that lightweight concrete is a concrete with a density of 2000 kg/m3 or less. American Concrete Institute International (2003) defined that foamed concrete as a lightweight product consisting of Portland cement, cement-silica, cement-pozzolan, lime-pozzolan, lime-silica pastes, or pastes containing blends of these ingredients and having a homogeneous void or cell structure, attained with gas-forming chemicals or foaming agents. Orchard (1979) stated that aerated, cellular or foamed concrete can be made in a weight ranging from 400 kg/m3 or even less, to 1765 kg/m3. Its most useful weight ränge in perhaps between 640 and 963 kg/m3. It can be produced in the following ways:

a) By mixing normal air entraining agents with cement or cement and sand in special high speed or whisking mixers. If an ordinary mixer is used it is doubtful if sufficient air would be entrained to obtain as low as 1445 kg/m3.
b) By making foam and adding a given quantity of this to a cement or cement sand mortar in mixer. An ordinary mixer is suitable for this method.
c) Mechanical foaming.
d) By adding hydrogen peroxide (H_2O_2) to the concrete.
e) By the use of calcium carbide (CaC_2).
f) By adding aluminium powder or zinc powder to a cement mortar.
g) A combination of mechanical foaming and aluminium powder.

There are two methods of producing aerated concrete which based on method pore formation, such as gas concrete and foamed concrete. Neville (1987) mentioned that foamed concrete can be produced by introduced in the mix either by a pre - formed (where made in a special foam generator) and then introduced into the mixer together with the cement, water and fine aggregate, or alternatively by mixing a foam concentrate together with other mix ingredients in high shear mixer. Narayanan and Ramamurthy (2000) stated that air-entraining method or gas concrete created when gas-forming chemicals are mixed into lime or cement mortar during the liquid or plastic stage, resulting in a mass of increased volume and when the gas escapes, leaves a porous structure whereas foaming method or foamed concrete is reported as the most economical and effective which pore-forming process can be controlled as there are no chemical reactions involved. Introduction of pores is achieved through mechanical means either by pre-formed foaming (foaming agent mixed with a part of mixing water) or mix foaming (foaming agent mixed with the mortar).

Table 2.1: Types and Grading of Lightweight Concrete

Type Of Lightweight Concrete	Type Of Aggregate	Grading of Aggregate(Range of Particle Size)
No-fines concrete	Natural Aggregate Blast-furnace slag Clinker	Nominal single-sized material between 20mm and 10mm BS sieve
Partially compacted Lightweight aggregate concrete	Clinker Foamed slag Expanded clay, shale, slate, vermiculite and perlite Sintered pulverized-fuel ash and pumice	May be of smaller nominal single sizes of combined coarse and fine (5mm and fines) material to produce a continues but harsh grading to make a porous concrete
Structural lightweight aggregate concrete	Foamed slag. Expanded clay, shale or slate and sintered pulverized fuel ash	Continues grading from either 20mm or 14mm down to dust, with an increased fines content (5mm and fines) to produce a workable concrete.
Aerated concrete/ Foamed concrete	Natural fine aggregate Fine lightweight aggregate Raw pulverized-fuel ash	The aggregate are generally ground down to finer powder, passing a 75 μm BS sieves,

The various foaming agents used are detergents, resin soap, glue resins, saponin, hydrolysed proteins such as keratin etc. The differences between the types of lightweight concrete are very much related to its aggregate grading used in the mixes. Table 2.1 shows the types and grading of aggregate suitable for the different types of lightweight concrete

2.2 CROSS-SECTIONS OF BEAMS

The cross section of a beam has a significant effect on how easily the beam will deform. For example, everyday experience tells us that a flat metal ruler will flex much more easily than a piece of metal tubing with walls of the same thickness. Because it is difficult to use the "shape" of a cross-section directly as a variable in an equation modeling beam behavior, we instead compute two quantities that describe properties of the cross section. These quantities are the *centroid* and the *moment of inertia* . Parrand Maggard (1972) mentions that a survey of bridges built or proposed in the last few years i n the United States reveals a growing awareness of at least two items :-

a) The utilization of materials and cross-section which may be more efficient and economical than those used in the past.
b) a more serious consideration of aesthetic requi rements.

For that reason the use of thin webbed or hollow structural sections has increased significantly throughout the last decade . The cross section of a beam has a significant effect on how easily the beam will deform. The sentroid and moment of inertia of a cross section might effect the way a beam bends. From research done by M.A.Mansur (2006), when produces discontinuities or disturbances in the normal flow of stresses, thus leading to stress concentration and early cracking around the opening region. This is meant is when load is applied, the stress is focus on hollow section compared to another section. From research done by Akwasi Manu Assenso Antwi B.S (2012) state that the shear and moment capacity at the hollow section will be reduced but will incress the stress. This is meant the hollow beam received more stress compared solid beam .

The ultimate moment carrying capacity of hollow beam is reduced if neutral axis of the beam at failure is located below the top flange and neutral axis of the beams at failure is located within the top flange, then the ultimate moment carrying capacity is at least equivalent to that of a solid beam. (Rosli Mohamad Zin). While research done by Gian Piero Lignola (2007) state that part of the beam cross-section is hollow, the second moment of area ,I of the section is reduced thus will affect the deflection as the I is proportionally inverse to the deflection. This is meant if the size of hollow section increase, the deflection also increase. This is because cross section area are decrease, that second moment area also will decrease.

2.3 BEHAVIOR OF BEAM

2.3.1 Deflection

In engineering terminology deflection usually refers to distortion or change in shape produced for example, by load, weight, temperature-change, pressure or vibration. It may be elastic, inelastic, temporary or permanent. Instrument indicating needles show deflection. But whereas distortion is an unquantified term, deflection is usually a quantifiable distance in m, cm, mm or µm. Deflection is usually distinguished from displacement which is a change in position resulting from motion alone. This distinction may not always be clearly made in common usage. In other word deflection is the difference between the final position of a point (for example the center of a beam) under a load condition and its position without the load.

Beam deflection is an important factor in building and construction. Beam deflection is a measurement of how much a load places strain on a the beam it is supported by. There are numerous calculations and calculators to help an engineer or construction working determine beam deflection. Beam deflection is key in ensuring that the building materials chosen for a structure will be safely.The deformation of a beam is usually expressed in terms of its deflection from its original unloaded position. The deflection is measured from the original neutral surface of the beam to the neutral surface of the deformed beam.

2.3.2 Cracking

When a load is applied to the beam, a lot of failure will be occur. One of the failure is cracking. The Figure 2.2 show the typical crack pattern of an overloaded beam. It can divided into 3 region that are dominated by shear, shear and bending and bending. Cracks occur when the tensile bending stress in the concrete exceeds the concretes ability to resist it. Figure 2.3 show the type of cracking on beam.The type of cracking on beam is identify from based on pattern carck at beam. A way to predict cracking is to determine the moment that causes cracking to occur and compare your actual moments to this cracking moment. The cracking moment is found by setting the elastic flexural stress equation equal to the tensile stress capacity of the concrete. If the actual moment for the load stage under consideration is less than the moment that will cause cracking, then use the gross moment of inertia in the deflection equations. If the actual moment exceeds the cracking moment, then find the cracked moment of inertia for use in the deflection equations.

According to Alnuaimi et al. (2007), beam that subjected to the small load by flexural test crack almost vertical crack pattern. By the adding of more loads, the crack pattern is change the angle from vertical to 45° to 60°. This show that the more the load applied , the crack pattern will become more inclined. This crack pattern called vertical bending crack and inclined torsional crack. while from the research made by Yang & Chen (2005) mentioned that there have two type of crack pattern which is smeared crack and discrete crack which able provided satisfactorily the load displacement responses and the crack path or pattern. Smeared crack modes and discrete crack modes is process where the works of meshing the crack pattern is carrying on when the crack start to propagated. This type of crack pattern is when the crack started to appear at mid-span and propagate upward with increasing crack width. As the load is increasing, the crack is propagate half of the beam and gradually curved towards the loading point

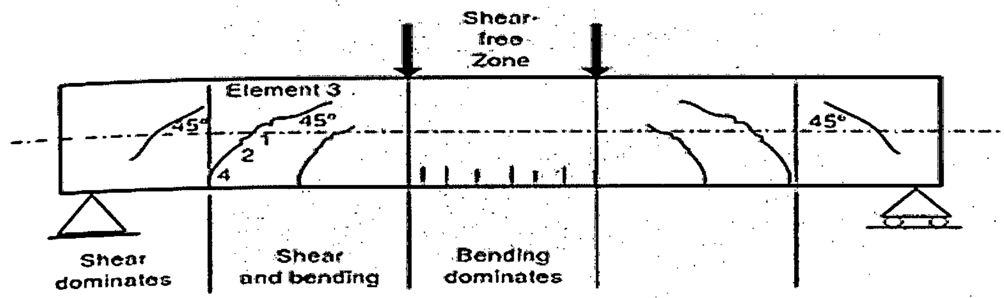


Figure 2.2: Type of crack region

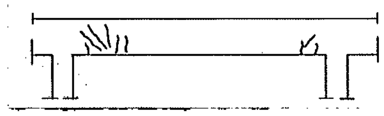
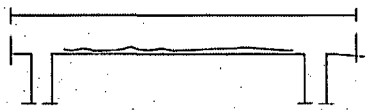
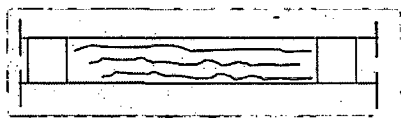
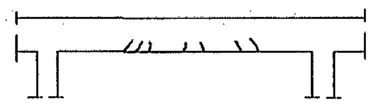
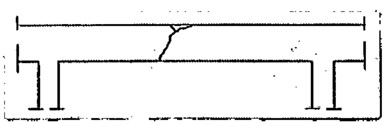
Type of cracking	Pattern cracking
Cracks in concrete beams due to increased shear stress	
Cracks in concrete beams due to corrosion or insufficient concrete cover	
Cracks parallel to main steel in case of corrosion in beams	
Cracks due to increased bending stress in beams	
Cracks due to compression failure in beams	

Figure 2.3 type of cracking on beam .

Source: by Gopal Misha (2006)

2.4 CURING

The strength developed by concrete made with given materials and given proportions increases for many months under favorable conditions, but in the majority of specifications the strength is specified at an age of 28 days. The strength development of concrete made with all types of Portland cement depends on the temperature and humidity conditions during curing. Higher temperatures increase the speed of the chemical reaction and thus the rate of strength development, and in order to achieve higher strengths at later ages loss of water from the concrete must be prevented. For test purposes the concrete test specimens is stored in water at a constant temperature as specified in BS 1881: Part 3.