PALM OIL CLINKER AS PARTIAL COARSE AGGREGATE REPLACEMENT IN PRODUCING HIGH FLEXURAL HOLLOW SECTION BEAM

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ABSTRACT

Concrete is a most widely used material in the construction line. There were many modifications made in the concrete materials. The lightweight aggregate concrete containing palm oil clinkers were introduced as a method to reduce the amount of gravel aggregates in order to produce concrete with sufficient strength. The palm oil clinker was used as the coarse and fine aggregate replacement. Hollow section beam with palm oil clinker as a partial coarse aggregate replacement was introduced. Concrete can withstand compression force but weak in resisting the tensile force. Therefore, we reduce the consumption of concrete at the tensile region. Thus after we reduce the concrete at the tensile region it is called a hollow section beam. The objective of the study is to determine the ultimate strength and deflection of the hollow section beam and also to determine the effect of cavity size in the hollow section beams. Three beams with cavity size 100mm×40mm, 100mm×50mm and 100mm×60mm were produced. The cross sectional area of the hollow beam is 250mm×300mm with a length of 2000mm. In order to construct the beam, searching and collecting information regarding hollow section beam and palm oil clinker were carried out. The palm oil clinker was crushed into the form of coarse aggregate in the preparation of the raw material. Besides that, the formwork and reinforcement steelwork were carried out. The flexural tests for the beam were conducted by using Magnus Frame. The graph load against deflection, load against time, deflection against time and the bar chart for load-deflection ratio was analysed. The beam with hollow cavity 100mm×60mm gives the best result. The beam able to withstand the highest ultimate load which is 145.55kN and with a deflection of 25.72mm which is lowest. The load-deflection ratio of the hollow beam of 100mm×60mm has the highest load-deflection ratio which is 5.67kN/mm. This means 5.67kN of load is required to produce 1mm deflection. In conclusion the results obtained from the research fulfill the objective of the study. The ultimate strength of the palm oil clinker as a partial coarse aggregate replacement in hollow section beam is 145.55kN with a deflection of 25.72mm. Besides that, 100mm×60mm is the largest cavity size among the three beams. Thus, it fulfills the criteria as saving more concrete materials and having the lowest self weight.

ABSTRAK

Konkrit merupakan bahan utama yang selalu digunakan dalam bidang pembinaan. Terdapat banyak pengubahsuaian yang telah diimplikasikan dalam bahan-bahan konkrit. Konkrit aggregate berketumpatan ringan yang mengandungi klinker kelapa sawit telah diperkenalkan sebagai salah satu kaedah untuk mengurangkan jumlah agregat kerikil dengan tujuan untuk menghasilkan konkrit yang mempunyai kekuatan yang mencukupi. Klinker kelapa sawit telah digunakan sebagai pengganti agregat kasar dan halus. Rasuk berongga yang mengandungi klinker kelapa sawit sebagai pengganti agregat kasar telah diperkenalkan. Konkrit mampu menahan daya mampatan tetapi lemah dalam menahan daya tegangan. Justeru, kita mengurangkan penggunaan konkrit di rantau tegangan. Selepas pengurangkan konkrit di rantau tegangan, rasuk tersebut dikenalpasti sebagai rasuk berongga. Objektif kajian ini adalah untuk menentukan kekuatan muktamad dan defleksi rasuk berongga serta menentukan kesan saiz rongga dalam rasuk. Tiga rasuk dengan saiz rongga 100mm × 40mm, 100mm × 50mm dan 100mm × 60mm telah dihasilkan. Luas keratan rentas rasuk berongga ini adalah 250mm × 300mm dengan panjang 2000mm. Dalam usaha untuk membina rasuk berongga ini, pencarian dan pengumpulan maklumat mengenai rasuk berongga dan klinker kelapa sawit telah dilakukan. Dalam penyediaan bahan mentah, klinker kelapa sawit dihancurkan ke dalam bentuk agregat kasar. Di samping itu, penyediaan acuan rasuk dan kerja mengikat tetulang keluli rasuk dijalankan. Ujian lenturan bagi rasuk telah dijalankan dengan menggunakan *Magnus Frame*. Graf beban lawan defleksi, beban lawan masa, defleksi lawan masa dan carta bar untuk nisbah beban-defleksi telah dianalisis. Rasuk dengan saiz rongga 100mm × 60mm ini memberi hasil yang terbaik. Rasuk ini dapat menahan beban muktamad yang tertinggi iaitu 145.55kN dengan defleksi terendah iaitu 25.72mm. Nisbah beban-defleksi bagi rasuk berongga 100mm × 60mm ini mempunyai nisbah yang tertinggi iaitu 5.67kN/mm. Ini bermakna 5.67kN beban diperlukan untuk menghasilkan defleksi sebanyak 1mm. Kesimpulannya keputusan yang diperolehi daripada kajian ini memenuhi objektif kajian. Kekuatan muktamad klinker kelapa sawit sebagai pengganti agregat kasar dalam rasuk berongga 100mm × 60mm ialah 145.55kN dengan defleksi 25.72mm. Di samping itu, rongga bersaiz 100mm × 60mm merupakan saiz rongga yang terbesar diantara tiga rasuk. Oleh itu, ia memenuhi kriteria iaitu penjimatan dalam penggunaan bahan konkrit dan mempunyai berat sendiri rasuk yang terendah.

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LIST OF ABBREVIATIONS

kN	kiloNewton
kN/mm	kiloNewton per millimeter
kg	kilogram
kg/m^3	kilogram per meter cube
mm	millimeter
m	meter
m^3	meter cube
MPa	Mega Pascal
N/mm^2	Newton per millimeter square
s	second

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete is the most widely used material in construction all over the world. It is an important material in the field of construction and infrastructural development. Nowadays, there are many modifications made in concrete. For an example the aggregates in the concrete were replaced with palm oil clinker. This new modification is already giving a big impact in the construction field.

Hollow section beam is a type of beam that contains a hollow cavity in the tensile region of the concrete beam. The main objective of having a cavity in the concrete beam is to reduce the self weight of the beam. Furthermore, the presence of the cavity also saves certain volume of concrete and the cavity can be used as utility duct. The duct can be used for wiring purposes and also as a canal or passage for various tasks in construction.

The concrete containing palm oil clinker was introduced as a method to reduce certain amount of gravel aggregates in order to produce concrete with sufficient strength. Therefore, palm oil clinker was used as a coarse aggregate replacement in concrete while the other materials remain the same.

Furthermore, the palm oil clinker can also be used as fine aggregate. The aggregate that passes through 5mm sieve is classified as fine aggregates whereas the aggregates that retains on 5mm sieve but passes through 20mm sieve is considered as coarse aggregates. The sieve information is based on British Standard.

Moreover, in this globalized era, the price of gravel aggregates is increasing Therefore the use of supplementary natural waste such as palm oil clinker has become significant for the use of the concrete industry. Besides that, effective usage of palm oil clinker as a supplementary material in concrete will reduce environmental pollution and also reduce the disposal process of the wastes.

1.2 PROBLEM STATEMENT

The usage of the gravel coarse aggregate has begun since the very first building was built. Coarse aggregates are natural resources and were used everyday around the world which finally it will deplete in the future.

Now, palm oil clinker is the solution for this problem. The palm oil clinker was used as partial replacement for coarse aggregate in the concrete casting. Furthermore, the invention of palm oil clinker as the supplementary coarse aggregates will reduce the usage of gravel aggregates in the construction process.

Besides that, the palm oil clinker which is lighter and strong, acts as a replacing material for gravel aggregates which is able to produce a normal weight concrete. Besides that, the aggregates made from palm oil clinker were used in only a certain percentage which will be determined from the literature review.

The reduction of concrete in the tensile region also saves certain volume of concrete. Thus after we reduce the concrete at the tensile region it is called a hollow section beam. This is because concrete is not efficient and sufficient enough to withstand or resist tensile force.

1.3 OBJECTIVES OF STUDY

i) To determine the ultimate strength and deflection of hollow section beam
ii) To determine the effect of cavity size in the hollow section beam

1.4 SCOPE OF STUDY

In this study, the coarse aggregate replacement that will be used is the palm oil clinker. The aggregate is a palm oil process waste products. The natural coarse aggregate will be used is the crushed granite gravels. River sand is used for the fine aggregates. For the maximum size of coarse aggregates that is 20mm. In the fine aggregate, the maximum size of fine aggregate that will be used in this study is 5mm. Besides that, Portland composite cement and ordinary tap water will be used during the mixing process.

A beam with a size of 250mm x 300mm x 2000mm will be designed for this study. The steel reinforcement in the concrete will be designed according to MS EN 1992: Eurocode 2 – design of concrete structures. The size of the main reinforcement bar is 20mm and the shear link size is 8 mm will be used in this study There will be three different cavity sizes of hollow section beam in this study. The size represents by 40mm x 100mm, 50mm x 100mm and 60mm x 100mm.

Wet gunny curing will be used in this study. The size of the beam is too huge such that it cannot be immersed in the water tank. The beam will be cured for 28days for this study. For this study the ultimate strength will be tested by using Magnus Frame. Figure 1.1 below shows the cross section of the hollow beam.

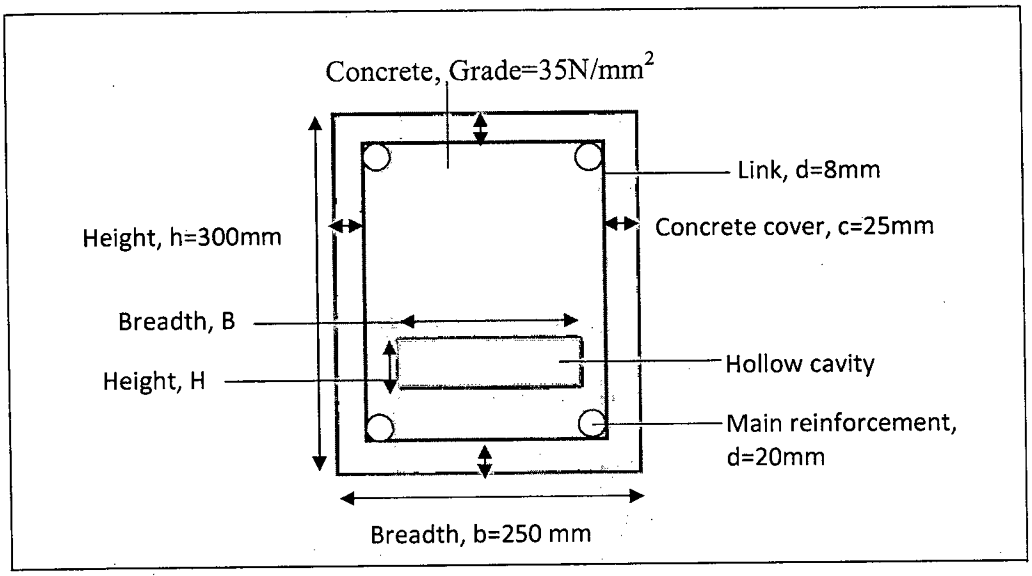

Figure 1.1: Cross section of a hollow section beam

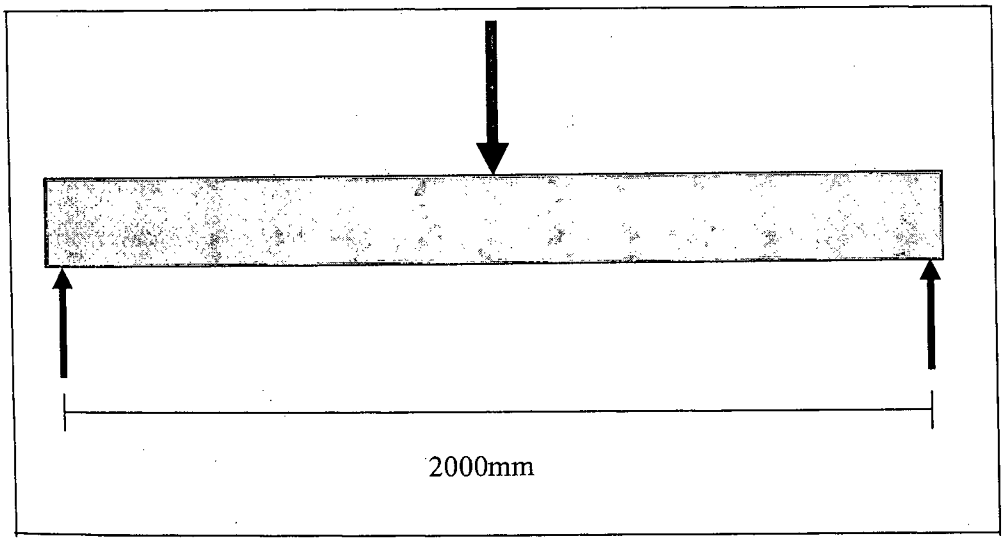

Figure 1.2: Schematic of flexural beam test

1.5 SIGNIFICANT OF STUDY

This study is about the structural characteristic of a palm oil clinker as partial coarse aggregate replacement in producing high flexural hollow section beam. The compressive strength of the lightweight aggregate concrete is determined by the cube test and the workability of the concrete is tested from the slump test. These are the basic criterias to determine the standard of the concrete before it is further used as construction elements such as beam, columns and many more.

The cast of hollow section beam results in reducing the volume of concrete at the tensile region of the beam. There are some concrete reduced at the tensile region of the beam. This is because concrete is weak in resisting tensile strength. The selfweight of the concrete taken into the calculation is the weight of the solid beam and the calculation is continued in order to check in order to prevent any failure. Therefore, selfweight of the concrete becomes the manipulated topic in my studies.

The flexure test of the hollow section beam, deflection and type of failure are becoming the significant in my research studies. The comparison between theoretical and experimental also will be done. This can be done by studying the actual bending moment and shear force diagram compared with the theoretical bending moment and shear force diagram.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this project, the concrete used for the hollow section beam is the concrete containing palm oil clinker as a partial coarse aggregate replacement. Some studies are required in order to fulfill the criteria to obtain a high flexural hollow section beam.

The criteria of the palm oil clinker as a replacing aggregate must be adequate enough in order to be added during the concrete mixing process. Besides that, according to Zakaria 1987, the chemical and physical properties of the clinker must fulfill the criteria which were referred to British Standard (BS).

On the other hand, the physical properties for the hollow beam design must be studied. This is because lack of information can cause the beam to undergo failure or not fit to be experimented (Susumu, 1996).

The bending behaviour of the hollow section beam should be studied. The bending stress should be studied first. As known fact that the tensile bending stress will be taken by the steel bar. The fact is proven that concrete has a weak tensile while steel have week compression (Gourley *et al.*,2001).

2.2 LIGHTWEIGHT AGGREGATE

2.2.1 Characteristics of Lightweight Aggregates

Aggregates contributes 70 percent to 85 percent of the concrete mass (ACI Comittee Sixteen,2000). The characteristic of the lightweight aggregate must fullfill the requirement stated in British Standard (BS).

There are many types of aggregates available as lightweight aggregates such as Natural materials, like volcanic pumice, the thermal treatment of natural raw materials like clay, manufacture from industrial by-products such as fly ash, processing of industrial by-products like Furnace Bottom Ash (FBA) or slag. On the other hand, palm oil clinker, hard organic and inorganic materials were also been used as lightweight aggregates (John Ries, 2008).

The strength, durability and tensile can be manipulated by using the type of aggregates (Mannan, 2010). Even lightweight aggregate concrete can be designed to sustain the compressive strength of a normal concrete. The concrete will be designed according to the requirements. For an example a concrete with high thermal insulation is required in areas in which the risk of fire accident is high. Therefore, lightweight aggregates can be used to produce concrete with high thermal insulation.

It was found out that, the lightweight aggregate contains more voids or pores compared to the normal concrete (Zakaria, 1987). Thus, this is a reason why the density of the lightweight aggregates is lower than the normal aggregate (Grider, 1999). The strength of the aggregates can be determined through by conducting the aggregate crushing and impact experiment (Hilton, 2007).

There are certain benefits in using lightweight aggregates in concrete such that, the dead load can be reduced, improve fire and thermal resistance, and reduce the cost, environmentally friendly. The usage of steel bar also can be reduced as the dead loads caused by the self weight of the concrete were reduced.

2.2.2 Lightweight Aggregate Concrete Mix

The compositions of lightweight aggregates are determined from the experimental analysis. The quantities of the lightweight aggregates are determined by trial and error during the mixing of the concrete (Zakaria, 1987). Certain percentage of lightweight aggregate are mixed with the normal aggregate. The percentages of the lightweight aggregate were manipulated until the maximum compressive strength of the concrete is achieved (Hassan, 2008). Thus this is the concrete mix design proportion.

The concrete produced from a mix design must not only be verified by its compressive strength but also in other aspects such as workability, durability, acid, seawater, sulphate attack, fire and thermal resistance, as well as drying and shrinkage. The moisture content of an aggregate must be taken into the account during the mixing process of the concrete as it will disturb the water to cement ratio (w/c) content. Therefore, the lightweight aggregate will absorb or release water to the binder paste (Hassan, 2008).

2.2.3 Palm Oil Clinker as a Partial Coarse Aggregate replacement

Palm Oil clinker is a material that can be used as an aggregate replacement material as a fine or coarse aggregate. The tendency of this aggregate is to produce lightweight aggregate as the weight of the aggregate is smaller than normal crushed rock. The palm oil clinker is a waste material and also a pozzolonic material which can reduce the sage of raw materials such as cement clinkers and also crushed stones. The bulk density for oven dry for fine aggregate of palm oil clinker is 1075kg/m^3 less than 1200 kg/m^3 (BS 3681(1)). The oven dry for the coarse aggregates is about 815kg/m^3 less than 960 kg/m^3(BS 3681(1)).The criteria of the bulk density suits this aggregates as lightweight aggregates.

The properties of the palm oil clinker are almost the same as the properties of normal aggregate. Specific gravity of fine and coarse aggregates is to be in the range of 1.70 to 1.95 (BS1165:1966(3)). Sulphate content in clinker is 1.2 percent to1.8 percent which is greater than 1.0 is not good (BS1165:1966(3)). The production process for the palm oil clinker starts from palm oil extraction process which contains fibres and shells. The fibres and shell were burned for more than 4 hours at a temperature of 400□C. After the cooling process the palm oil clinker can be obtained. The clinker has an irregular shape of 150mm to 225mm size and whitish grey in colour (Zakaria, 1987).

The material has a cellular porous structure compared to normal aggregates. High water absorption compares normal aggregates is a property of the palm oil clinker. This is because of the porous structure of the material (Hilton, 2007). Therefore, during the water to cement ratio calculation,the water absorption must be calculated in order to prevent any disturbance in the water to cement ratio.

2.3 HOLLOW BEAM MADE FROM PALM OIL CLINKER

2.3.1 Composition of Concrete contains Palm Oil Clinker as a Partial Coarse Aggregate Replacement

The aggregate contains about 60 to 70 percent in a concrete. The materials that normally contribute to the strength of the concrete is the fine and coarse aggregates. The portion of the coarse aggregate is mixed such that a certain percentage of palm oil clinker size of 20 mm mixed with crushed stone of 20 mm. The best percentage of the aggregate mixture is determined from the experimental value which is 25% (Hassan, 2008).

The water to cement ratio should be calculated in order to prevent any reduction in the workability or causing to concrete to undergoes creep and shrinkage. It is known that palm oil clinker is a porous structure and able to absorb water in the concrete mixture which can reduce the water content in the cement (Abdullahi, 2008).

2.3.2 Reduction of Concrete at the Tensile Region

Concrete is a poor tensile resistant material. The concrete construction element particularly a beam always subjected to a transverse force will undergoes bending due to the presence of the moment at the major axis. Figure 2.1 shows the bending moment and shear force diagram. Figure 2.2 shows the deflection of a simply supported concrete beam.

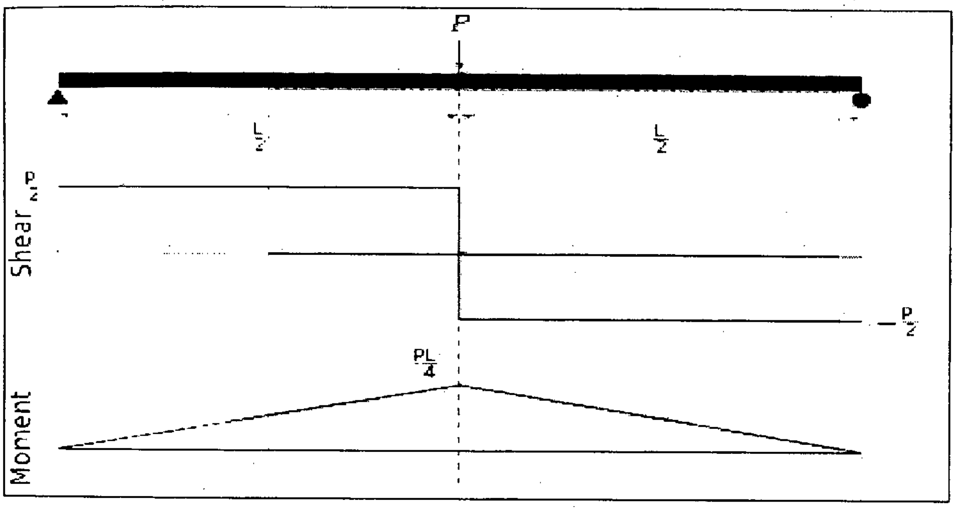

Figure 2.1: Bending moment and shear force diagram

Source: Skier (2013)

The diagram above shows the bending moment diagram and the shear force diagram of a simply supported beam subjected to a point load (P) The shear force obtained is P/2 which is half of the point load value. The moment value can be obtained from the area from the shear force diagram .The multiplication of the shear force and half of the beam length (L/2) will result in the maximum moment value (R.C Hibbler, 2011).

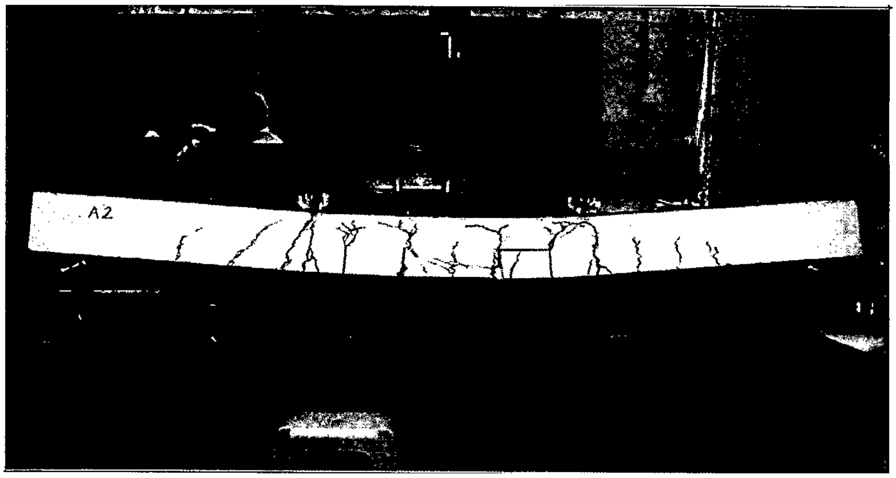

Figure 2.2: Deflection of a simply supported beam

Source: H.Y Leung (2003)

Figure 2.2 shows the deflection pattern occured in a simply supported beam..The top of the beam subjected to compression and bottom part of the beam subjected to tension. This deflection can be explained by the bending stress and its direction. Besides that, the stress block concept shows the stress distribution in a concrete cross- section.

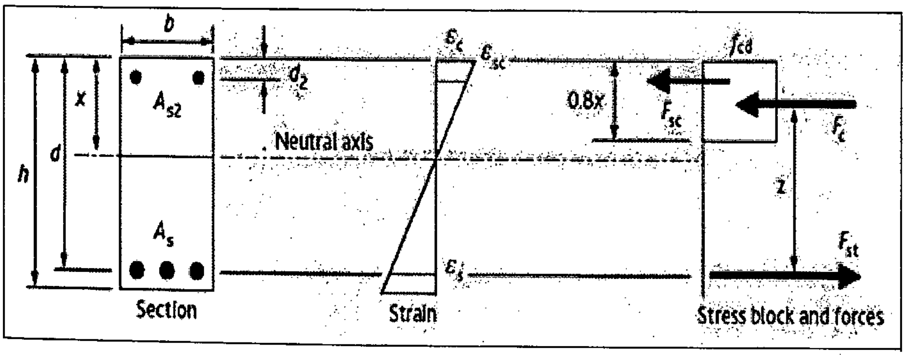

Figure 2.3: Stress block of a Rectangular concrete beam section

Source: Eurocode 2 (2014)

Figure 2.3 shows the stress block of a rectangular concrete beam section. The stress block explains that the compressive strength will be taken by the concrete and also the compressive steel bar reinforcement located in the compressive region of the cross section. The tensile region of the concrete is located below the neutral axis. The tensile strength of the concrete beam is directly taken by the steel bar reinforcement located in the tensile region of the concrete.

2.3.3 Strength of Hollow Section Beam

The concrete hollow beam should be investigated the major failure which is due to the bending moment and also shear failure. The torsional and minor axis bending must be taken into consideration during the testing. If the load doesn't pass through the shear centre of the beam, torsional effect or twisting of the cross section will occur causing the beam to undergoes torsion failure (Zuhair, 2012).

Hollow section beam is considered to be having high fexural rigidity and also reduced self weight of the concrete beam. However, the hollow section beam might not be having enough plastic deformation capacity and energy dissipation. The thinner web causes the shear failure to occur (Susumu, 1996).

Besides that, the cavity duct of the hollow section can be used for various purposes such as internal wiring. The loborious work and time can be saved as most of the hollow section concrete are precast. The cost of formwork also can be reduced as well (Zuhair, 2012).

Figure 2.4 shows the bending stress of a beam. The diagram below shows the bending moment cause the bending stress and its direction. The diagram below relatively shows the bending of a rectangular beam.

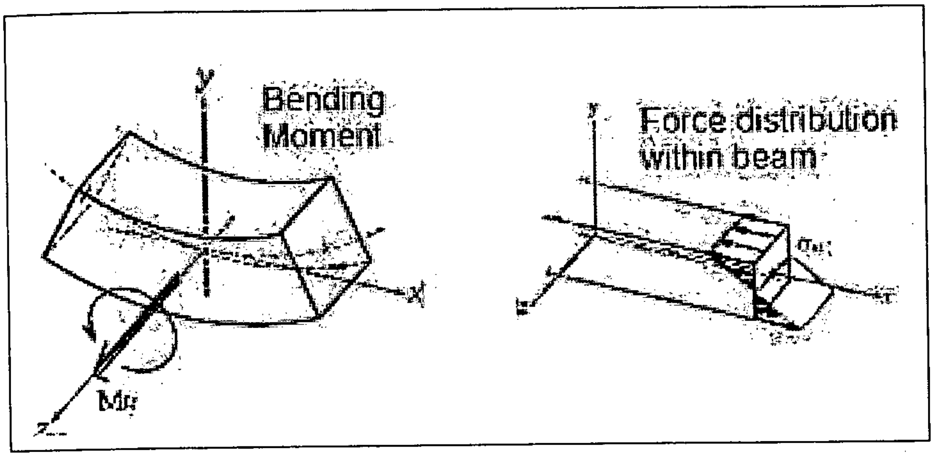

Figure 2.4: Bending stress of a beam

Source: Cdang (2008)

The cross section of the beam remains in the plane despite the beam deforms in bending. This cause the tensile stress on the one portion and compression on the another portion by having a neutral axis which is zero stress in between the tensile and compression stress (Deepak, 2011).

According to R. C Hibbler (2011)

$\sigma_b = My/I$

Where, σ_b = Bending stress

M = Calculated bending moment

y = Vertical distance away from the neutral axis

I = Moment of inertia around the neutral axis

Besides bending stress, there are also shear stress present in a hollow section beam. The shear stress is formed from the direct shear force acting parallel to the cross section of the beam.

According to R. C Hibbler (2011)

$\tau = QV/Ib$

Where, τ = Shear stress

Q = Calculated statical moment

V = Calculated shear at specific point

I = Moment of inertia around the neutral axis

b = Width of beam at depth of specific section

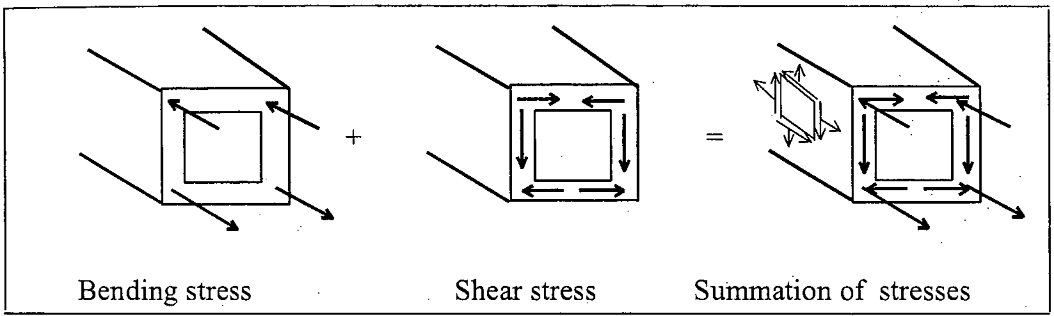

Figure 2.5: Internal stresses of a hollow section beam

Source: Al-Nuaimi (2005)

Figure 2.5 shows the internal stresses that occurs at the cross section of the hollow section beam. The formation of the bending and shear stress occurs in a cross section of a hollow section beam. The summation of these two stress results in the form of general plane stress shown in the diagram above.

2.4 BEHAVIOUR OF HOLLOW SECTION CONCRETE BEAM

2.4.1 Deflection of a hollow Section Beam

The deflection of a beam must be calculated during the design process so that the allowable deflection can be determined. The maximum vertical displacement will occur at the midspan of the beam and the maximum angular displacement will occur at the support of the beam. The Figure 2.6 below shows an example of the vertical deflection

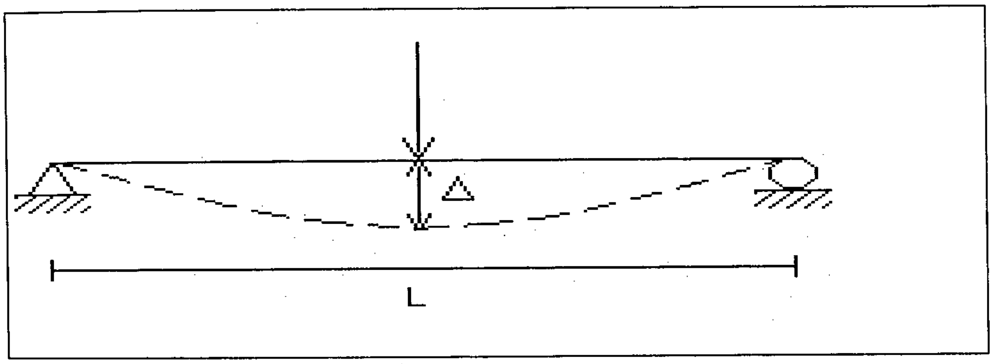

Figure 2.6: Vertical deflection of a simply supported beam

Source: Michael Terk (2005)

Figure 2.6 shows the deflection of a simply supported beam. There is a point load acting at the centre of the beam, which also shows the maximum deflection or vertical displacement occured in the centre of the beam. The higher the point load, the higher the deflection produced (R.C Hibller, 2011).

This deflection occurs because of the bending moment. If the deflection is too big, then the concrete beam can fail due to bending. This is because the inability of the concrete material to withstand the moment which can cause deflection failure. The deflection will lead to shear and flexural cracks (Susumu, 1996).