FINITE ELEMENT MODELLING OF REINFORCED CONCRETE BEAM USING SYNTHETIC LIGHTWEIGHT COARSE AGGREGATE (SYLCAG) OF OFFSHORE SAND

MOHAMAD HASRUL BIN JAMALUDIN

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Faculty of Civil Engineering & Earth Resources
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ABSTRACT

Computer analysis can be used as an effectives tool to analyse structures and components without need to build the structures first. The analysis can be carried out in various condition and time with the verification of the actual condition under laboratory testing too. This study use a computer analysis program called ANSYS to verify what is actually occur to the structure such as beam during laboratory test. The research of lightweight concrete using SYLCAG that used for beam structure has been conducted and the result has been covered based on the theoretical and laboratory test. This study was conducted to analyse the flexural behaviour of the beams using ANSYS. The manipulated variable of the beams are the concrete strength and beam density. The objectives that want to be achieved in this study are to understand the advantages of finite element method. Then, the result is compare between theoretical and experimental results. Besides that, the flexural behaviour of reinforced concrete and SYLCAG beam using ANSYS were studied. After the modeling and analysis were complete, the result proved that ANSYS manage to produce accurate result that similar to theoretical within 1% different for deflection for Beam A (Control) even though the experimental result was out of track. For other beams show the flexure behaviour within the manipulation of beam density and concrete strength. Somehow, ultimate moment capacity gives the closest result upon theoretical calculation for ACI 318 and Eurocode 2. This study concludes that the advantages of Finite Element Modeling (FEM) were discovering upon the accuracy of the result. Next is the comparison between theoretical and experimental gives relevant values and lastly the differences properties of the beams show the flexure behaviour.

ABSTRAK

Analisis komputer boleh digunakan sebagai media yang berkesan untuk menganalisis struktur dan komponennya tanpa perlu untuk membina struktur terlebih dahulu. Analisis ini boleh dijalankan dalam pelbagai keadaan dan masa mengikut situasi sebenar seperti mana ujian di makmal. Kajian ini menggunakan perisian komputer iaitu ANSYS yang mampu mengesahkan keadaan struktur seperti rasuk sebagaimana ujian di makmal. Penyelidikan ke atas konkrit ringan menggunakan SYLCAG untuk struktur rasuk telah dijalankan dan hasilnya telah di bincang berdasarkan kefahaman teori dan ujian makmal. Kajian ini dijalankan untuk menganalisis kelakuan lenturan rasuk menggunakan ANSYS. Terdapat tiga jenis rasuk yang di model menggunakan ANSYS menggunakan keratan rentas yang sama iaitu 200mm × 150mm × 1500mm. Pemboleh ubah di manipulasi bagi kajian ini adalah gred konkrit dan ketumpatan rasuk. Objektif yang ingin dicapai dalam kajian ini adalah untuk memahami kelebihan kaedah unsur tak terhingga. Kemudian, hasilnya akan dibandingkan bersama hasil kiraan teori dan keputusan ujian makmal. Di samping itu, kajian ini juga bertujuan untuk mengkaji kelakuan lenturan rasuk konkrit bertetulang dan campuran SYLCAG menggunakan ANSYS. Setelah selesai struktur dimodelkan dan analisa telah di siap di lakukan, hasilnya telah membuktikan bahawa ANSYS mampu memberikan keputusan yang hampir sama dengan kiraan teori dalam lingkungan 1% perbezaan bagi lenturan untuk Beam A (Control) walaupun keputusan bagi ujian makmal agak tersasar jauh. Bagi rasuk lain, ia berjaya menunjukkan kelakuan lenturan berdasarkan pemboleh ubah manipulasi iaitu gred konkrit dan ketumpatan rasuk. Selain itu, keputusan bagi keupayaan momen muktamad memberikan hasil yang paling hampir dengan pengiraan teori untuk ACI 318 dan Eurocode 2. Melalui kajian ini, rumusan telah di buat bahawa kelebihan model menggunakan unsur tak terhingga telah memberi ketepatan dalam keputusan yang diperoleh. Seterusnya, perbandingan antara kiraan teori dan ujian makmal telah memberikan nilai-nilai yang saling berkait dan akhir sekali sifat-sifat perbezaan lenturan rasuk telah berjaya di tunjukkan.

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V	Shear force
M	Moment
ϕ	Degree
d	Displacement
Y	Yield
P	Force
CL	Control
%	Percentage
kN	Kilo Newton
mm	milimeter
kg/m^3	Kilogram per meter cube
MPa	Mega Pascal
N/mm^2	Newton per milimeter square

LIST OF ABBREBIATIONS

SYLCAG	Synthetic Lightweight Coarse Aggregate
UMP	Universiti Malaysia Pahang
BS	British Standard
ACI	American Concrete Institute
FEM	Finite Element Modeling
DOF	Degree Of Freedom
CS	Coordinate System

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Computer analysis can be used as an effectives tool to analyze structures and components without need to build the structures first. The analysis can be carried out in various condition and time with the verification of the actual condition under laboratory testing too. This study use a computer analysis program called ANSYS to verify what is actually occur to the structure such as beam during laboratory test. In the scope of structural analysis solution, ANSYS provide the ability to simulate every structural aspect including linear static analysis that simply provides stresses or deformations, nodal analysis that determines vibration characteristics, through to advanced transient nonlinear phenomena involving dynamic effects and complex behaviors. For the initial step of this study, we will look at the background of the study that will brief about what the material is used to build lightweight beam structures and some explanation on uses of ANSYS. Then, the problem statement that explain about the disadvantages of laboratorial test. Next, there are three objectives to be achieved with the following of the scope of study that will brief the limitation in this study. Lastly, the significance that can be found in this study is that in the future it can be enhanced further.

1.2 BACKGROUND OF STUDY

Concrete has become a key ingredient in the construction field in the world, especially in Malaysia. The mixture consists of coarse aggregate and fine aggregate that bonded with cement and water. For common type of concrete mixture usually normal to become high or moderate with permeability, resistance to freezing, corrosion and chemicals reaction therefore it is can be controlled. But, these characteristic can be upgraded with lightweight concrete that can expand the increase of volume and qualities in sustaining and lessened to the dead weight. In lightweight concrete mix ingredient, the coarse aggregates were replaced with artificial offshore sand coarse aggregates. Offshore sand is one alternative after river sand that widely used. Offshore sand should extract from 15m ocean depth (Dias, 2007). The study of offshore sand that mixed with concrete to become lightweight concrete has been made and named as Synthetic Lightweight Coarse Aggregate (SYLCAG).

A beam is a one of the structural element that capable to sustain dead and live load with bending resisting. In terms of bending moment, it is kind of force that induced into the material of the beam from external loads, self-weight and external reaction. Within the study of lightweight concrete using SYLCAG, to see more accurate result of strengthen and flexural behavior, the real structure as beam were made to been analyze in the laboratory. This paper presents the test results of 3 beams consist of 1 beam with common sand mixture as control parameter and 2 lightweight beams using SYLCAG that will be compare with computer analysis using software call ANSYS.

Experimental based on testing has been commonly used to analyze individual or combination elements and its effects under loading. To further analyze these lightweight beams and compare with laboratory testing results, the modeling of finite element method using ANSYS software were create. The finite element model was creating to be tested again in the software to show flexural behavior and failure from load-deflection response. The Finite Element Modeling (FEM) analysis and laboratory testing produced close or similar results. With computer analysis, the analysis can be done frequently without having to concrete mixing repeatedly to build a beam. It can also verify the condition of the beam under laboratory testing in daily observation.

1.3 PROBLEM STATEMENT

Recently, the usage of sand in the construction field tu build up lightweight structures such as beam, column and slab demand a lot of these materials. In this scenario, over-exploitation of river sand will lead to environmental harm locally. For solution, offshore sand is the best way to take over the uses of common sand as alternative material. The study, testing and analyze on structure part that mixed with offshore sand has been covered in laboratory. But, seems here to run the testing and analyze some element and parameter on structure part such as beam in laboratory are time consuming, need men power and costly in uses of materials. Besides that, the produced data can be not very accurate cause of some error in terms of apparatus or technical. The analysis with computer software by using Finite Element Modeling (FEM) to get the graphical result will minimize the time usage, energy and cost. Furthermore, with computer analysis, the analysis can be run frequently and better in produce accurate result.

1.4 OBJECTIVES

(i) To understand the advantages of Finite Element Modeling (FEM) for analysis of simply supported concrete and SYLCAG beams

(ii) To compare the Finite Element Modeling (FEM) results with the theoretical and laboratory experimental results

(iii) To study the flexural behavior of reinforced concrete and SYLCAG beams using ANSYS

1.5 SCOPE OF RESEARCH

This study use computer analysis software called ANSYS to analyze the flexural behavior of reinforced concrete beam using Synthetic Lightweight Coarse Aggregate (SYLCAG) from linear response and up to failure. This study simulated by numerical model the 3 types of beams consist of one control beam with common sand mixture and another two beams using SYLCAG. The lightweight beam has the strength with grade 16MPa and 20MPa while the control one has the gred 30MPa. The size of beams is 200mm × 150mm × 1500mm. The mixtures are difference in aggregate density that will come out with the differences beam density which is for 1st lightweight beam is 2030kg/m³, 2nd lightweight beam is 1900kg/m³ and the 3rd or control beam is 2300kg/m³. Flexural tests were performed in the laboratory to gain the load-deflection curve and has been calculated to get the flexural behavior consists of bending moment, ultimate moment capacity and deflection. The next action is, by using ANSYS; the result will be verified with the same properties as the actuals. The results from ANSYS will be compared with the flexural test result in laboratory and theoretical. The results from ANSYS also will show the characteristics of the beams that could not be seen from the laboratory testing immediately and gain understanding on how the beams will react in actual conditions.

1.6 RESEARCH SIGNIFICANCE

The significance of this study is it can be test frequently with differences material or element such as steel, timber and composite. This study also can be expanding with various parameters by changing concrete grade, density and size of the beam. Besides that, this software is potential to produces more result that cannot get by laboratory test immediately such as linear and non-linear analysis that consists of elastic and non-elastic structure, stress and strain. Furthermore the study can be much further with investigation of stiffness of the beam in the Finite Element Modeling (FEM) and the result can be as guideline to check and fix the lack of existing beam or re-design another beam.

1.7 EXPECTED OUTCOME

Based on the objectives that want to be achieved, the expected outcome of this study is firstly, the finite element method will ease the analysis especially for checking in terms of flexural behavior or other analysis. Then, this method can produce more accurate data if the ANSYS modeling has the exactly same material properties and specification with the laboratory sampling (conventional beam). Lastly, based on the result outcome from ANSYS, the deformed shape of the graph in terms of shear, bending deflection and cracking, we can study and analyze the data to conduct solution to strengthen the actual structure by changing the parameter or reduce the failure limit.

1.8 CONCLUSION

Based on this chapter, there are advantages of Finite Element Modeling (FEM) to analyze the lightweight beam in three ways. Firstly, the analysis will show the graphical and accuracy result compare to laboratorial test. Secondly, the usage of ANSYS will verify the various results that cannot obtain from laboratorial testing immediately. Finally, this study can be run frequently also with further investigation for very complex data needed. In the next chapter, we will look at the fundamental part of the flexural analysis including under the laboratorial test and Finite Element Modeling (FEM) that consist of shear and bending moment, deflection and cracking.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will define at both laboratorial and finite element analysis. The analysis will explain the design based on flexural that consist of bending moment, deflection and crack based on theoretical terms, calculation and formula derivation also with the procedure on both laboratorial and finite element method.

2.2 LABORATORIAL ANALYSIS

Usually, to run the experiment based on structural analysis, basically it involve mixing of concrete, steel reinforcement installation and running test on the structure with various load to identify the level of strength, flexibility, shear and lots more parameter needed before design some structures.

2.2.1 Design Based On Flexural Analysis

Three concrete control beams were cast with flexural and shear reinforcing steel and shear reinforcement was placed in each beam to force a flexural failure mechanism. All three beams were loaded with transverse point loads at third points along the beams until failure occurred (Buckhouse et al, 1997)

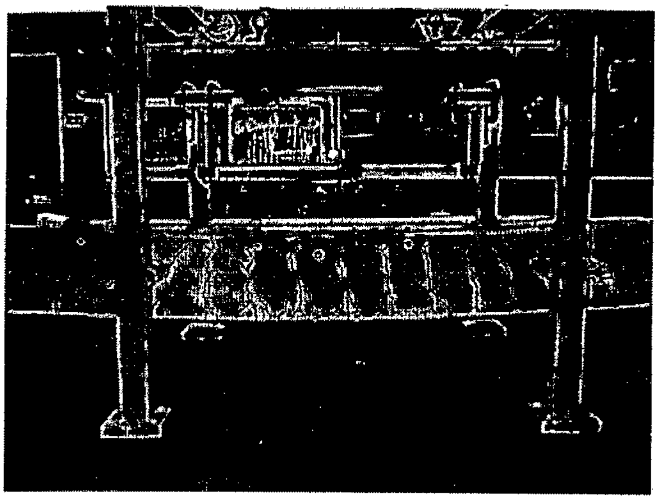


Figure 2.1: Typical Cracking of Control Beam at Failure (Buckhouse et al, 1997)

Because of the concrete in the constant moment region (flexural failure), the beams was failed in compression and were ductile with significant flexural cracking of the concrete in the constant moment region. To predict ultimate load, every beams were plotted the load-deflection curves and compared.

2.2.1.1 Shear & bending

The shear and moment diagrams provide a useful means for determining the largest shear and moment in a member, and they specify where these maximums occur. When the load is applied on the beam, it will develop an internal shear force and bending moment that, in general, vary from point to point along the axis of the beam. In order to properly design a beam, before that the maximum shear and moment must be determined as defined in the Mechanics of Materials (Hibbeler R.C, 8th ed, p56 – p57)

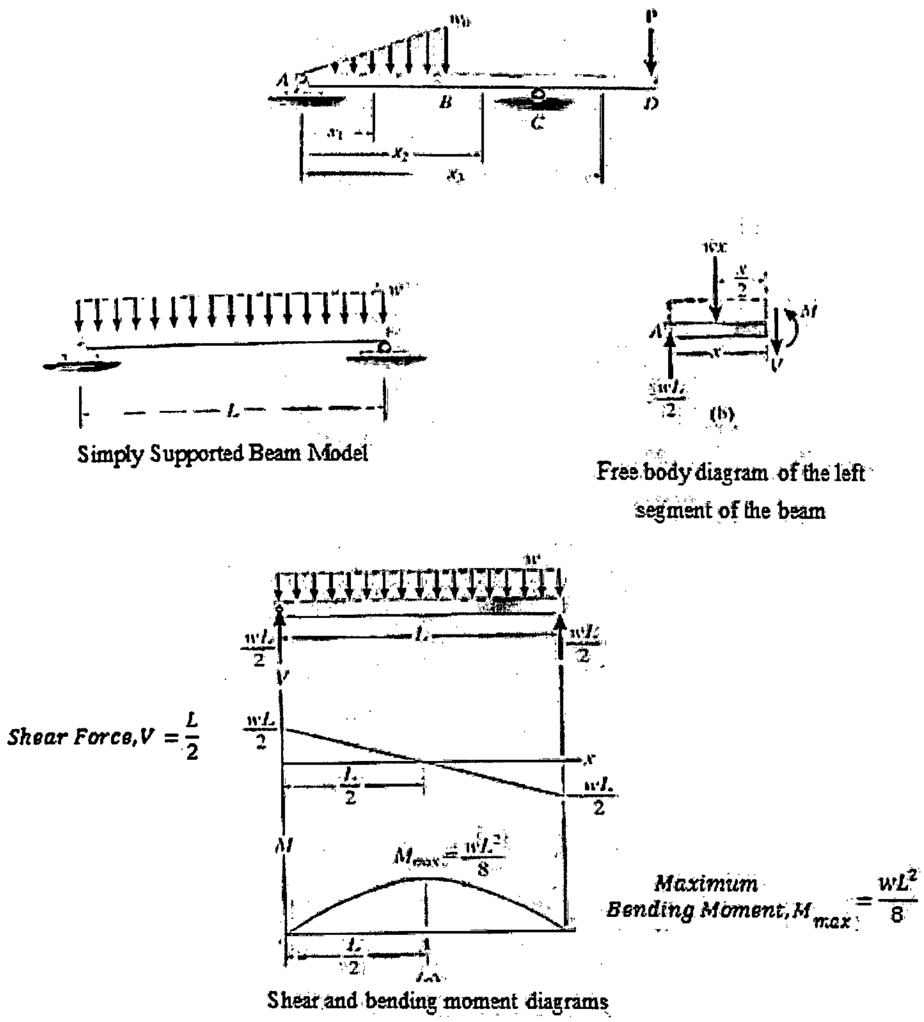


Figure 2.2: Shear & Bending Moment diagram based on the Simply Supported Beam as defined in the Mechanics of Materials (Hibbeler R.C, 8th ed, p56 – p57)

Bending moment are depends on the loading and the length of the beam. Even though the materials of the several beams are differences in terms of density and concrete strength, it is proven that those factors cannot give affect for bending moment. Furthermore, the material of the beam itself are used to investigate the ultimate strength in terms of ultimate moment capacity that can be influenced thorough the manipulation of density and concrete strength.

An increases load that is subjected on simply supported beam causes the bending and the top surface will shorten under compression and the bottom surface lengthens under tension. The load also causes the beam to bend downward at mid-span and upward over the supports. (Yassin, 2012)

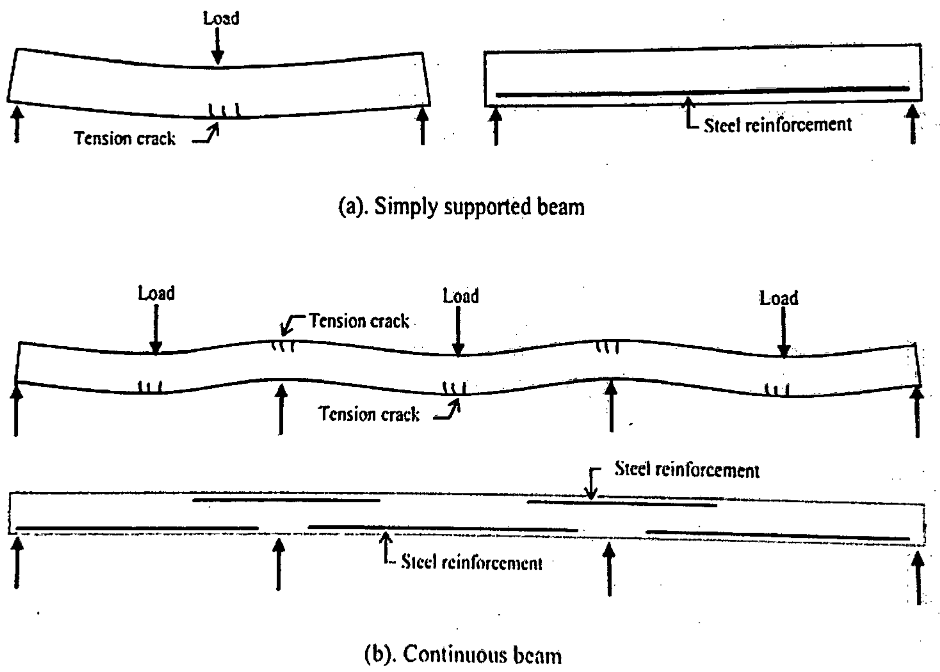


Figure 2.3: Behavior of concrete beams in bending (Yassin, 2012)

2.2.1.2 Deflection

Deflection is defined as degree to which the structural element is displaced under a load. The limit of deflection in design scope must be achieved so that the structures will have stability and integrity. Structures subjected to a load that will return to its original undeformed after the load is removed are under condition called *linear elastic material response*. The causes of deflection are from its internal loadings such as normal force, shear force or *internal bending* such as bending moment as defined in the Structural Analysis (Hibbeler R.C, 8th ed, p305 – p307)

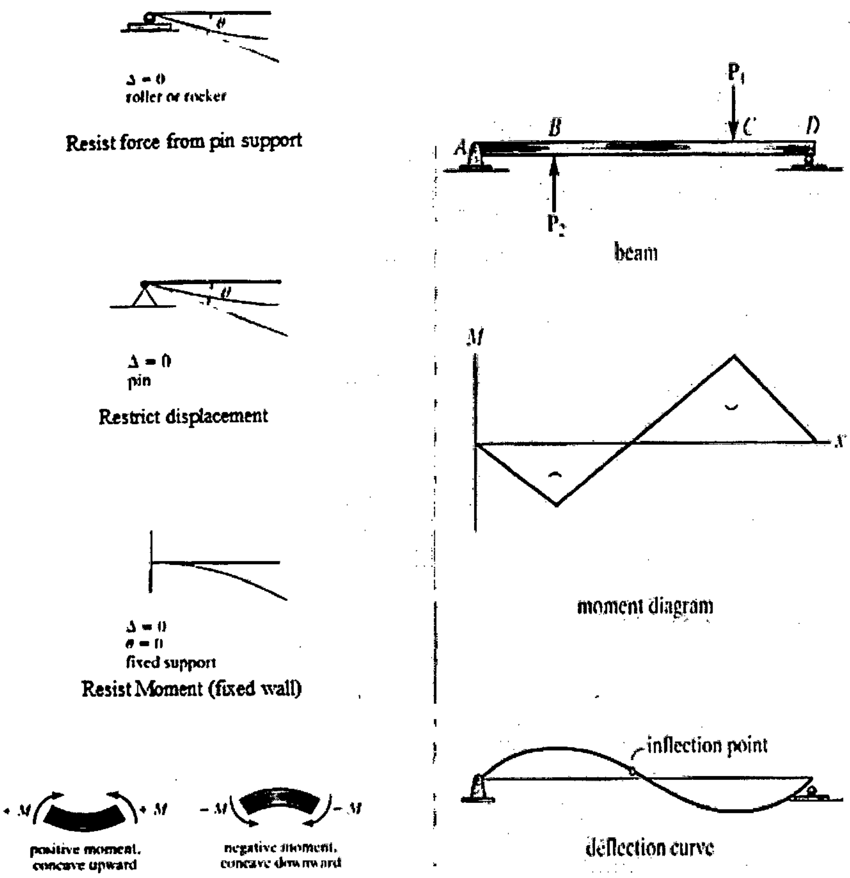


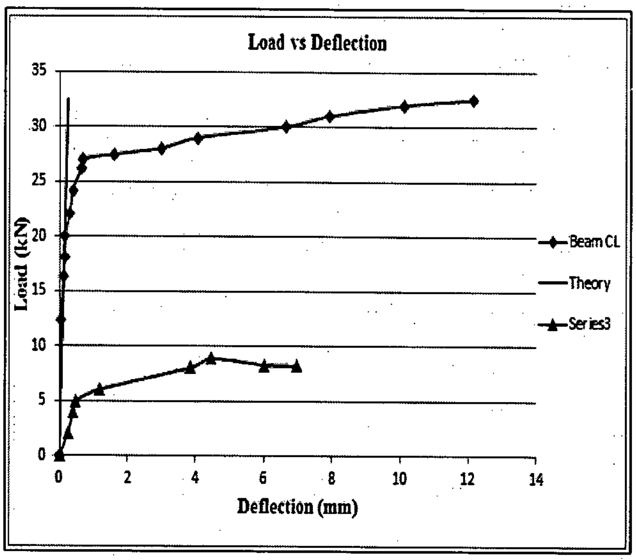
Figure 2.4: Fundamental of deflection consists of type of restriction, curve and tends direction as defined in the Structural Analysis (Hibbeler R.C, 8th ed, p305 – p307)

Flexural test of lightweight beam manage to show the flexural behavior upon the manipulation of the density and concrete strength of every different beam. The increases of deflection value were discovered during laboratory test to study and investigate about flexure behavior of lightweight beam that mix with offshore sand.

Table 4.2: Mid-span deflection of beam CL

Load(kN)	Theory Deflection (mm)	Experimental Deflection (mm)	Remarks
0.0	0.00	0	
12.4	0.09	0.04	
16.32	0.12	0.13	
18.17	0.14	0.14	
20.05	0.15	0.17	
22.13	0.17	0.3	
24.19	0.18	0.39	
26.24	0.20	0.64	
27.01	0.21	0.67	
27.5	0.21	1.62	First crack observed
28.02	0.21	2.98	
29	0.22	4.06	
30.02	0.23	6.64	
30.99	0.24	7.91	
32	0.24	10.14	
32.5	0.25	12.16	Ultimate Load

(a)



(b)

Table 4.3: Mid-span deflection of beam 1300

Load(kN)	Theory Deflection (mm)	Experimental Deflection (mm)	Remarks
0.00	0.00	0.00	
2.06	0.02	0.25	
4.01	0.03	0.40	
4.99	0.04	0.48	First crack observed
6.01	0.05	1.17	
8.06	0.06	3.86	
8.88	0.07	4.45	Ultimate Load

(c)

Figure 2.5: Load – deflection data and curve from flexural test conducted in laboratory. (a) Control beam deflection data based on experimental and theoretical, (b) Load-Deflection curve of control beam, (c) Lightweight beam deflection data based on experimental and theoretical (Zawawiv Aziz, 2013)

2.2.1.3 Crack

Flexural cracks are normally expected during the service life of a safely-designed, ordinary, reinforced concrete structure. The cracks will develop in a reinforced concrete member under services loads. When concrete dry, it shrinks and if the shrinkage is restrained, tensile stresses developed and then if the stresses exceed the tensile strength of the concrete. The progression of flexural cracking as the bending moment on a reinforced concrete beam is increased due to consideration of three principal stages of behavior like the beam is un-cracked, the beam is cracked but stresses are within the elastic range and the beam reaches its ultimate strength (Carino & Clifton, 1995)

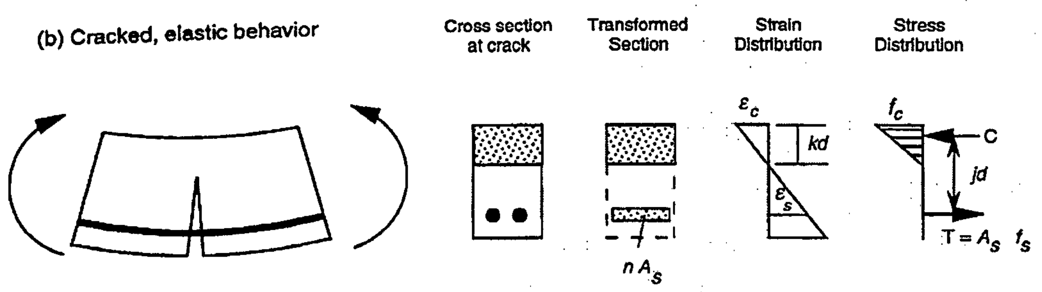


Figure 2.6: Behavior of reinforced concrete beam with increasing bending moment

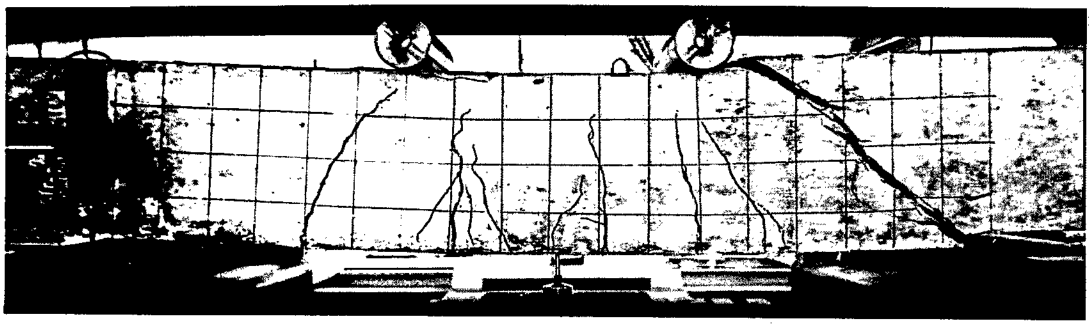


Figure 2.7: Cracks pattern on reinforced concrete beam (Zawawiv Aziz, 2013)

Flexural cracks tended to develop at approximately the location of the stirrups. Therefore, the spacing of cracks was dominated by the location of the stirrups. Therefore, the spacing of cracks was dominated by the location of the stirrups. For beams without transverse reinforcement as shown in figure 6 (Beams G1-M0, G2-M0, G3-C0 and G3-M0) has further increase in load resulted in the formation of a critical diagonal shear crack and sudden failure. For beams G1-M0 and G2-M0 characterized by the formation of a single critical diagonal crack spanning from the point of load application to the support (Munikrishna, Hosny, Rizkalla & Zia, 2011)