COMPERATIVE STUDIES OF REINFORCEMENT CONCRETE BEAM DESIGN USING BS 8110 AND ACI 318

AHMAD ADLI BIN JAMALUDIN
AA07192

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Faculty of Civil Engineering & Earth Resources
University Malaysia Pahang

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ABSTRACT

The application of reinforced concrete beam is a cheap and widely used in Malaysia. Therefore in order to cope with concrete development, a study has been carrying out. This study is basically to discover designs with economical purposes by using BS 8110 and ACI 318. In obtaining results, the value of moment and shear are set as constant. The scope of this study is on four various sizes of rectangular beams which are the beam size (500 mm x 450 mm, 600 mm x 350 mm, 650 mm x 500 mm, 700 mm x 400 mm). Microsoft Office Excel is used in this study in making the calculation easier and accurate. Microsoft Office Excel acts as a medium in obtaining results and there are also manual calculation being done to make sure that the calculation using Microsoft Office Excel is similar with the manuals. From analysis and result, it show that in order to get the area of reinforcement, ACI 318 is more economical while in spacing and link size, ACI 318 shows that it is more economical in term of number of link in used. From this findings, it shows that certain codes has it owns advantage and designer has options on it because all of these codes are still the same in terms of safety.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF SYMBOLS

BS 8110: 1997 Code of Practice

A_c	area of concrete
A_{ps}	area of tendon
d	effective depth; void diameter
d'	depth to compression reinforcement in beam
E_c	elastic modulus of concrete
e	eccentricity
F	Prestressing force
f_{ci}	concrete strength at transfer
f_{cm}	average concrete tensile stress between cracks
f_{cp}	compressive stress due to prestress
f_{cu}	characteristics strength of concrete
f_k	characteristic strength
f_{pe}	effective prestress
f_{pu}.	characteristic strength of tendon
I	second moment of area
β	creep factor
ε_c	creep strain
ε_{cs}	free shrinkage strain
ε_s	shrinkage strain
μ	coefficient of friction
ϕ	creep coefficient

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Since early of 19th century, many outcome researches in designing reinforce concrete structure by experienced engineers have been practiced and it shows success. After all, it is then have been used as a basic guideline in design in suiting the engineering principal from the view of:

a. Economy
b. Safety
c. Serviceability

These are actually three of the important design objectives that should be fulfill. Economic factor means investment which including both construction cost and maintenance, should be in a minimum level. Factor of safety said that the failure possibility in whole or part of the structure should be low along the expected duration. Besides that, it is also said that the aesthetical value's factor of the complete structure should be balance with the environment condition. The outcome guidance should be used as the design practice code.

In concrete structure design, a few practice codes such as CP 114, CP 110, BS 8110 and Eurocodes are already used. These codes of practice have been studied

in order to get a better method in designing concrete structure.

British Standard BS 8110 Code is a developed practice code and being used after CP 110 practice code. This code is being used around mid 90s and 90s. Nowadays, ACI 318M – 05 Code (Standard of the American Concrete Institute) in developing the provisions contained in "Building Code Requirements for Structural Concrete (ACI 318M-05)," hereinafter called the code or the 2005 code. Emphasis is given to the explanation of new or revised provisions that may be unfamiliar to code users. In addition, comments are included for some items contained in previous editions of the code to make the present commentary independent of the previous editions. Comments on specific provisions are made under the corresponding.

In this project, a consideration of design has been seen on the comparison of design beams (moment and shear) between British Standard 8110 code and America Concrete Institute 318 Code.

1.2 PROBLEM STATEMENT

This project is being proposed in order to make sure which beam design comes out with more economical and save cost for reinforcement resistance towards shear force and moment from the view of reinforcement area and link size and spacing besides to understand deeper on the design principals of different practice codes. This project could give benefits because at least the development of reinforced concrete design theories could be studied with further understanding.

1.3 AIM OF THE PROJECT

The aim of this project is to analyze the comparison design beams (moment and shear) using British Standard 8110 code and America Concrete Institute 318 Code under the various sizes of beam. In this project, the value of beam span and design load are constant so that the area of reinforcement and spacing and link size obtained can

show which design is more economical.

The reason why this project is being proposed is to achieve the aim of this project which is about:

1. To analyze and determine design beams (moment and shear) using BS 8110 code.
2. To analyze and determine design beams (moment and shear) using ACI 318M – 05 code.
3. To compare the result of this project.

1.4 SCOPE OF PROJECT

This project is concentrating more on method in designing reinforce concrete beam for moment and shear using British Standard 8110 code and America Concrete Institute 318 Code under four different sizes of concrete beam. This project is only covers simply supported beams.

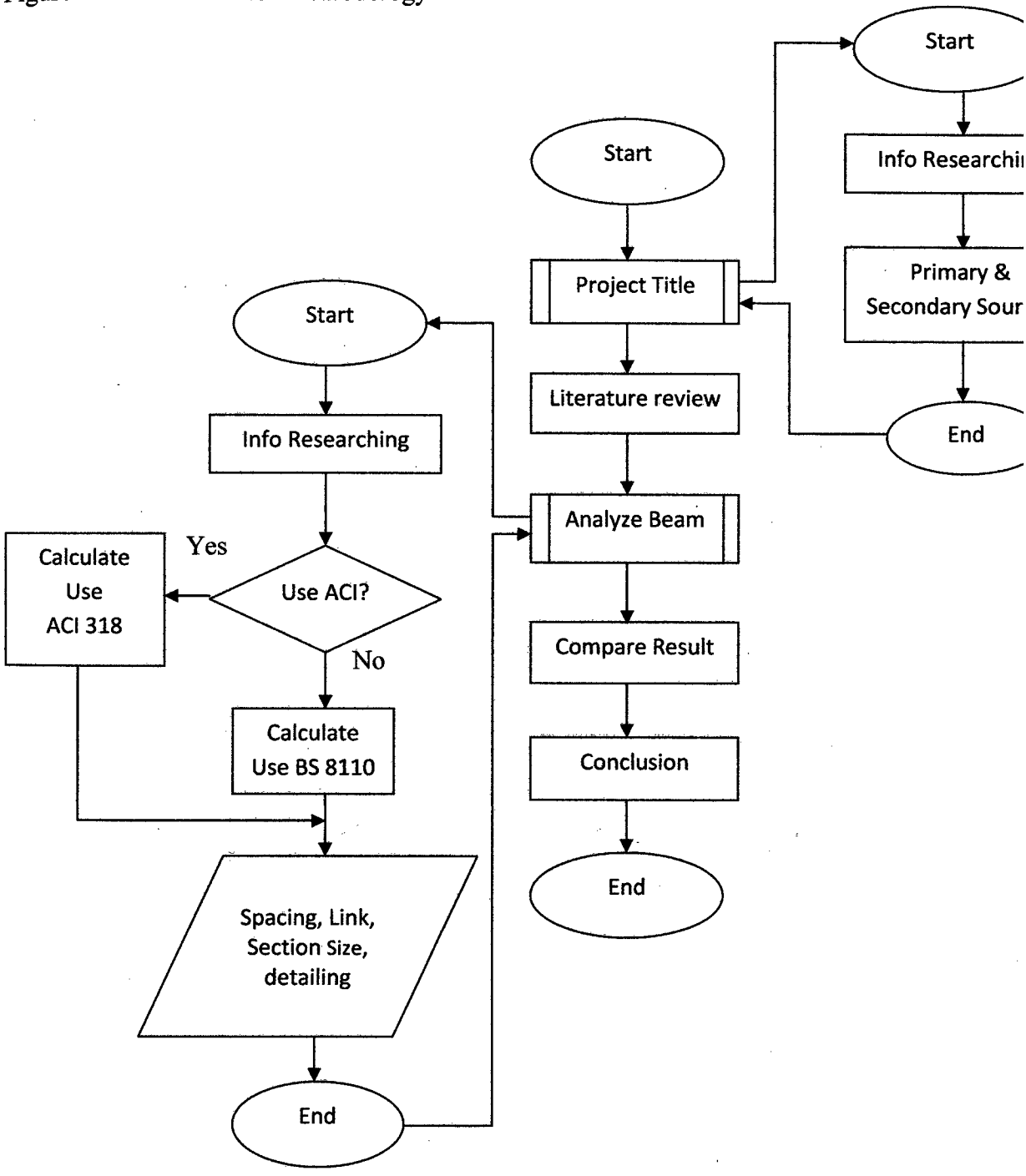
In this design, the initial criteria have been set up which are the beam size (500 mm x 450 mm, 600 mm x 350 mm, 650 mm x 500 mm, 700 mm x 400 mm), concrete grade (35 N/mm ^{2}), Strength of Link (250 N/mm^2), Strength of Reinforcement (460 N/mm^2), diameter size of link (10mm), cover of beam (20mm) and diameter size of main reinforcement bar (25mm).

In this project scope that had been research, flowcharts of methodology will used to show the designing process in order to obtain the results of four different sizes of concrete simply supported beams for the comparison between British Standard 8110 code and America Concrete Institute 318 Code.

1.5 MEHTODOLOGY

The methodology shows the sequence of works along the project. The sequences are as follows which expressed term of flowchart is.

Figure 1.1 : Flowchart for Methodology



CHAPTER 2

LITERATURE REVIEW

2.1 SHEAR IN CONCRETE BEAM

2.1.1 Introduction

The failure of a concrete beam is preferably referred as the failure of perpendicular tension. Shear failure is hard to predict accurately and if the beam is designed without using any shear reinforcement, loading can cause immediate beam failure without any early signs or warning. Shear happens due to part of the beam being pushed downward by loading and this failure is called as shear failure. If a beam is designed with shear reinforcement, the failure in deflection will happen earlier with act of defeating by tension reinforcement followed by concrete cracking and a clear signs of deflection. The behaviors of the concrete give many signals and therefore there are still many times to do any correction on that beam. That is why the shear reinforcement is always applied when it comes to design a concrete beam just to make sure that the deflection failure will show up first rather than the failure of shear occurs when the beam receive maximum load.

2.1.2 Transformation and Shear Crack

In normal dimension of reinforced concrete beam, initial cracks happen as a bending crack in the maximum moment area where shear force is small. When load increase, the next shear will form on the area where the shear force is bigger. At this moment, shear failure will happen. Cracks in this area starts with moment crack which is right-angle to the

normal beam's axis. After that, crack lines will bend and move incline with the beam axis. This is a condition known as perpendicular shear crack.

Even the overall parts of crack started right-angle with main tension stress crack- however crack displacement will take place soon. The open displacement rate depends on the resistance of reinforcement which is placed across the cracking lines. Shear stress which were distributed to the cracking area increased with the presence of reinforcement bar and shear beams strength. More numbers of reinforcement will minimize the crack distance and higher shear force will transfer to the compression zone (un-crack zone). All types of reinforcement whisk placed across crack will decrease the shear strength.

Combination of normal stress and shear stress on crack areas will cause the forming of 'second' crack. This crack will placed across the initial crack and this brings to unstable condition and failure may happen soon. This crack also named as perpendicular stress failure.

If there are no any formations of 'second' crack, shear crack spreading may cause to strength decreasing in compression zone. Final failure depends on reduction of strength in compression zone where it caused by combination of compression stress and shear stress. This type of failure is known as compressive shear failure.

2.1.3 Shear Transfer Mechanism

When main tensional stresses on element of a beam exceed the concrete stress value, it will form crack. On the middle section of simply supported beam where the shear value is still undeveloped with dominant moment value, the direction of main tensional stresses is horizontal and similar to tensional stresses bending. This will yield right angle crack with beam axis, where shear force is more dominant, main tensional stresses almost similar to shear force crack which is incline 45° with the beam axis.

2.1.4 Shear According to BS 8110 code and ACI 318

Shear force which comes along with the changes in bending moment can produce perpendicular tension in concrete. This perpendicular tension will cause cracking near the supports. According to BS 8110 design code and ACI 318 the basic principles of shear design are just the same which are:

i. If $v < v_c$, only nominal reinforcement is required in the beam while shear reinforcement is not required.
ii. If $v_c < v < v_{max}$ only the designed shear reinforcement is required.
iii. If $v > v_{max}$ the section cannot be designed to sustain the shear but a bigger section have to be selected.

There are a few important things to remember while making comparison of shear between BS 8110 and ACI 318 so it would not be any misconception which are;

i. V_{Rd1} in ACI 318 is the same with $v_c bd$ in BS 8110.
ii. V_{Rd2} in ACI 318 is the same with $v_{max} bd$ in BS 8110.
iii. V_{Rd3} in ACI 318 is the shear strength of a section that has been provided with shear reinforcement.

2.1.4.1 Shear Strength of Section without Shear Reinforcement

Concrete is weak in tension, and the beam will collapse if proper reinforcement not provided. The tensile stress develops in beam due to axial tension, bending, shear, torsion or a combination of these forces. The location of cracks in the concrete beam depends on the direction of principle stresses.

Shear strength of a section according to both codes without shear reinforcement will only depends on the concrete strength, percentage of tension reinforcement, depth of a section and axial load that being loaded on that section. According to research by Taylor

(1974), resistance against shear for a concrete beam without shear reinforcement is given by summation of three internal forces component and given by this equation:

$$V_c = V_{cz} + V_a + V_d \quad \text{.....(2.1)}$$

Where, V_{cz} is shear in compression zone (20 — 40%)

V_a, is aggregates action which locked each other (35 — 50%)

V_d dowel action dowel (35 — 50%)

The direction of shear component action is shown in Figure 2.1:

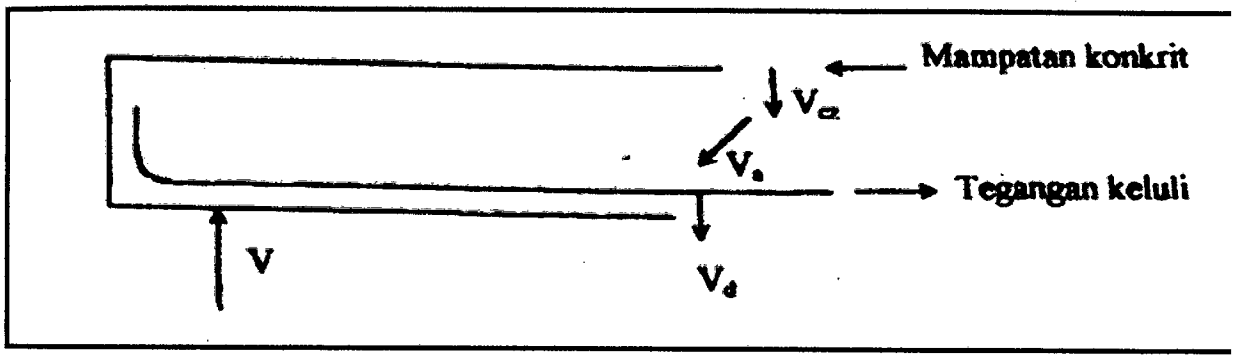


Figure 2.1: Resistance against shear without reinforcement concrete.

Relationship between shear force components is hard to fully understand and its theory is too complex for practical works. Nevertheless, shear stress design on ultimate limit can be obtained from 'the interaction line of lower level' which is the experimental result that has been obtained by *Shear Study Group 1969.* the summation of these three force components can be clarify as design shear stress and for these value, the equation according to both codes ACI 318 and BS 8110 are different as shown below:

BS 8110;

$$v_c = 0.79\,[\,(100As/bd)^{1/3}\,(400/d)^{1/4}\,(f_{cu}/25)^{1/3}]\,/\,\gamma_m \quad \text{.....(2.2)}$$

ACI 318;

$$V_c = 2\sqrt{f'_c}b_w d \quad (2.3)$$

Where, f'_c = specified compressive strength of concrete

b_w = web width

d = distance from extreme compressive fiber to the centroid of longitudinal tension reinforcement

For equations, 2.1 and 2.2 or 2.3 which are given above, there are different limits which are used by BS 8110 and ACI 318.In BS 8110, value of $100A_s/b_v$ cannot exceed 3.0 and value of d that being used cannot exceed 400mm. Other than that, BS 8110 also has limited the value of f_{cu} which is concrete strength that will be in used so it would not exceed 40 N/mm^2. Meanwhile according to ACI 318, all of these conditions are different where in ACI 318 the value of $100A_s/b_v$ cannot exceed 2.0, value of d that being used cannot exceed 600mm and while for strength of concrete, ACI 318 do not state any limits. The other obvious difference between ACI 318 and BS 8110 in the shear equation is the value of 'f. where in BS 8110 the value is 1.25 while in ACI 318 the value that in used is 1.5.

2.1.4.2 Section Strength with Shear Reinforcement

In previous, both codes explain that shear reinforcement is needed when v is bigger than v_c, value and smaller than v_{max}. There is a standard method used in BS 8110 in order to obtain the area of shear reinforcement. It also stated that there are three ways that can be use in resisting shear force:

a) using vertical links
b) using bent-up bars
c) Composition of vertical links and bent-up bars.

According to ACI 318, there are two methods which are useful in resisting shear force. First is the standard method which owns a principle similar to BS 8 110 and the second method is the variety of shear link inclination. Based on ACI 318, designer has options in optimizing the design. It happens so because in certain cases, second method is more economical than the standard method in ACI 318 and BS 8110. All methods in use assume that shear reinforcement functioned as tension clement.

In standard methods for ACI 318 and BS 8110, angle for compression is θ, owns a constant value which is 45^0. Other than that, both codes also stated that for beams, it is assume that internal reinforcement do not have to sustain all the shear force instead only sustain surplus shear force of concrete which is from $v-v_c$. According to both codes, designs are the same except for moment arm value. In BS 8110, moment arm value is 0.9d while in ACI 318 moment arm value is only d. what it is meant by moment arm value is that z value in the equation from reinforcement analysis. It is the tensile clement in obtaining the area of shear reinforcement which is needed to resist shear force and the equation is as follows:

$$A_{sv} = V_s S \gamma_m / \{z f_{yy} (\cot\theta + \cot\alpha) \sin\alpha) \quad \text{.....(2.4)}$$

Where, S is distance between shear reinforcement z is moment arm between internal forces

θ is angle between beam axis and compression links

α is angle between beam axis and shear reinforcement

As for vertical I inks, two more equations can be obtained from ACI 318 and BS 8110 as the sequence to the difference in moment arm value for both design codes. Equation has been simplified which are:

$$V = V_c + V_{link}$$

$$0.95 f_{yv} A_{sv} d\, S_v = v b_v d - v_c b_v d$$

$$= (v - v_c)\, b_v d$$

$$\frac{A_{sv}}{S_v} = \frac{b_v (v - v_c)}{0.95 f_{yv}} \quad \text{.....(2.5)}$$

For ACI 318, where the moment arm value is 0.9d, the equation above then modified and the following equation can be obtained:

$$0.87 f_{yv} Asv(0.9d)\, S_v = v b_v d - v_c b_v d$$

$$= (v - v_c)\, b_v d$$

$$\frac{A_{sv}}{b_v S_v} = \frac{(v - v_c)}{0.87 f_{yv}} \quad \text{.....(2.6)}$$

From both equations above, 2.6 and 2.5 shows a clear view that because of v. value in ACI 318 is smaller than v. in BS 8110, ACI 318 being recognized to give 15% more for link which are to be provided compared to BS 8110 in most cases.

For both BS 8110 and ACI 318, from equation 2.6 and 2.5 above, when characteristic of f_{yv} and link diameter being chosen, cross-section area of A_{sv} can be obtained while spacing or distance between link s_v can be decided. In order to make sure that every existing crack being covered by reinforcement, BS 8110 in clause 3.4.5.5 has put a limit on maximum spacing between links which is 0.75d in inlay direction and for the right-angle direction with inlay, spacing between links could not exceed d and vertical bars cannot exceed 150 mm from vertical links. In BS 8110 which is in Table 3.8 in BS 8110 being set that minimum link is to provide resistance design 0.4 N/mm^2.

$$A_{sv}/b_v s_v = 0.4 b_v / 0.87 f_{yv} \quad \text{.....(2.7)}$$

However, according to ACI 318 minimum links can be obtained by interpolating the values in Table 2.2 and substitute the value in equation 2.8 as follows:

$$\rho = As / bd \quad \text{.....(2.8)}$$

Table 2.1: Minimum value of ρ_w from Table 5.5(4) ACI 318

Concrete classes	Steel classes		
	S220	**S400**	**S500**
C12/15 and C20/25	0.0016	0.0009	0.0007
C25/30 and C35/45	0.0024	0.0013	0.0011
C40/50 and C50/60	0.0030	0.0016	0.0013

Limits for shear force are shown below in Table 2.3:

Table 2.2: Minimum link spacing based on ACI 318

If	$V_{sd} \leq 1/5\ V_{Rd2}$	$S_{max} = 0.8d \leq 300mm$
If	$1/5\ V_{Rd2} \leq V_{sd} \leq 2/3\ V_{Rd2}$	$S_{max} = 0.6d \leq 300mm$
If	$V_{sd} \leq 2/3\ V_{Rd2}$	$S_{max} = 0.3d \leq 200mm$

2.1.4.3 Section Bearing Maximum Shear

The maximum shear a section can bear is depends on the strength of provided links. In both codes, BS 8110 and ACI 318, there are certain rules need to be obeying according to conditions.

From BS 81 10, clause 3.4.5.2, shear stress design, v in any sections needs to be calculating using equation 2.9:

$v = V/bd$ ..... (2.9)

And in cases, value of v should not exceed $0.8\sqrt{f_{cu}}$ or 5 N/mm^2 whichever is the lesser, for any shear reinforcement in used. However, for ACI 318 value for maximum shear force is given by equation 2.10:

$$V_s = \frac{A_v f_{yt} d}{s} \quad (2.10)$$

2.2 BENDING MOMENT IN CONCRETE BEAM

2.2.1 Introduction

Concrete being weakest in tension, a concrete beam under an assumed working load will definitely crack at the tension side, and the beam will collapse if tensile reinforcement is not provided. Concrete cracks occur at a loading stage when its maximum tensile stress reaches the modulus of rupture of concrete. Therefore, steel bars are used to increase the moment capacity of the beam; the steel bars resist the tensile force, and the concrete resist the compressive force.

2.2.2 Behavior of Beams in Bending

Concrete is strong in compression and unreliable in tension. Reinforcement is required to resist tension due to moment. A beam with load at the third points where the central third is subjected to moment only is shown in Figure 2.4(a). Tension cracks at collapse due to moment are shown.

The load- deflection is given in Figure 2.4(b). Initially the concrete in the untracked section will resist tension, but it soon cracks. The behavior of the cracked section is elastic at low loads and changes to plastic at higher loads.

The effective section resisting moment a crack position is shown in Figure 2.4(a). The concrete at the top of the section resists compression and steel resist tension. At low loads, the concrete stress in compression and the steel stress in tension are in the elastic range. At collapse, the stresses are at ultimate values.

Originally the design of concrete section was to elastic theory with linearly varying compressive stress in the concrete, as shown in Figure 2.4(c). Design now is based on the strength of the section calculated from the stress distribution at collapse which has been determined from test.

Beam section design fro the ultimate limit state is given first. The elastic section analysis is then set out because this is required in calculations for checking the serviceability limit states.

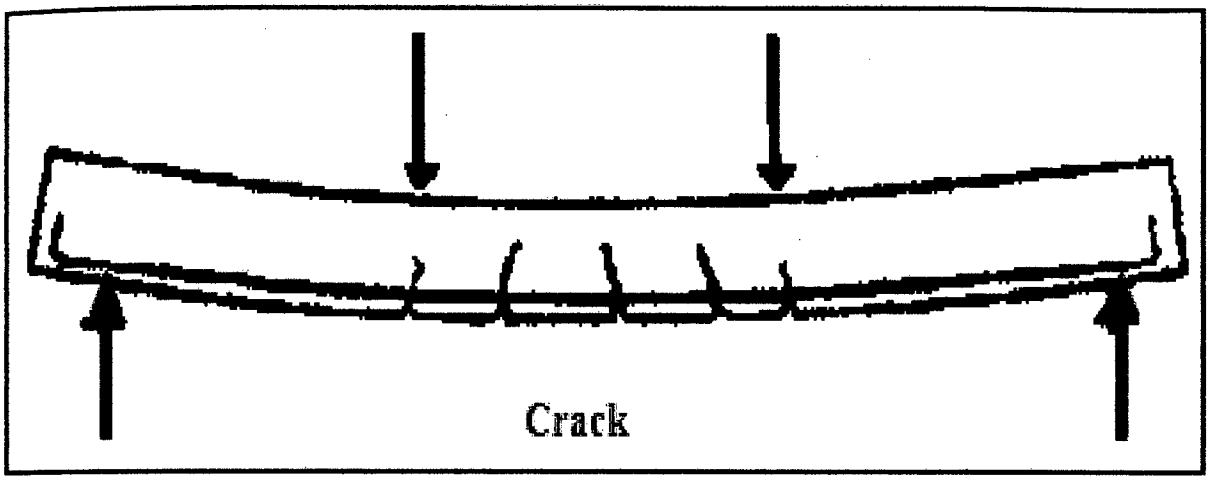


Figure 2.2(a)

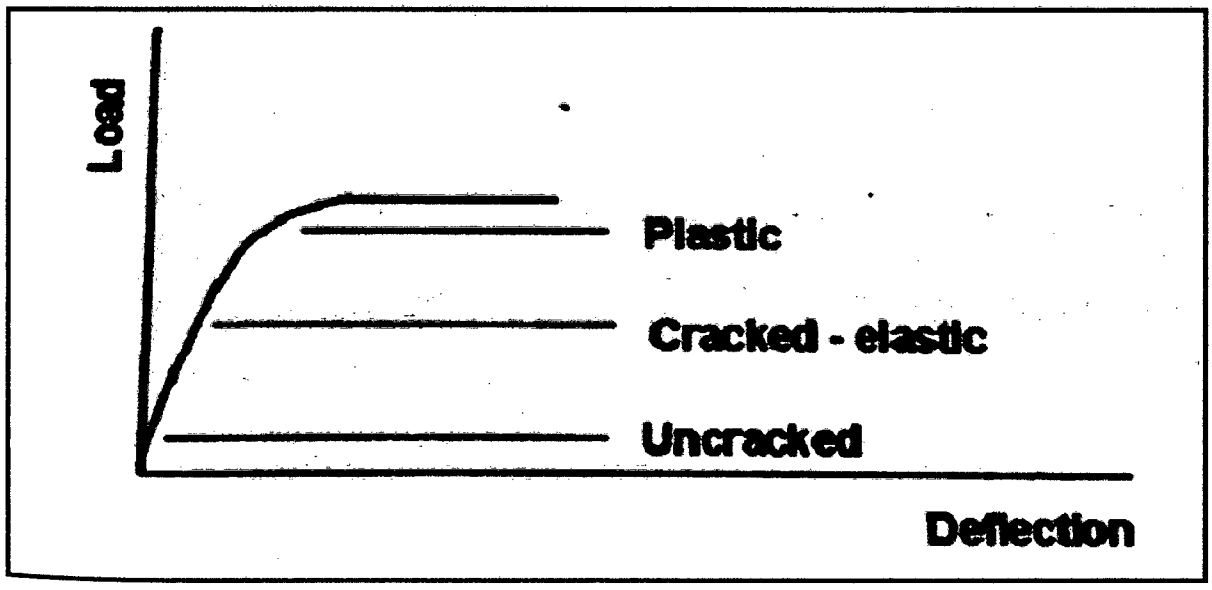


Figure 2.2(b)