BHUBANANDAODISHASCHOOLOFENGINEERING, CUTTACK

DEPARTMENT OF CIVIL ENGINEERING

LECTURE NOTE ON: STRUCTURAL DESIGN -I

(TH-1) 4TH SEMESTER

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1.1 Objectives Of Design and Detailing

The objectives of structural design is to design the structure for stability, strength and serviceability. It must also be economical and aesthetic. The design of a structure must satisfy three basic requirements

1) Stability to prevent overturning, sliding or buckling of the structure, or parts of it, under the action of loads.

2) Strengths to resist safely the stresses induced by the loads in the various structural members;

3) Serviceability to ensure satisfactory performance under service load conditions – which implies providing adequate stiffness to contain deflections , crackwidths and vibrations within acceptable limits , and also providing impermeability , durability etc.

There are two other considerations that a sensible designer ought to bear in mind, viz. economy and aesthetics.

The structures so designed should have an acceptable probability of performing satisfactorily during their intended life.

The design and structures should sustain all loads and deformed within limits for construction and use.

The design structures should be durable.

The design structures should adequately resist to the effects of misuse and fire.

Methods of design of concrete structures(page-32)

Working Stress Method:

The earliest codified design philosophy is that of working stress method of design (WSM). Close to a hundred years old, this traditional method of design, based on linear elastic theory is still surviving in a number of countries. In WSM it is assumed that structural material e.g. concrete and steel behave in linearly elastic manner and adequate safety can be ensured by restricting the stresses in the material induced by working loads (service loads) on the structure. As the specified permissible (allowable) stresses are kept well below the material strength, the assumption of linear elastic behavior considered justifiable. The ratio of the strength of the material to the permissible stress is often referred to as the factor of safety. While applying WSM the stresses under applied loads are analysed by 'simple bending theory' where strain compatibility is assumed(due to bond between concrete and steel).

Ultimate Load Method:

With the growing realization of the shortcomings of WSM in reinforced concrete design, and with increased understanding of the behavior of reinforced concrete at ultimate loads, theultimate load method of design (ULM) evolved in the 1950s and became an alternative to WSM. This method is sometimes also referred to as the load factor method or the ultimate strength method In this method, the stress condition at the state of impending collapse of the structure is analysed, and the nonlinear

stress-strain curve of concrete and steel are made use of the concept of 'modular ratio' and its associated problems are avoided. The safety measure in the design is introduced by an appropriate choice of the load factor, defined as the ratio of the ultimate load(design load) to the working load. This method generally results in more slender sections, and often more economical design of beams and columns (compared to WSM), particularly when high strength reinforcing steel and concrete are used.

Limit State Method:

The philosophy of the limit state method of design (LSM) represents a definite advancement over the traditional WSM (based on service load conditions alone) and ULM (based on ultimate load conditions alone). LSM aims for a comprehensive and rational solution to the design problem, by considering safety at ultimate loads and serviceability at working loads. The LSM uses a multiple safetyfactor format which attempts to provide adequate safety at ultimate loads as well as adequate serviceability at service loads by considering all possible 'limit states'.

1.2 Reinforced concrete sections and its behaviour

1)Reinforced concrete section made of a composite material which having concrete and steel.

2)Concrete is brittle material it takes compressive load and steel is a ductile material it takes tensile load.

3) reinforced concrete section steels are provided to convert the concrete brittle material to ductile material.

Grade of concrete and steel

Grade of concrete **Is 456 :2000 page -16,80,81**

Grade of Steel mainly divided into two types **(Is 456 :2000 page -15,82)**

Mild steel Fe250 grade

HYSD High yield strength deformed bar Fe415

Permissible stresses in concrete

Is 456 :2000 page -81 Table-21

Permissible stresses in steel

Is 456 :2000 page -82 Table-22

Assumptions in working stress method

Is 456 :2000 page -80 cl-B-1.3

1.4 Concept of under reinforced,over reinforced & balanced section

Balanced sections:-A balanced sections is that in which stress in concrete and steel reach their permissible stresses at the same time

$X_{balance}$ or $X_{critical}$ =X_{actual}

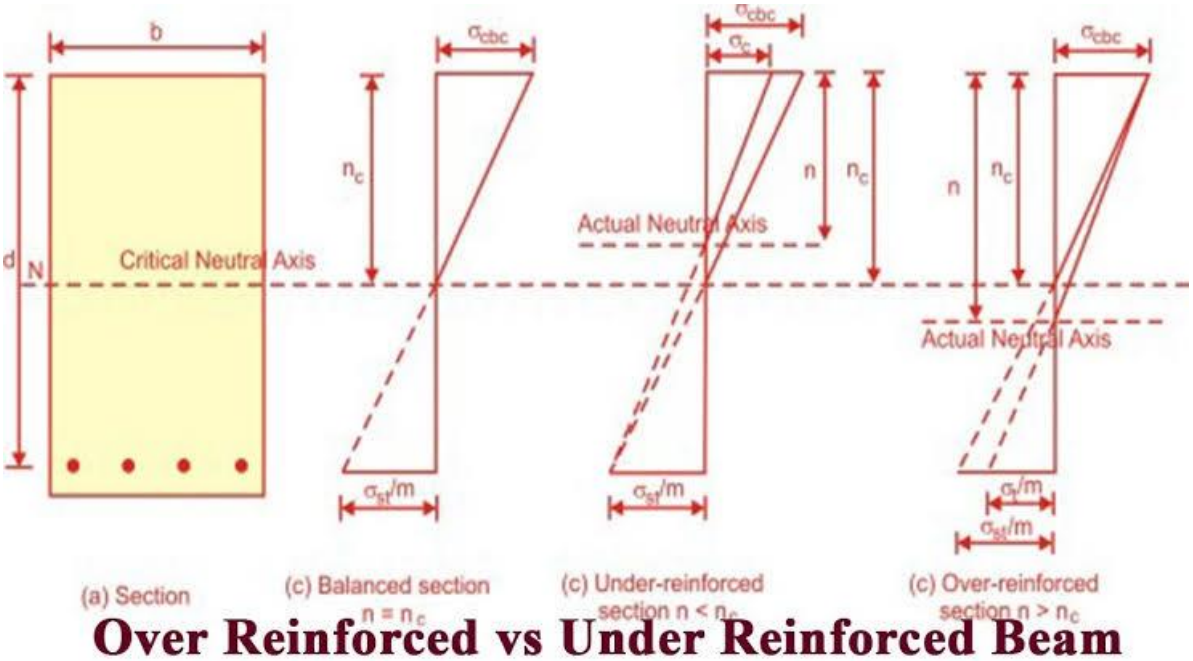
Under reinforced Section:- A under rainforced section is that which stress in steel first reaches its permissible value while the concrete is under stressed.

$X_{actual} < X_{balance\ or}\ X_{critical}$

In an under reinforced section the percentage of Steel provided is less than that provided in balanced section so the actual neutral axis shifts upward and less than balanced neutral axis it is a ductile failure.

Over reinforced section:-A over reinforced section is that which stress in concrete reaches its permissible value while steel is not fully stressed it is a brittle failure or sudden failure.

In an over rainforced section the percentage of Steel provided is greater than the balance section so the actual neutral axis shifts downward and greater than balanced neutral axis.



Over Reinforced vs Under Reinforced Beam

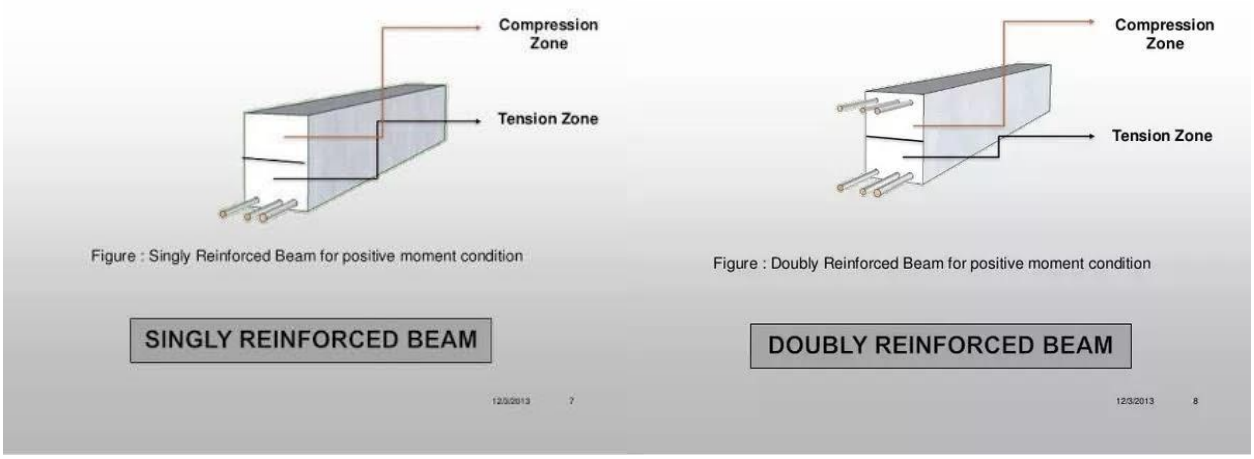
1.3 Singly reinforced section/beam :-when the section is rainforced with tension zone only the section is known as singly reinforced section.

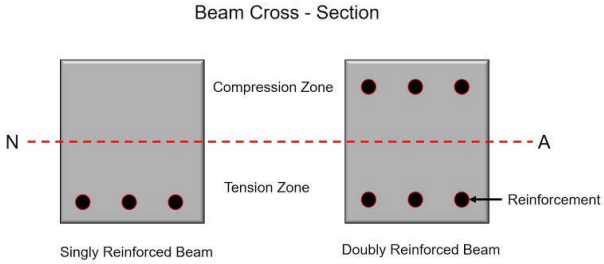
In Such beams, the ultimate bending moment and the tension due to bending are carried by the reinforcement, while the compression is carried by the concrete.

Doubly reinforced section/ beam:-when the section is reinforced with tension and compression zone the section is known as doubly reinforced section

This type of beam is provided mainly when the depth of the beam is restricted.

A doubly reinforced beam is provided to increase the strength of a beam





2. Limit state method

2.1Definition-page 67 clause number 35.1

Advantages of limit state method over working stress method

* It uses modern method of design of structure which involves wide range of logical and technical consideration.

* It involves separate consideration of different kinds of failure, types of materails, and types of load.

* It provides economical design of structure.

* Limit state method hepls to design structures based on both safety and serviceability. The structures are designed to withstand ultimate loads or the loads at which failure occurs unlike working stress method where only service loads are considered. This leads to enhanced safety.

* Using design results, the study established that the economic advantage expressed through saving in materials cost for LSM was around 13% over WSM, and this consolidated the fact that the LSM was the only method currently in use for design of all important structures all around the world.

* It gives thinner sections.

2.2 Types of limit state.
Limit state of collapse

The limit state of collapse of the structure or part of the structure could be assessed from rupture of one or more critical sections and from buckling due to elastic or plastic instability (including the effects of sway where appropriate) or overturning. The resistance to bending, shear, torsion and axial loads at every section shall not be less than the appropriate value at that section produced by the probable most unfavourable combination of loads on the structure using the appropriate partial safety factors.

Limit state of serviceability

Limit state of serviceability relates to the performance or behavior of structure at working loads. To satisfy the limit state of serviceability the deflection and cracking shall not be excessive. Durability is taken care of by prescribing appropriate grade of concrete, nominal cover for various exposure conditions, cement content etc.
a. Limit state of deflection

The deflection of a structure or parts thereof shall not adversely affect the appearance or efficiency of the structure or finishes or partitions. This has been dealt with in Cl. 23.2 (Page 37) of IS 456: 2000.

b. Limit state of cracking

Cracking of concrete should not adversely affect the appearance or durability of the structure; the acceptable limits of cracking would vary with the type of structure and environment. The surface width of the cracks should not, in general, exceed 0.3 mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel nor upon the durability of the structures.In members where cracking in the tensile zone is harmful either because they are exposed to the effects of the weather or continuously exposed to moisture or in contact soil or ground water, an upper limit of 0.2 mm is suggested for the maximum width of cracks. For particularly aggressive environment, such as the 'severe' category in Table 3, the assessed surface width of cracks should

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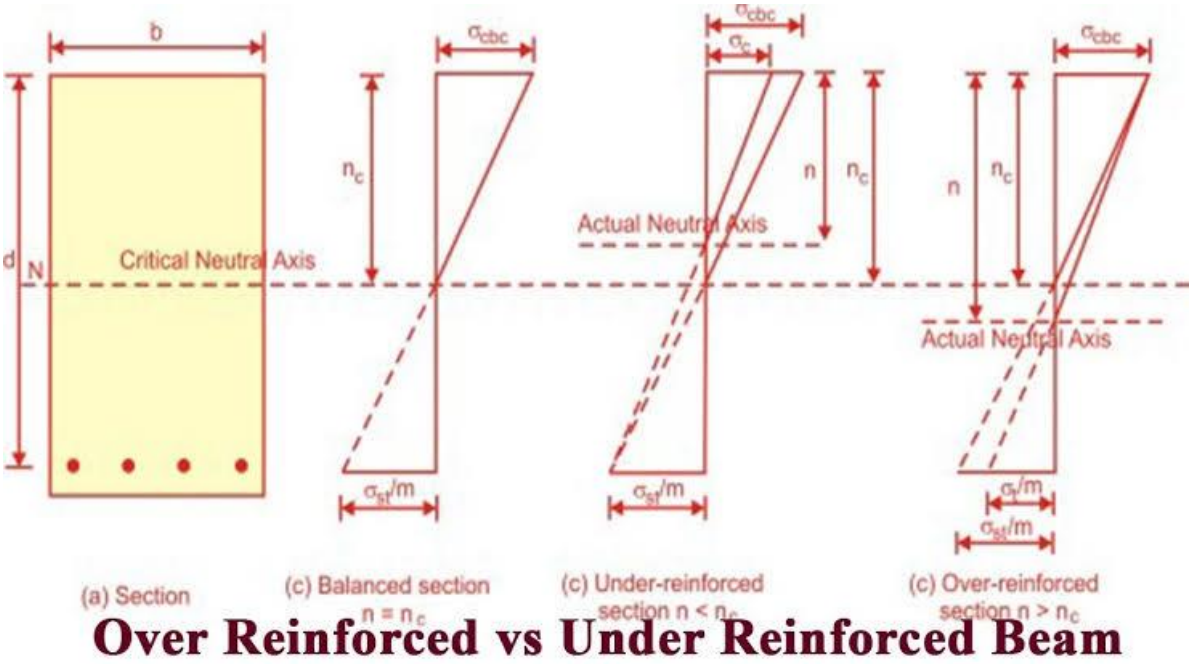

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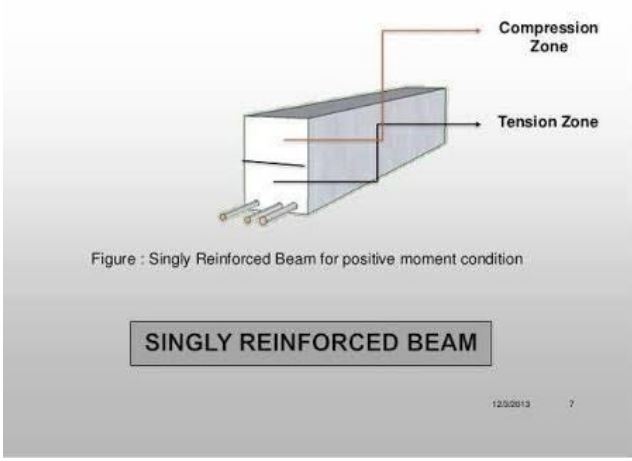

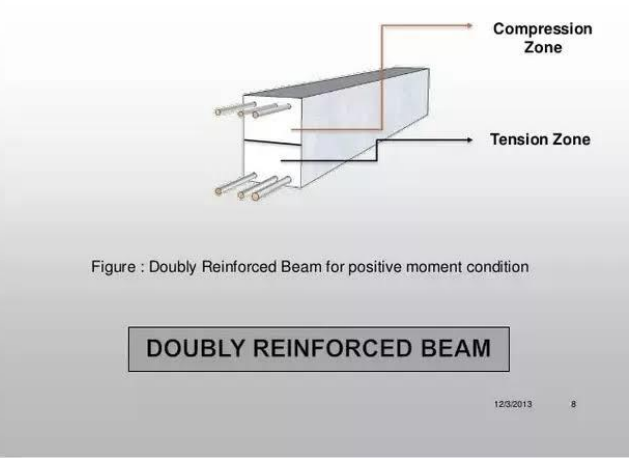

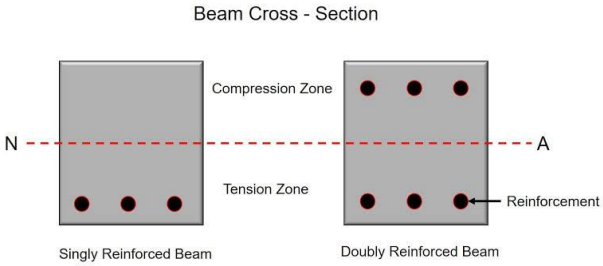

1.5 Advantages and disadvantages of WSM:

Advantages of WSM:

• It is simple, both in concept as well as in application.

• It is reasonably reliable.

• It is essential to have a knowledge of WSM, since it forms a part of LSM. IS:456-2000 has incorporated LSM and WSM. But the concept of WSM is retained for checking serviceability states of deflection and cracking.

• The design usually results in large sections of structural members as compared to LSM. Due to this, structure design by WSM gives better serviceability performance, i.e. less deflection, less crack width, etc.

Dis-advantages of WSM:

• It gives larger section of structural members, thus it is uneconomical.
• It assumes that, stress and strain relationship is constant for concrete, which is not true.
• WSM does not consider the mode of failure of the structure (brittle or ductile).
• Because of creep and non-linear stress-strain relationship, concrete does not have definite modulus of elasticity.
• The modular ratio design results in larger percentage of compression steel than that given by the limit state design, thus its lead to uneconomic design.
• WSM fails to discriminate between different types of loads that act simultaneously but have different uncertainties.