INTRODUCTION TO R.C.C.

The tensile strength of cement concrete is just about 10% of its compressive strength . In other words, cement concrete is very strong in compression. Steel is equally strong in tension as well as in compression . Steel is high strength material as compared with concrete.

The steel used in the form of bars to reinforce the concrete is called reinforcement. (reinforcement is a term form military or police organization . It means to increase the existing strength of concrete as well as controls the effect of shrinkage and temperature changes.

The cement concrete reinforced with steel bars is known as reinforced cement concrete (R.C.C.) . The weight Of R.C.C. Is 25000N/cum

SUITABILITY OF STEEL AS A REINFORCING MATERIAL

Steel fulfills almost all the characteristics required for a reinforcing material . Hence it is the most suitable reinforcing material . Steel is used as a reinforcing material because of the following reasons :

- It has high tensile strength
- It is highly elastic.
- It can develop good bond with concrete as its co – efficient of expansion is nearly equal to that of concrete (i.e. 11.7×10^{-6} /C.
- it is easily available in India.

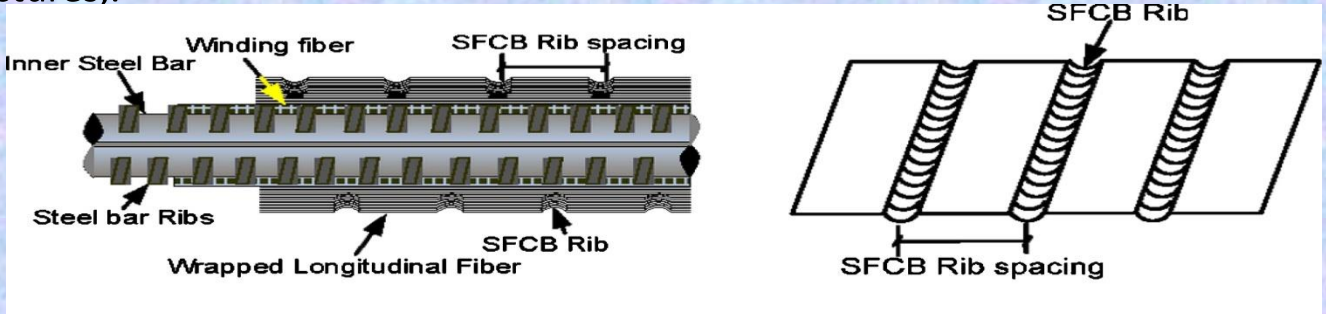
Properties of Mild steel and HYSD steel

Mild steel

- Most ductile amongst all kinds of steel .
- They have plain surface and have sufficient bond with concrete .
- these bars need hooks and bends at their end for anchorages.
- they are less commonly used in R.C.C. because they have less strength and cost approximately same as that HYSD.
- Due to higher ductility mild steels bars are used in blast and earthquake resistant structures,.

High yield strength deformed bars (HYSD bars)

- These are obtained by subjecting the mild steel plain bars to cold working by tensioning and twisting .
- These bars have some type of projection or deformation or lugs or ribs which helps in increasing the bond strength . So, they do not need end hooks.
- High yield strength
- Increase in bond strength



(a) Longitudinal components of SFCB (b) SFCB rib geometry

LOADS ON STRUCTURE (AS PER IS: 875)

- ## Dead load

Deal **load** refers to **loads** that relatively don't change over time, such as the **weight** of. All **permanent components** of a building including walls, Beam, columns, flooring material etc) Fixed **permanent equipment** and fitting that are an integral part of the structure.(like plumbing, HVAC, etc.)

- ## Live load

Refers to **loads** that do, or can, change over time, such as people walking around a building (occupancy) or movable objects such as furniture

- # Wind loads

Wind loads on structural frames are calculated on the basis of the elastic response of the whole building against fluctuating **wind** forces. **Wind loads** on components/cladding are calculated on the basis of fluctuating **wind** forces acting on a small part.

- # Snow loads

- **Snow load** is the downward force on a building's roof by the weight of accumulated snow and ice. The roof or the entire structure can fail if the **snow load** exceeds the weight the building was designed to shoulder. Or if the building was poorly designed or constructed.

- # Seismic loads (Earthquake loads) .

- **Seismic load** is one of the basic concepts of **earthquake engineering** which means application of an **earthquake**-generated agitation to a building structure or its model. It happens at contact surfaces of a structure either with the ground, or with adjacent structures, or with gravity waves from tsunami.

Working stress method

- Traditional method of design
- Simple conceptual basis: The structural material behaves in a linear elastic manner, and that adequate safety can be ensured by suitably restricting the stresses in the material induced by the expected ‘working loads’ (service loads) on the structure.
- As the specified permissible (‘allowable’) stresses are kept well below the material strength (i.e., in the initial phase of the stress-strain curve), the assumption of linear elastic behaviour is considered justifiable.
- The ratio of the strength of the material to the permissible stress is often referred to as the **factor of safety.**
- **Still in use for the design of bridges, chimneys, water tanks etc.**
- Modular ratio is not a constant: increases with time due to creep of concrete.
- Assumption of linear elastic behaviour not always justifiable.
- WSM does not account for behaviour under loads that exceed service loads.
- WSM does not account for varying degrees of uncertainty in different loads under combined loading.
- Uneconomical section design

LIMIT STATE METHOD

- A limit state is a state of impending failure, beyond which a structure ceases to perform its intended function satisfactorily, in terms of either strength or serviceability; i.e., it either collapses or becomes unserviceable.
- Unlike WSM, which bases calculations on service load conditions alone, and unlike ULM, which bases calculations 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.
- LSM is described as a 'semi-probabilistic' method or a 'Level 1 reliability' method
- **Code Recommendations for Limit States Design**
- **Characteristic Strength**
- 5 percentile strength to be taken as 'specified yield strength' in case of steel.
- **Characteristic load**
- the load that "has a 95 percent probability of not being exceeded during the life of the structure"
- In the absence of statistical data regarding loads, the nominal values specified for dead, live and wind loads are to be taken from IS 875 (Parts 1–3) : 1987 and the values for 'seismic loads' (earthquake loads) from IS 1893 : 2002

Shear strength of concrete without shear reinforcement

- Shear strength of concrete is to be considered in design . For beams , shear strength of concrete varies according to the grade of concrete and the percentage of tension steel
- The shear strength of concrete increases with the increase in the grade of concrete. Higher the grade, higher is the shear strength . The shear strength of concrete also increases with the increase in area of tensile reinforcement .
  - P = 100As/bd
- P= percent area of longitudinal steel
- As= area of tensile reinforcement which continues, atleast one effective depth beyond the section under consideration
- b = width of the beam
- d = effective depth of beam

MAXIMUM SHEAR STRESS

When nominal shear stressƲc exceeds the shear strength of the concreteƲc, shear reinforcement is to be provided. but the nominal shear stress shall not exceed the values of the maximum shear stress in concrete are given Ʋv>Ʋcmax if then the section is to be redesigned i.e. the dimensions of the beam are to be changed so that becomes less than Ʋcmax.

Table 19 Design Shear Strength of Concrete, τ_c, N/mm^2

(*Clauses* 40.2.1, 40.2.2, 40.3, 40.4, 40.5.3, 41.3.2, 41.3.3 *and* 41.4.3)

$100\frac{A_s}{bd}$	Concrete Grade					
	M 15	M 20	M 25	M 30	M 35	M 40 and above
(1)	(2)	(3)	(4)	(5)	(6)	(7)
≤0.15	0.28	0.28	0.29	0.29	0.29	0.30
0.25	0.35	0.36	0.36	0.37	0.37	0.38
0.50	0.46	0.48	0.49	0.50	0.50	0.51
0.75	0.54	0.56	0.57	0.59	0.59	0.60
1.00	0.60	0.62	0.64	0.66	0.67	0.68
1.25	0.64	0.67	0.70	0.71	0.73	0.74
1.50	0.68	0.72	0.74	0.76	0.78	0.79
1.75	0.71	0.75	0.78	0.80	0.82	0.84
2.00	0.71	0.79	0.82	0.84	0.86	0.88
2.25	0.71	0.81	0.85	0.88	0.90	0.92
2.50	0.71	0.82	0.88	0.91	0.93	0.95
2.75	0.71	0.82	0.90	0.94	0.96	0.98
3.00 and above	0.71	0.82	0.92	0.96	0.99	1.01

NOTE — The term A_s is the area of longitudinal tension reinforcement which continues at least one effective depth beyond the section being considered except at support where the full area of tension reinforcement may be used provided the detailing conforms to 26.2.2 and 26.2.3

SHEAR REINFORCEMENT

- The simple definition of **Shear Reinforcement** is : reinforcement which is designed to resist shear or diagonal tension stresses.
- Shear reinforcement is usually provided in the form of stirrups to hold the longitudinal reinforcement and also to take the shear to which the structure is subjected to.
- Now the doubt is here that if the stirrups are provided to resist the shear force, why are these provided parallel to shear force and this way how will they resist shear force. That's for two main reasons -
- Shear force doesn't directly acts at stirrups but gets transmitted through tensile and compression reinforcement, thus shear stirrups actually bear the shear force as like a tensile bar.
- The profile of crack developed due to shear force shall not be absolutely vertical (in case of beam) as there are other forces acting also and because of this the crack shall be always be inclined and if stirrups are there, the crack profile shall pass through the stirrups and shall be resisted.

MINIMUM SHEAR REINFORCEMENT

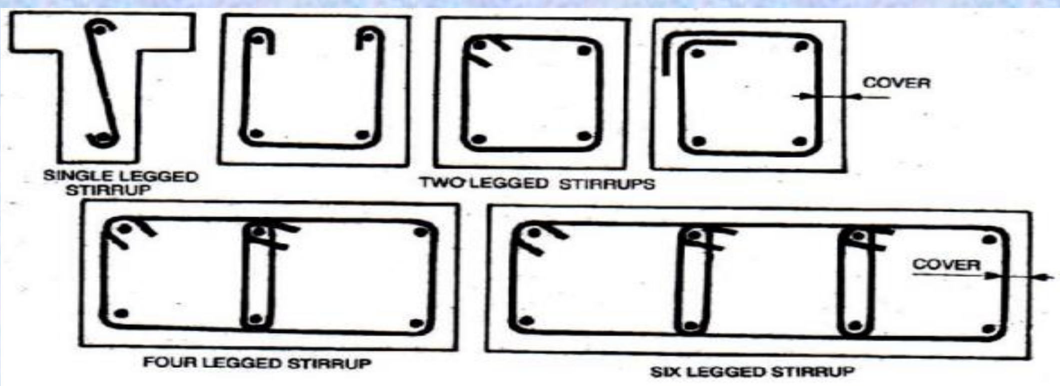
- When nominal shear stress is less than or equal to shear strength of concrete no shear reinforcement is required to be designed. However, under such circumstances, minimum shear reinforcement shall be provided as follow:

$$\frac{A_{sv}}{b \times S_v} \geq \frac{0.4}{f_y}$$

Where

A_{sv} = total cross – sectional area of stirrup legs effective in shear
S_v = stirrup spacing along the length of the member
b = breadth of the beam or breadth of the web of flanged beam and
f_y = characteristic strength of stirrup reinforcement in N/mm which shall not be taken greater than $415\ N/mm^2$.

- When τ_v exceeds τ_c shear reinforcement is provided in the beam. Shear reinforcement shall be provided in the following forms :
- ➢ Stirrups (vertical and inclined)



- ➢ bent-up bars

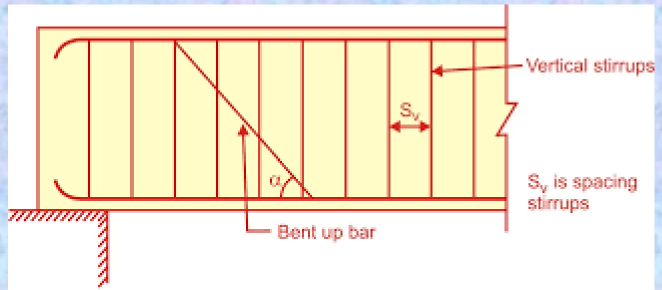


Fig. 5.6. Bent up bars alongwith stirrups.

- ➢ Combination of (a) and (b)

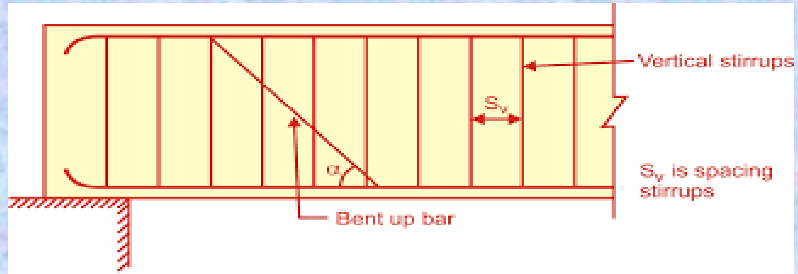


Fig. 5.6. Bent up bars alongwith stirrups.

Assumption in the theory of simple bending for R.C.C.beam

- The assumptions made in the Theory of Simple Bending are as follows:
- The material of the beam that is subjected to bending is homogenous (same composition throughout) and isotropic(same elastic properties in all directions).
- The beams have a symmetrical cross section and they are subjected to bending only in the plane of symmetry.
- The beam is made up of a number of fibers that run longitudinally to each other and are all straight initially. On bending, they do so in the form of circular arcs, with a common centre of curvature.
- The effect of Shear stresses is neglected. The bam is subjected to pure bending.
- No warping of the cross section takes place. That is, transverse sections through the beam taken normal to the axis of the beam remain plane after the beam is subjected to bending.
- The dimensions of the beam are very small as compared to the radius of curvature of the beam.

Neutral axis

The **neutral axis** is an **axis** in the cross section of a**beam** (a member resisting bending) or shaft along which there are no longitudinal stresses or strains. If the section is symmetric, isotropic and is not curved before a bend occurs, then the **neutral axis** is at the geometric centroid.

Balanced section

Reinforced concrete beam sections in which the tension steel also reaches yield strain simultaneously as the concrete reaches the failure strain in bending are called **balanced sections.**

Over-reinforced beam

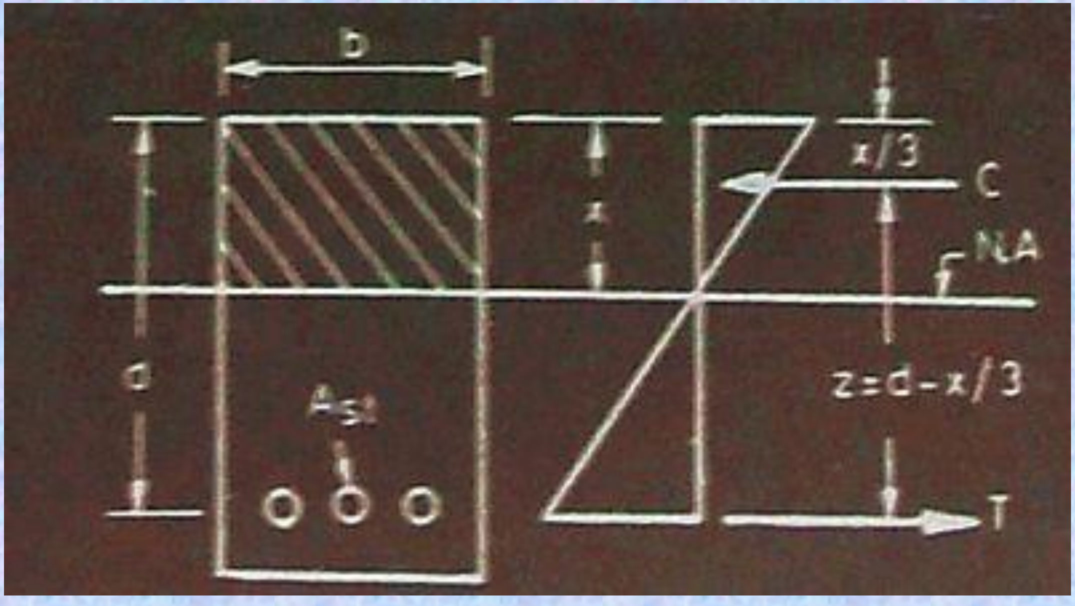
Reinforced concrete beam sections in which the failure strain in concrete is reached earlier than the yield strain of steel is reached, are called **over-reinforced beam sections.**

Under reinforced beam

Reinforced concrete beam sections in which the steel reaches yield strain at loads lower than the load at which the concrete reaches failure strain are called **under-reinforced sections.**

MOMENT OF RESISTANCE FOR SINGLY REINFORCED BEAM

- ***The moment of resistance of the concrete section is the moment of couple formed by the total tensile force (T) in the steel acting at the centre of gravity of reinforcement and the total compressive force (C) in the concrete acting at the centre of gravity (c.g.) of the compressive stress diagram. The moment of resistance is denoted by M.***



SHEAR STRESS

- Shear Stress The distribution of shear stress in reinforced concrete rectangular, T and L-beams of uniform and varying depths depends on the distribution of the normal stress. However, for the sake of simplicity the nominal shear stress τv is considered which is calculated as follows (IS 456, cls. 40.1 and 40.1.1):

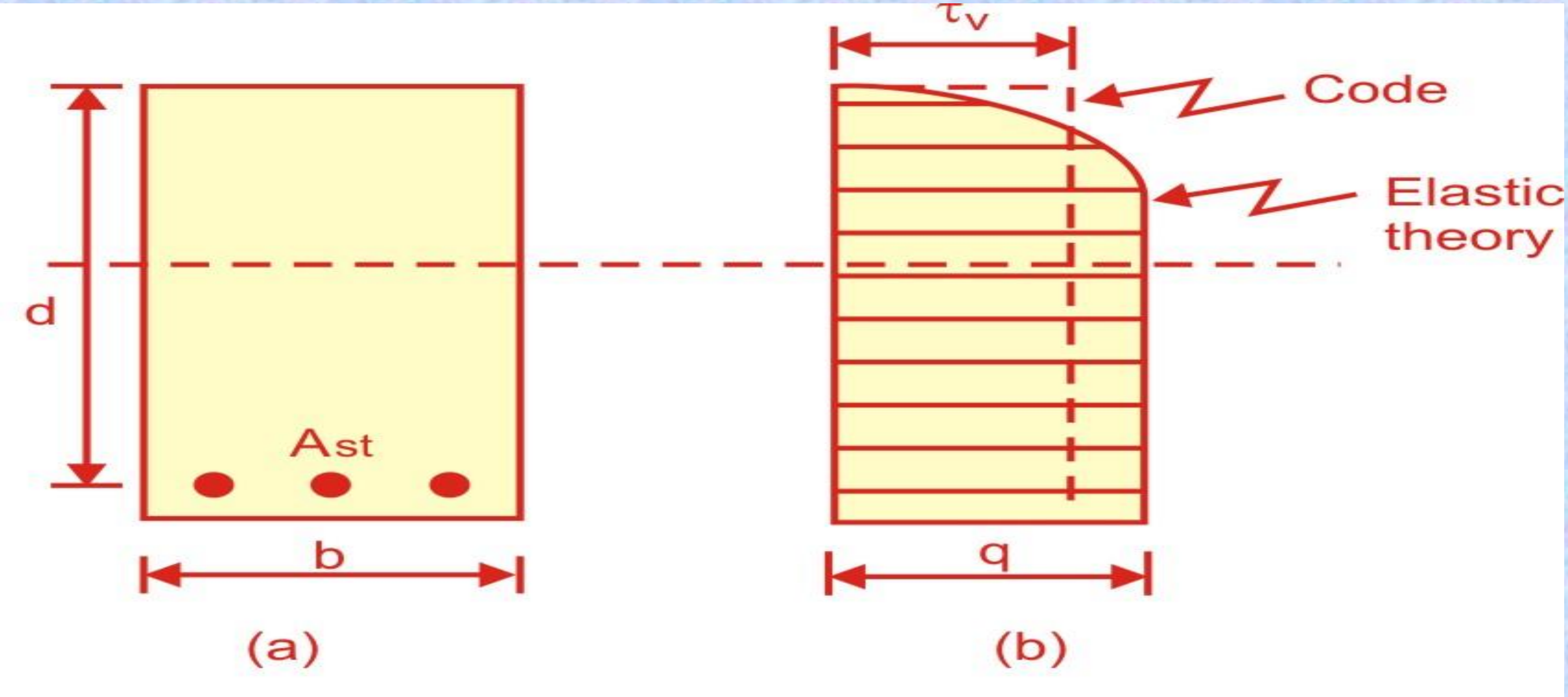
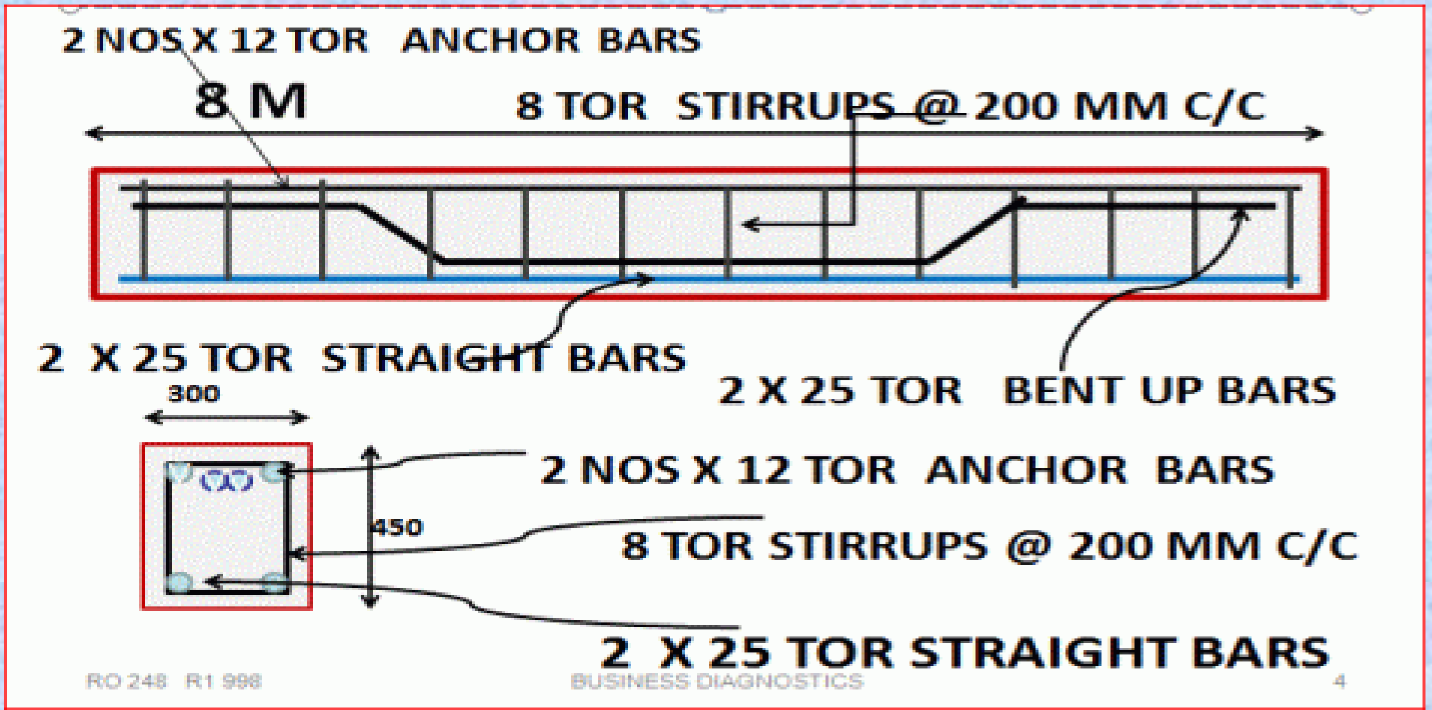


Fig. 5.2. Shear-stress distribution in RCC beam.

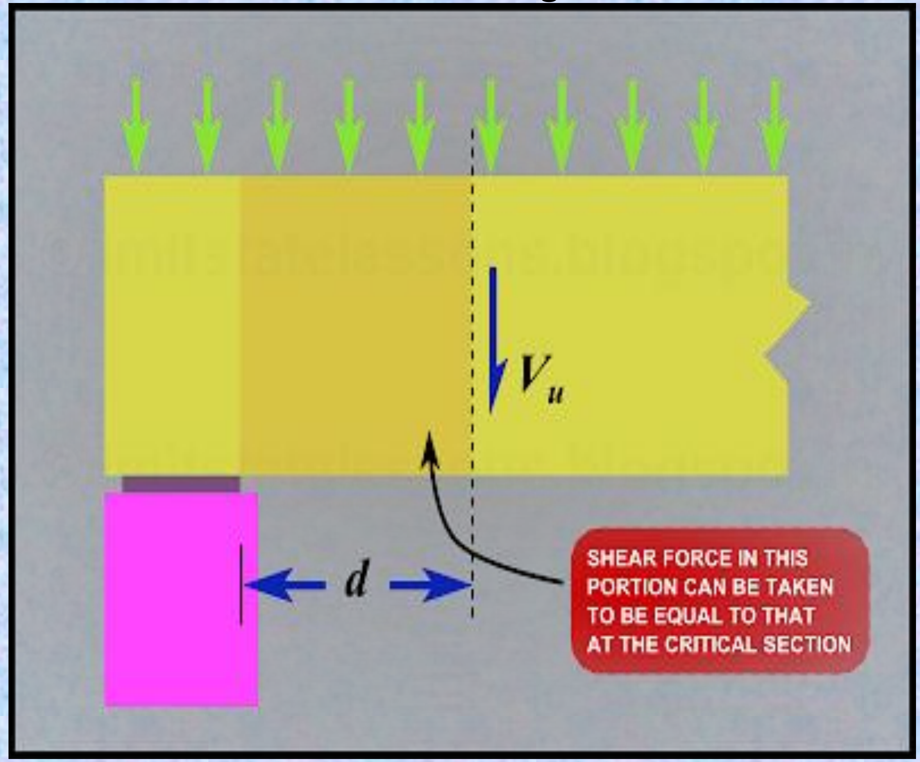
Placement of Stirrups

- The stirrups in beams shall be taken around the outer-most tension and compression bars. In T and L-beams, the stirrups will pass around longitudinal bars located close to the outer face of the flange. In the rectangular beams, two holder bars of diameter 10 or 12 mm are provided if there is no particular need for compression reinforcement



CRITICAL SECTION FOR SHEAR DESIGN

- We know that the shear force applied on the structure is not uniform. It is usually greatest near the supports, and decreases as we move away from the supports. If a beam carries a number of concentrated loads, the shear force is high at the region in between the support and the first concentrated load. We must have a thorough knowledge about selecting the section at which the investigation about the shear force will be made.



Lever arm

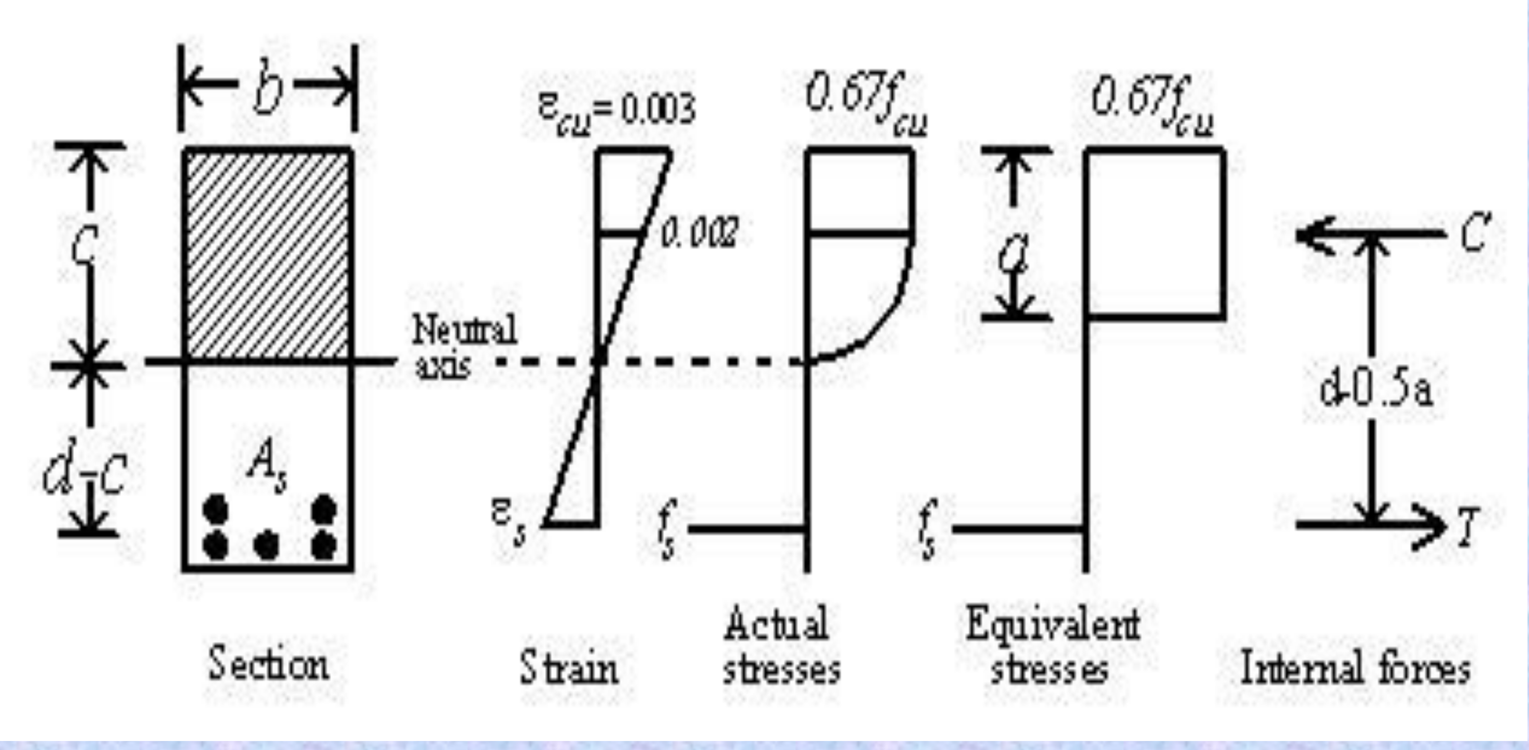
- **Why is the lever arm important in RCC design?**
- Lever arm is the perpendicular distance between the line of action of the couple forming compressive and tensile force in a section. The magnitude of lever arm changes with the change of section type: balanced, under-reinforced and over-reinforced section.
- The lever arm plays vital role in the calculation of the moment of resistance, maximum and minimum reinforcement ratios etc. thus influencing the entire design of a RCC section. The moment determines the deflection on a beam and the amount of deflection determines whether you're ceilings are going to crack.
- These calculations determine the size of steelwork required in order to support the forces that are applied on them; this determines whether your section will fail or not

Why is the partial safety factor for concrete greater than the partial safety factor of steel?

- steel is produced in a sophisticated factory with good quality assurance measures. The product is tested by the manufacturer at several stages and the material that gets approved is only despatched to the market.
- The end user can again get the material tested in another laboratory and satisfy himself before using the product. If any issues are found the product can be rejected. Thus steel reinforcement underperforming is rare. The only issue is it should be stored properly and cast in to concrete before any rust sets in.
- Concrete is generally produced at site and used. Though Cement is produced in a factory with all quality checks similar to steel, it is only the most and not sole ingrediant of concrete. Concrete also comprises of the various sizes of aggregate, admixtures, water etc.
- Further the concrete need to be transported and placed in the form. Further concrete need to be compacted optimally and cured sufficiently. Concrete once cast is difficult to remove or repair.
- Keeping in view of the various factors in production and placing of concrete it is assumed that achieving full strength at all times may not be possible. Hence a higher factor of safety is adopted for concrete when compared to steel.

STRESS AND STRAIN DIAGRAMS

- So firstly as per assumption in **Limit State of Collapse in Flexure**-"At any section, plane section before bending remains plane after bending". This is only possible when the Strain diagram is linear(Strain is directly proportional to the distance from neutral axis).



DESIGN PROCEDURE FOR SHEAR REINFORCEMENT

- **Step one**
- Nominal shear stress
- Tv = Vu/bd
- Where, Vu = shear force due to design load
- b = width of the beam
- d = depth of the beam
- **Step two**
- Percentage of steel
- Percent steel = Ast/bd x 100
- **Step three**
- Find the shear stress in concrete (Tc) for the above percentage of steel as per IS:456:2000
- **Step four**
- If, Tv < Tc
- No shear reinforcement is required. However, nominal stirrups are provided and their spacing is determined by,
- Asv/b.Sv= 0.4/(0.87fy)
- Where, Sv = spacing of stirrups
- Asv = Area of stirrups
- In any case, the spacing should not be more than 0.75d
- **Step five**
- If, Tv > Tc
- Sv = 0.87fy. Asv. d/(Vus)
- Where, Vus = strength of shear reinforcement