Subject Notes: - Reinforced Cement Concrete Design & Drawing (180745)
Semester: - 5th

THIS SUBJECT DEALS WITH ELEMENTARY DESIGN PRINCIPLES AS PER IS: 456-2000

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   Theory and design of singly reinforced beam by Limit State Method

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UNIT-1 (INTRODUCTION)

Topic 1.1. Concept of PCC & RCC with their unit weight?

Ans. PCC-: Plain Cement concrete, it is the mixture of cement, sand, aggregate with suitable per portions of water & its unit weight is-24KN/M^3 or 24000N/M^3

RCC-: Reinforced cement concrete, it is the mixture of cement, sand, aggregate & Steel Bars with suitable per portions of water & its unit weight is-25KN/M^3 or 25000N/M^3

Que1. Differentiate Between RCC & PCC?

Ans.

RCC	PCC
1. Reinforced cement concrete. 2. Material= Cement+ Sand+ Aggregate+ Steel + Suitable per portions of water 3. Ratio Used = CEMENT: SAND: AGGREGATE 1 : 1 : 2 1 : 1.5 : 3 1 : 2 : 4 4. Unit Weight= 25KN/M^3 5. Uses- Column, Beam, Slab, Stairs etc.	1. Plain cement concrete. 2. Material= Cement+ Sand+ Aggregate with suitable per portions of water 3. Ratio= CEMENT: SAND: AGGREGATE 1 : 4 : 8 1 : 5 : 10 4. Unit weight= 24KN/M^3 5. Uses- foundations and floors of buildings. They provide Plain surface over foundation etc.

Topic 1.2. Define reinforcing material?

Ans. The material which develops a good bond with concrete to increase its tensile strength called R/F material.

Reinforcing material can be mild steel bars, Tor steel bars, etc.

Topic 1.2.1. Suitability of steel as a reinforcing material.

OR

Why steel is considered as a best reinforcing material in concrete?

Ans. Steel is used as a most common reinforcing material because of the following reason:-

1. Steel develops a very good bond with concrete.
2. Steel is very strong in tension, compression, shear and tension.
3. The steel bars can be cut, bent, welded easily.
4. Steel has longer life and it is easily available throughout India.
5. Co-efficient of linear expansion of steel is nearly same as concrete.

Steel-$11.7x10^{-6/0C}$

Concrete-$9.9x10^{-6/0C}$

Topic 1.2.2 Explain properties of Mild Steel and HYSD.

PROPERTIES OF MILD STEEL	PROPERTIES OF HYSD
1. The mild steel bars are plane round and hot rolled bar.	1. HYSD means High Yield Strength Deformed Bars. It is also known as TOR steel.
2. These bars are more ductile as compare with HYSD. (due to less % age of carbon)	2. These bars are less ductile as compare with mild steel. (due to high % age of carbon)
3. To develop sufficient bond with concrete.	3. HYSD provide good bond with concrete due to ribs. (Projections are provided on the surface of bars as a rib)
4. They required hooks & bends at their ends for proper anchorage.	4. They do not require hooks or bends at ends hence these bars are economical.
5. Mild steel bars are also known as Fe-250 because of its yield strength is 250 N/mm^2.	5. HYSD bars may be hot rolled high yield strength bars or cold worked high strength deformed bars.
6. It is available in market in Fe-250 grade.	6. It is available in market in following grades. Fe-415, Fe-500, Fe-550, Fe-600
7. A mild steel bar gives sufficient warning before failure.	7. Tensile strength of HYSD is very high.

NOTE:-Nowadays TMT and CRS are available in the market.

- ✓ **TMT (Thermo Mechanically Treated) Bars:-**

  TMT steel is new generation high strength steel having superior properties as compared to common HYSD bars.

  In India, SAIL (Steel Authority of India Limited) is producing TMT steel.

  The TMT bars have following advantages:

  1. High yield strength
  2. Better weld ability
  3. Excellent ductility
  4. Better corrosion resistance

- ✓ **CRS (Corrosion Resistant Steel) Bars:-**

  The latest development in steel bars is the production of CRS bars.

  The carbon content in the bars is 0.18% as compared to 0.2% of HYSD bars.

  In India, SAIL (Steel Authority of India Limited) and TISCO (Tata Iron and Steel Company) are Producing CRS bars.

Topic 1.2.3 -: State loading on structure as per IS-875.

Ans. The various types of loads act on a structure as per IS-875 are:-

1. Dead load
2. Live load (Superimposed Load)
3. Wind load
4. Snow load
5. Seismic load (Earthquake Load)

1. **Dead load-** The dead loads are due to self weight of the structure. These are permanent loads of finishing and filling material etc depends upon the unit weight of material. Example- floor, beams, column etc.

2. **Live load-** loads which are varying in magnitude and position are called live loads. It is called superimposed loads. Example- loads of people, furniture and movable equipments etc.

3. **Wind load-** The force exerted by horizontal component of wind is to be considered in the design of building. It depends upon the velocity of wind, shape and size of building. It should be considered as the design of multi-story building, towers, and poles. (Upto height 30m wind pressure is considered to act uniformly). (Above 30m height, the wind pressure is increases).

4. **Snow loads-** Building which are located in the regions where snow fall is very common are to be designed for snow load.

5. **Seismic load-** Seismic loads are caused by the shocks due to earthquakes which are calculated as per IS-1893-2000. Now it is mandatory to follow the recommendations regarding seismic loads in the design of structures, if the structure is situated in the seismic areas.

Que: - Define Characteristics Compressive strength of concrete.
Ans: - It is that strength below which not more than 5 percent of the test results are expected to fall

Que: - **Explain M 25**.
Ans: - "M" refers to the mix and 25 represents that the characteristics compressive strength of 150 mm size concrete cube at 28 days, expressed in N/mm^2

Que: - **What is Yield strength of Fe-250**?
Ans: - Yield strength of Fe 250 steel is 250 N/mm^2

UNIT-2
(INTRODUCTION TO METHODS OF RCC DESIGN)

Topic 2.1: - **Define Working Stress Method**

Ans: - This method is based on the linear elastic theory and assumes that both steel and concrete are elastic and obeys Hooks Law. Therefore, this method is also known as "Elastic Method of design" or "Modular ratio Method"

- **Basic assumptions of Working Stress Method?**
  1. At any cross-section, Plain Section before bending remain plain after bending.
  2. The concrete is assumed to be homogeneous.
  3. Tensile strength of concrete is ignored.
  4. There is a Perfect bond between steel and concrete.
  5. There is no initial stress in concrete and steel.
  6. The modular ratio(m)=280/3 σcbc
  7. All tensile stress taken up by steel none by concrete.

Topic 2.2: - **Define Limit state Method**

Ans: - This is the most rational method which is based on safety at ultimate loads and serviceability at working load. The acceptable limit of safety and serviceability requirements before failure of a structure takes place is known as a limit state.

The important limit states which are to be considered in design are:-

(1) Limit State of Collapse

(2)Limit state of Serviceability

(1) **Limit State of collapse: -** limit state of collapse is also known as ultimate limit state as it corresponding to the maximum load carrying capacity.

Limit state of collapse occur when the structure as a whole or part of the structure collapses under following condition:-

I. Limit state of collapse in flexure (Bending).
II. Limit state of collapse in compression.
III. Limit state of collapse in shear.
IV. Limit state of collapse in Torsion.
V. Limit state of collapse in Bond.

(2) **Limit State of Serviceability: -** This limit state is introduced to prevent excessive deflection and cracking.

Limit state of serviceability based on the structure under working loads (Service load)

- **Basic assumptions of Limit State Method?**
  1. Plain sections normal to the axis remain plain after bending.
  2. The Maximum strain in concrete at the outermost compression fibre is taken as 0.0035 in bending.
  3. Design compressive strength in concrete=0.67fck/1.5 = 0.45fck
  4. The tensile strength of concrete is ignored.
  5. For design purpose, the partial safety factor for material (Ym)=1.5 for concrete & (Ym)=1.15 for Steel is considered.
  6. The Relationship between stress-strain distribution in concrete is assumed to be parabolic as shown in fig. 2.1

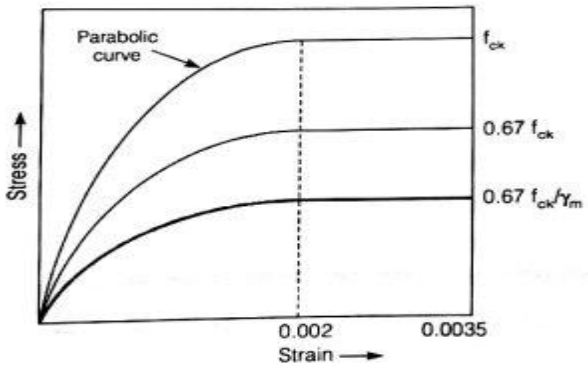


Fig. 21 : Stress-strain curve for concrete

- ✓ **Difference between WSM and LSM.**

Working stress Method	Limit state method
1. It is based on the behaviour of structure under working load.	1. The structure is designed on the basis of critical limit.
2. Factor of safety is considered for concrete FOS=1.75 for steel FOS=3 for concrete	2. Partial safety factor is considered For Concrete=1.5 For Steel=1.15
3. It is known as deterministic method.	3. It is known as in deterministic method.
4. Stress distribution is assumed to be linear.	4. Stress distribution is non-linear.
5. In working stress method required higher quantity of steel reinforcement.	5. Required less quantity of steel reinforcement.
6. Safety against ultimate load is not known	6. It satisfies all the limit state of collapse and serviceability
7. This method is also known as "Elastic Method of design" or "Modular ratio Method"	

UNIT-3
(Shear and Development Length)

- **Define nominal shear stress:-** shear force per unit cross-sectional area of a beam at any section is known as nominal shear stress.
  It is denoted by (τ_v).
  $\tau_v = V/bd$ N/mm^2 V=WL/2 τ_v= Nominal shear stress
  L= clear span V= Shear force in beam b= width of beam d= depth of beam

- **Define diagonal tension:-** the tension which is caused in the tensile zone of the beam, due to shear at or near the supports are called as diagonal tension. Due to this cracks at 45^0 occur in beams.

- **Shear strength of concrete without shear reinforcement:-**
  (As per IS 456-2000 clause number B-5.2)
  The design of shear strength t_c depends basically on the grade of concrete (f_{ck}) and the percentage of tensile steel (P_t).
  τ_c= permissible shear stress in concrete N/mm^2

- **Define maximum shear stress and shear reinforcement:-** Maximum shear stress ($\tau_{c\,max}$) the value of $\tau_{c\,max}$ is limited to the value in IS 456-2000.
  Clause No: 5.2.3 Pg 73/table 20
- **Conditions for shear reinforcement-**
  1. If $\tau_v < \tau_c$ no shear R/F provided. (Provided only nominal shear R/F).
  2. If $\tau_v > \tau_c$ then reinforcement provided.
     Check: τ_v & τ_c is not more than $\tau_{c\,max}$

- **Why shear reinforcement is provided: -** Shear reinforcement is provided in beam to avoid cracks due to shear.

- **Why minimum shear R/F (nominal shear R/F) is provided: -** If $\tau_v < \tau_c$ no shear R/F provided. But as per IS 456-2000, even in such cases minimum shear R/F (nominal shear R/F) in the form of vertical stirrups shall be provided due to the following reasons:-
  1. It confines the concrete and hence increases its strength.
  2. It holds the reinforcement in place while pouring concrete.
  3. It act as effective tie for the compression steel

- **What are the functions of the vertical stirrups:-**
  1. They hold the reinforcement both compression and tension.
  2. They keep the bars in place while placing concrete.
  3. They prevent brittle shear failure.
  4. If the bond between steel and concrete is lost, even then shear reinforcement can sudden failure.
  5. It helps in reducing the cracks due to tension.

- **What are different forms of provided shear reinforcement-:** Shear R/F Provided in the beam in any of the following forms

  1. In the form of vertical bars is known as stirrups.
  2. In the form of bent-up bars.
  3. In the form of combination of stirrups and inclined bars.

- **Define development length:-** The minimum length of bar which must be embedded in concrete beyond any section to develop its full strength. It is denoted by L_d.

  $L_d = \phi\sigma_{st}/4\tau_{bd}$ does not exceed $M_1/V+L_0$

  M_1= moment of resistance of section

  V= shear force at section due to design load

  Φ= diameter of bar

  L_0 = sum of anchorage

- **Define bond and bond stress: -** Bond refers to adhesion between concrete and steel which resists the slipping of steel bar from the concrete. On other hand the shear stresses developed along the contact surface between steel bar and the surrounding concrete which prevents the steel bars from slipping out of concrete is known as bond stress. It is denoted by τ_{bd}.

UNIT-4
(Concept of Limit State Method)

- **What is partial factor of safety for material (γ_m):-** In which partial safety factors for material divide by characteristics strength of material to get design value.
  It is denoted by **(γ_m)**

  Values of partial safety factor (γ_m) for strength of material

Material	limit state of collapse	Limit state of serviceability	
		Deflection	Cracking
Concrete	1.5	1.0	1.3
Steel	1.15	1.0	1.0

- **What is partial factor of safety for load.**
  It is denoted by **(γ_f).** (SEE CODE) Page No. 68. TABLE 18

- **Write design value for material and load?**
  Design values: - are obtained when partial safety factor are applied to characteristic strength of material and characteristic load.
  These are obtained as below:-

a) **Design value for material:-** it is denoted by (f_d) is given by **$f_d = f/\gamma_m$**

Where f_d= design strength of material
f = characteristic strength of material
γ_m= partial safety factor for material (1.5 for concrete and 1.15 for steel)

Note:- For Concrete=$0.67f_{ck}/1.5$ ($0.45f_{ck}$)
For Steel= $f_y/1.15$ ($0.87f_y$)

b) Design value for load:- it is denoted by (F_d) is given by **$F_d = F \times \gamma_f$**

Where F_d = design load or factor load
f = characteristic load

γ_f = partial safety factor for load (SEE CODE) Page No. 68. TABLE 18

- **Which is the limit states considered in design:-**

  The most important limit states which are considered in design are:-

  A). limit state of collapse-it is also known as ultimate limit state as its correspondence to maximum load carrying capacity. It includes

  1. Limit state of collapse in flexure
  2. Limit state of collapse in compression
  3. Limit state of collapse in shear
  4. Limit state of collapse in torsion
  5. Limit state of collapse in bond

  B). limit state of serviceability- it is introduced ton prevent excessive deflection and cracking. The two important limit state of serviceability are

  1. Limit state of deflection
  2. Limit state of cracking

- **Define characteristics strength of material: -** Characteristics strength means that value of strength of material below which not more than 5% of test result are accepted to fall.

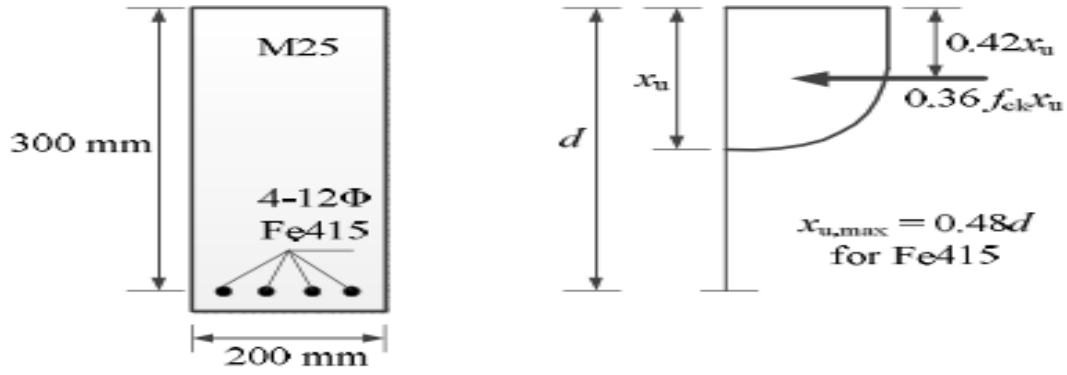
  Characteristics strength of material is designated by (f) **as per IS: 456-2000 Clause 36.1**

  A). Characteristics strength of concrete (f_{ck})-: **See IS: 456-2000 Clause 6.1.1**

  B). Characteristics strength of steel (f_y)

- **Characteristics strength of steel**:- It is denoted by (f_y) N/mm^2 and defined as that value of yield stress in case of mild steel or 0.2 to proof stress in case of HYSD bars which not more than 5% of the test specimen are expected to fall.

- **State stress block parameter:-** for the stress-strain curve, the design stress block parameters are as follows:



  Where area of stress block= $0.36f_{ck}.x_u$
  f_{ck}= characteristic compressive strength of concrete
  x_u = depth of neutral axis

UNIT-5

(Singly Reinforced Beam) https://youtu.be/s5gS9A-asUo

- **Define singly reinforcement beam:-** Singly reinforcement beam in which the main reinforcement is provided in tension zone and other bars in compression zone.
- **Define neutral axis:-**The axis at which the stresses are zero in the section and it divides the cross section into a tension and compression zone.
- **Depth of Neutral Axis (X_u)**

Total tension (T) =Total Compression (C)

$$0.87\, f_y\, A_{st} = 0.36\, f_{ck}.b.x_u$$

$$X_u = 0.87\, f_y\, A_{st} / 0.36\, f_{ck}.b$$

- **Maximum depth of Neutral Axis ($X_{u,\,max}$)**

Grade of Steel	f_y (N/mm^2)	$X_{u,\,max.}$
Fe 250	250	0.53d
Fe 415	415	0.48d
Fe 500	500	0.46d

- **Limiting (Maximum) Percentage of steel ($P_{t,lim}$):-**

$$(P_{t,lim})\ \% = \frac{0.36 f_{ck}.x_{umax}}{0.87 fy.\ d} \times 100$$

- **Limiting Moment of Resistance($M_{u(lim)}$):-**

$$(M_{u(lim)}) = 0.36 f_{ck}.b.x_{u(max)}\,(d-0.42.x_{umax})$$

Value of Limiting Moment of Resistance ($M_{u(lim)}$)

Grade of Steel	Value of ($M_{u(lim)}$)
Fe=250 (f_y=250 N/mm^2)	0.148 $f_{ck}.b.d^2$
Fe=415 (f_y=415 N/mm^2)	0.138 $f_{ck}.b.d^2$
Fe=500 (f_y=500 N/mm^2)	0.133 $f_{ck}.b.d^2$

- **Explain types of beams:-**Types of beam sections depending upon the tensile steel. Hence, they can be classified into three categories: - **https://youtu.be/mOip8glVbmU**

A. Balance section
B. Under R/F section
C. Over R/F section

A. BALANCE SECTION:-

1. It may be defined as a section in which the maximum stress in concrete and tensile stress in steel reach their permissible value simultaneously.
2. $Xu = Xu_{max}$
3. pt=pt(limiting max.)
4. $Mu_{(limi)}=0.3f_{ck}.b.Xu_{max}(d-0.42Xu_{max})$

B. UNDER R/F SECTION

1. In which the percentage or area of steel is provided less than required for a balance section.
2. In this section steel is fully stressed and concrete is under stressed.
3. $Xu < Xu_{max}$
4. pt<pt (limi)
5. $Mu = 0.87f_yA_{st.}\ (d-0.42Xu)$

C. OVER R/F SECTION

1. In which the % age or area of steel provided is more than that required for balance section.
2. In this section concrete is fully stressed and steel is under stressed.
3. $xu>xu_{(max)}$
4. $pt> pt_{(limi)}$
5. $Mu=Mu_{(limi)}$, $0.36f_{ck}.b.xu_{(max)}X(d-0.42xu_{max})$

- **Reinforcement in beams:-**

i) Maximum reinforcement:- maximum tensile reinforcement shall not exceed 0.04 bD,

Where b= width of beam

D= overall depth

ii) Minimum reinforcement:-

$A_{st}= 0.85bd/f_y$

f_y = characteristics strength of reinforcement (N/mm^2)

- **Side face reinforcement:-** when depth of the beam exceeds 750mm, then it is necessary to provide shear force reinforcement @ 0.1% of web area.