Design of Concrete Structure-I

Plain cement concrete:- plain cement concrete is a hardened mass obtained from a mixture of cement, sand, gravel and water in definite propotions. These engredients are mixed together to form a plastic mass which is poured into desired shape moulds called as forms. This plastic mass hardens on setting and we get plain cement con.

The hardening of this mixture is caused by a chemical reaction between cement and water.

Reinforced cement concrete:- plain cement concrete has very low tensile strength. To improve tensile strength of concrete, some sort of reinforcement is needed which can take up the tensile stresses developed in the structure. The most common type of reinforement is in the form of steel bars which are quite strong in tension.

The Reinforcing steel is placed in the forms and fresh concrete is poured around it. This solidified composite mass is called a Reinforced Cement Concrete and is abbreviated as R.C.C. Thus "Reinforced cement concrete is a composite material which is made up of concrete and steel reinforcement.

The composite action of steel and concrete in a reinforced concrete section is dependent on the following imp. factor
(i) The bond bwt steel and concrete
(ii) prevention of corrosion of steel bars embedded in the concrete.
(iii) practically equal thermal expansion of both concrete and steel.

Advantages & disadvantages of R.C.C:- There are the following types of the advantages-

1. R.C.C has a very good strength in tension as well as compression

(2) Durability - R.C.C structures are durable if designed and (2) laid properly. Then They Can last up to 100 years.

(3) The steel reinforcement impart durability to the R.C.C structure.

(4) R.C.C is cheaper as compared to steel and prestressed concrete.

(5) R.C.C. is almost impermeable to moisture

(6) properly designed R.C.C structures are extremely resistant to earth quakes.

There are following disadvantages -

(1) R.C.C. structures are heavier than structures of other Materials like steel, wood and glass etc.

(2) R.C.C. needs a lot of formwork, centering and shuttering to be fixed. Thus require lot of site space and skilled labour.

Grades of Concrete :-

M10
↓ ↳ characteristic strength
Mix (fck) N/mm²

ordinary concrete – M10 to M20
Standard concrete – M25 to M55 (For post tensioning work)
High strength concrete - M60 to M80 (For pretensioned Prestressed con.)

Concrete making Materials :-

(1) Cement - Cement is the only chemically active ingredient of concrete which shows binding properties after reacting with water. It consists of silicates and aluminates of calcium which form a hardened mass after mixing with water. This type of cement is also known as hydraulic cement.

(a) ordinary portland cement -

ordinary portland cement (OPC) is commonly used in construction. The BIS has classified OPC in three grades. This is based on compressive strength of cement sand mortar cubes.

(i) 33 grades
(ii) 43 grades
(iii) 53 grades.

here the grade no. indicates the minimum compressive strength of cement - sand mortar cubes in N/mm^2 at 28 days.

(2) Rapid hardening portland cement
(3) Low heat portland cement
(4) Portland slag cement
(5) sulphate Resisting cement
(6) portland pozzolona cement
(7) white cement

(2) Aggregate:- The bulk of concrete is made up of aggre. Aggregate are inert material or chemically inactive material like crushed rock, sand broken bricks, gravel etc. Aggregate, less than 4.75 mm size are known as fine aggregate and which are more than 4.75 mm size are known as coarse aggregate.

Coarse aggregate gives strength to concrete and fine aggregates acts as a filler but the coarse agg. and provides workability to the concrete mix.

(3) water:- water is required for chemical reaction of cement and also for providing workability to concrete. The water is used for mixing and curing of concrete should be clean and free from injurious amounts of acids, alkalies, salts or other chemical substances, which can harm concrete or steel. and the water cement ratio is 0.45 to 0.55 and it is the factor for the making of the concrete.

Properties of concrete:- The properties of concrete depend upon the properties and proportions of its ingradients. 4

① **Compressive strength:-** The characteristic compressive strength of concrete is deffined as the compressive strength of 15 cm cubes at 28 days in N/mm², below which not more than 5% of the test results are expected to fall. It is represented as f_{ck} and it is determined by cube test

$$f_M = f_{ck} + 1.64\sigma$$

σ = standard deviation

$\sigma = \sqrt{V}$ V → Variate

f_M = Mean strength has 50% probability that strength of concrete is not exceeded by f_M.

② **Workability:-** The workability of concrete is defined as the ease by which it can be mixed, placed, compacted and placed and finished. A workable conc. should not bleed or segregate.

It depend on the following factors:

(i) water cement ratio
(ii) Size of aggregate
(iii) shape of aggregate
(iv) Ratio of fine to coarse aggregate

workability can be measured by following tests:

(i) slump test
(ii) Vee-Bee Consistometer test
(iii) compaction factor test.

③ **Durability:-** The concrete should be durable to the environment it is exposed to, during its life. The main characteristic of durability is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate etc

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④ **Tensile strength:-** The tensile strength of concrete can be correlated with the characteristic compressive strength of concrete. IS 456 gives the following correlation

flexure strength $\left\{ f_{tc} = 0.7\sqrt{f_{ck}} \right\}$ N/mm²

⑤ **Modulus of Elasticity:-** The short term static modulus of elasticity can be expressed in terms of the chara. compressive strength and may be:

$$\left\{ E_c = 5000\sqrt{f_{ck}} \right\}$$

long term modulus of elasticity (E_{ce} or E_e) -:

$$E_{ce} \text{ or } E_e = \frac{E_c}{1+\theta} \quad (\theta = \text{creep coefficient})$$

⑥ **Poisson's Ratio:-** Poisson's ratio is defined as the ratio of lateral strain to the longitudional strain. it varies from 0.1 to 0.3 for concrete.

⑦ **Creep:-** Creep is caused under sustained loading. It is seen that when concrete is subjected to sustained loading, strain keeps ↑ with time, even without any ↑ in the load

⑧ **Shrinkage:-** Concrete shows shrinkage due to loss of moisture by evaporation. Shrinkage also causes strain in concrete.

⑨ **Freezing & Thawing:-** If freezing & thawing condition exists, then durability of concrete should be enhanced by ading suitable air entraining admixtures.

⑩ **Sulphate attack:-** Concrete exposed to sulphate attack such as in coastal environment, should be made from sulphate resisting cement.

in IS 456 (Table 1.4) gives recommendations regarding the type of cement

Concrete mix proportioning:- The determination of the proportions of cement, aggregates and water to attain the desired strength and properties such as workability durability etc. is called the concrete mix proportioning.

design of concrete mix is classified into following two types by IS:456:2000 (clause 9)

I. Nominal mix concrete
II. Design mix concrete

(I) Nominal mix concrete:- A concrete mix in which the proportions of cement, aggregate and water are adopted is called as nominal mix. It is not necessary that such a mix will give the desired strength and properties. For ex. M15 is 1:2:4. Nominal mix is not used for grades higher than M20. it is used for ordinary concrete only.

(II) Design mix concrete:- The concrete obtained by properly determining the proportions of the ingredients of concrete to get the concrete of desired strength & properties is called as Design mix concrete.

$$f_{cm} = f_{ck} + 1.65\sigma$$

σ → standard deviation

f_{ck} → characteristic strength

f_{cm} → Mean target strength

mixes of grades

M10 - 1:3:6
M15 - 1:2:4
M20 - 1:1.5:3
M25 - 1:1:2 → aggregate

(1 → cement, 1 → sand)

Design philosophies :- Design of any R.C.C. member comprises of the following-

① To decide the size of the member and the amount of reinforcement required.

② To check whether the adopted section will perform safely and satisfactory during the life time of the structure.

Various methods used for the design of R.C.C member-

I. working stress method

II. Load factor or ultimate load method

III limit state method

① **working stress method :-** This method of design was oldest method. It is based on the elastic theory and assumes that both steel and concrete are elastic and obey hooke's law. It means that the stress is directly proportional to the strain up to the point of collapse.

In this method, the ultimate strength of concrete and yield strength of concrete or 0.2% proof stress of steel are divided by factors of safety to obtain permissible stress.

II. **Load factor method or ultimate load method :-** In this method, ultimate or collapse load is used as design load. The ultimate load are obtained by increasing the working / service loads suitably by some factors. These factors which are multiplied by the working load to obtain ultimate loads are called as load factors.

$$\text{Load factor} = \frac{\text{Collapse load}}{\text{Working load}}$$

This method used the real stress - strain curve of concrete

③ **Limit state method** :- This the most rational method which takes into account the ultimate strength of structure and also the serviceability requirements. It is a Judicious combination of working stress & ultimate load method of design." The acceptable limits of safety & serviceability requirements before failure occurs is called a limit state.

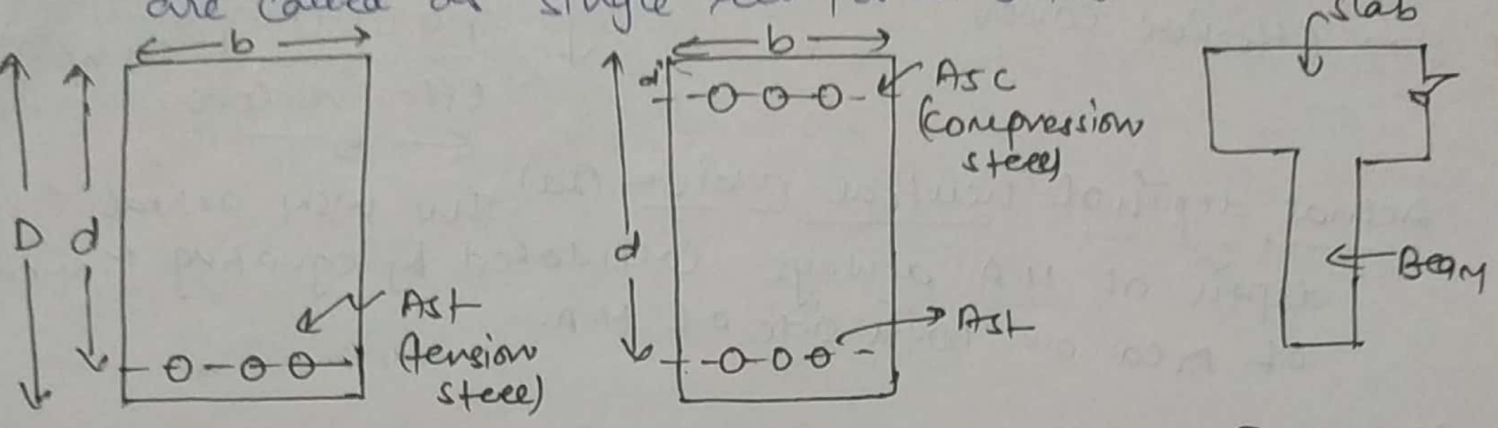
Two imp. limit states to be considered in design are:

I. Limit state of collapse

II. Limit state of serviceability

Types of R.C.C. Beams:- R.C.C. beams are of following three types:-

① **Single reinforced Beams:-** The beams in which steel reinforcement is placed in the tensile zone only are called as single reinforced beams.



I. singly reinforced beam

II. Doubly reinforced beam

III. T-beam

(II) **Doubly reinforced beam:-** The beams in which reinforcement is placed in the tensile as well as compression zone are called as doubly reinforced beam.

(III) **Flanged beams (T beams & L beams):-** In most reinforced concrete structures, the slab and beams are cast monolithic. Thus the beam forms a part of the floor system.

Modular ratio:- It is defined as the ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete.

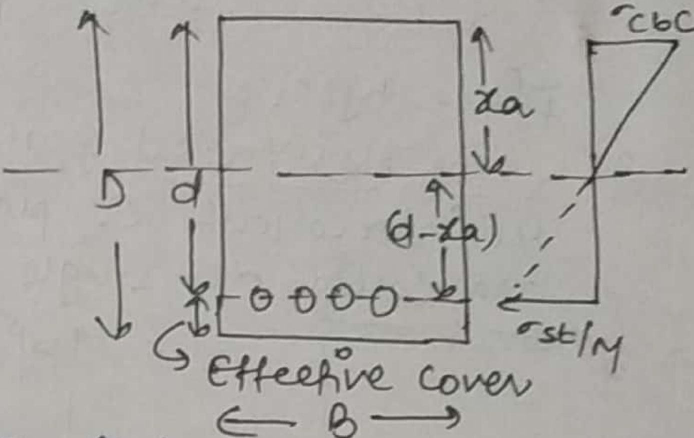
$$m = \frac{E_s}{E_c}$$

$$m = \frac{280}{3\sigma_{cbc}}$$

Grade of concrete	M15	M20	M25	M30	M35	M40
σ_{cbc}	5	7	8.5	10	11.5	13
$m = 280/3\sigma_{cbc}$	18.67 ≈19	13.33 ≈13	10.98 ≈11	9.33 ≈ 9	8.17 ≈ 8	7.17 ≈7

Single reinforced section:

- D → over all depth
- d → effective depth
- B → effective width
- D−d → Effective cover



Actual depth of neutral axis − (xa) In WSM actual depth of N.A. always calculated by equating Moment of area on both side of N.A.

Moment of area − In compression $= B \cdot x_a \cdot \frac{x_a}{2}$

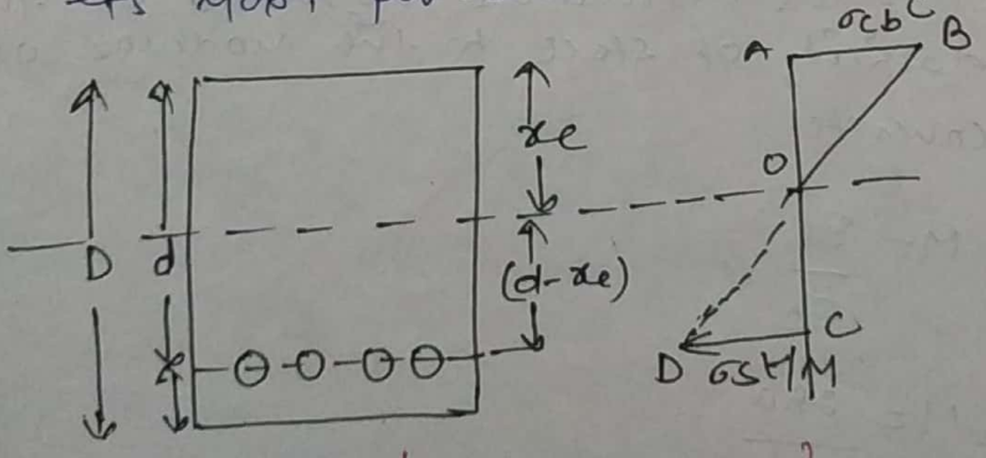
or From $C = T$ $= \frac{B x_a^2}{2}$

In tension $= m A_{st} \cdot (d - x_a)$

then $\frac{B x_a^2}{2} = m A_{st} \cdot (d - x_a)$

then $A_{st} \uparrow \Rightarrow x_a \uparrow$

Critical depth of neutral axis : critical depth of neutral axis is such depth of the actual neutral axis for which stress in concrete & steel are attained its maxm permissible value at the same time.



From similar Δ

$$\frac{\sigma_{cbc}}{x_c} = \frac{\sigma_{st}/M}{(d - x_e)}$$

$$\frac{d}{x_e} = \frac{\sigma_{st} + M\sigma_{cbc}}{M\sigma_{cbc}}$$

$$x_e = \left(\frac{M\sigma_{cbc}}{\sigma_{st} + M\sigma_{cbc}}\right) d$$

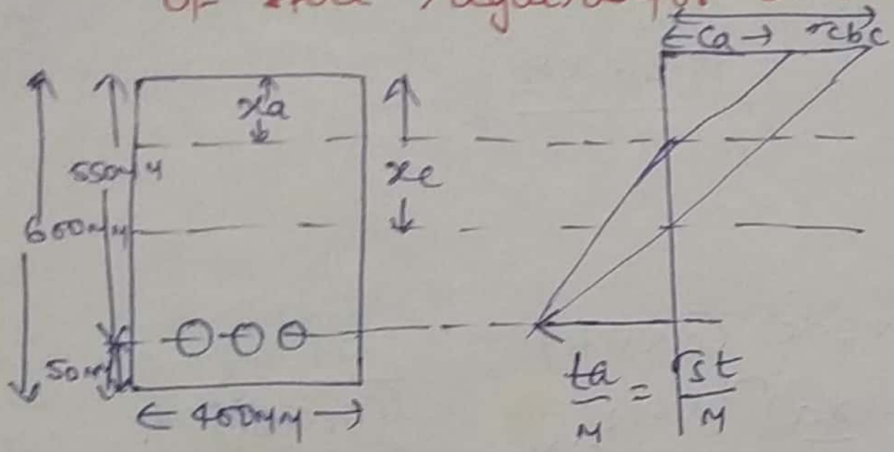
$\sigma_{cbc} = c$

$\sigma_{st} = t$

$\boxed{x_e = kd}$ $\left\{ k = \frac{M\sigma_{cbc}}{\sigma_{st} + M\sigma_{cbc}} \right\}$

$\left\{ k = \frac{MC}{t + MC} \right\}$

Que: Find out MOR of an RCC Beam section of size 400×600MM M20 concrete and Fe415 steel used. used WSM and effective cover 50MM, area of steel (i) 3 NOS 16MM dia(ϕ)
(ii) 4 NOS 25MM ϕ(dia)
(iii) Calculate MOR of the balance section and find out area of steel required for balance section.



d = 550MM
B = 400MM
D = 600MM
M20, Fe415

(i) 3 NOS 16MM ϕ (dia)
↳ 3 bars of 16MM ϕ (dia.)

area of steel $A_{st} = 3 \times \frac{\pi}{4} \times (16)^2 = 603.185 MM^2$

Step:1. to find actual depth (x_a)

$$\frac{B x_a^2}{2} = m A_{st} (d - x_a)$$

$$400 \frac{x_a^2}{2} = 13 \times 603.185 (550 - x_a)$$

$$\Rightarrow 200 x_a^2 = 13 \times 603.185 (550 - x_a)$$

$$x_a = 128.5456 MM$$

Step:2 To find critical depth (x_c) $\quad x_c = kd$

$t = 230$

$$k = \frac{mc}{t + mc} = \frac{13 \times 7}{230 + 13 \times 7}$$

$k = 0.2834$ $\quad x_c = kd = 0.2834 \times 550$
$= 155.9190$
$\simeq 156 MM$

$x_a < x_c$

So this section is under reinforced section.

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MOR from tension side (steel)

$MOR = t_a A_{st} (d - x_a/3)$ $t_a = 230$

Fe415 P/81 T/22

$MOR = 230 \times 603.185 \left(550 - \frac{128.54}{3}\right)$ KN.MM

(in under reinforced section steel at the yield value)

$= \frac{70358675.17}{10^6} = 70.36$ KN.M.

MOR from compression side (concrete) T/21 (c_a, σ_{cbc})

$MOR = \frac{c_a}{2} B x_a \left(d - \frac{x_a}{3}\right)$ → lever arm

from similar triangle $\frac{c_a}{x_a} = \frac{\sigma_{st}/m}{(d - x_a)}$

$\sigma_{st} = 230$ for Fe415

$c_a = \frac{x_a}{(d - x_a)} \frac{\sigma_{st}}{m} = \frac{128.54}{(550 - 128.54)} \frac{230}{13}$

$c_a = 5.395$ N/MM^2

$MOR = \frac{5.395}{2} \times 400 \times 128.54 \left(550 - \frac{128.54}{3}\right)$ KN.MM

$= 70339459.13$ KN.MM

$= 70.3339$ KN.M. Ans

(iii) MOR for balance section – ($x_a = x_e$)

$MOR = Q B d^2$ $Q = \frac{1}{2} \sigma_{cbc} J K$

$J = (1 - K/3)$

$K = \frac{MC}{t + MC} = 0.283$

$J = 0.906$

$\sigma_{cbc} = \frac{20}{3} \simeq 7$

$Q = 0.8973$

$MOR = .897 \times 400 \times 550^2$

$MOR = 108584553$ KN.MM

$MOR = 108.58$ KN.M.

Find out area of steel of balance section

$MOR = \sigma_{st} A_{st} (d - x_a/3)$

$x_a = x_e$ For (Balancing)

$MOR = \sigma_{st} A_{st}\, d\,(1 - K/3)$

$MOR = \sigma_{st} A_{st}\, J d$

$108.58 \times 10^6\ N.mm = 230 \times A_{st} \times 0.906 \times 550$

$A_{st} = 947.43\ mm^2$

Ans

Doubly Reinforced section (Beam) :-

$M.R = QBd^2$

Que:- A Rectangular Beam over all x-section 230 x 600 MM and effective cover 50 MM is reinforced 5 Nos - 25 ϕ (i.e.) bars on tension side, 3 No-s 16 ϕ bars on compression side it is carrying an impose load of 50 KN/M over in an effective span of 7 M.
permissible stress in steel $\sigma_{st} = 230 N/MM^2$ &
" " " concrete $\sigma_{cbc} = 7 N/MM^2$
M = 15 check the adequacy of the section. ?

self weight = density x area ($25 KN/M^2$)

$= 25 \times .23 \times 0.6 = 3.45 KN/M$

Total load = self load + imposed load

$= 3.45 + 50 = 53.45 KN/M$

span = 7 M $\quad BM = \frac{we^2}{8} = \frac{53.45 \times 7^2}{8} = 327.38 KN.M$

$x_c = kd \quad k = \frac{MC}{t + MC} = \frac{15 \times 7}{230 + 15 \times 7}$

$k = 0.3134$

D = 600
$d_c = 50$
d = 550

$x_c = 172.38 MM$

For x_a equate the MOA from tension & compression side

$$\frac{Bx_a^2}{2} + (1.5M - 1) A_{sc}(x_a - d_c) = m A_{st}(d - x_a)$$

$$230 \times \frac{x_a^2}{2} + (1.5 \times 15 - 1) A_{sc}(x_a - 50) = 15 \times A_{st}(550 - x_a)$$

$A_{sc} = 3 \times \frac{\pi}{4} \times 16^2 \quad A_{st} = 5 \times \frac{\pi}{4}(25)^2$

$x_a = 261.63 MM$

so $x_a > x_c$ over reinforced section

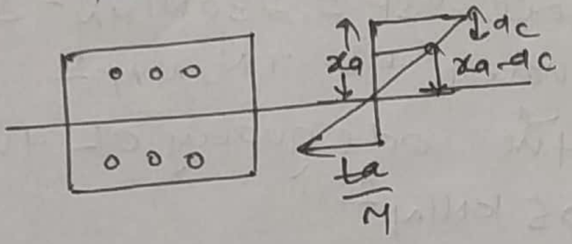
$C_a = \sigma_{cbc} = 7$

$t_a < \sigma_{st}$

use compression side (concrete failure)

$$MOR = \frac{C_a}{2} B x_a \left(d - \frac{x_a}{3}\right) + (1.5m - 1) A_{sc} c' (d - d_c)$$

For c' use similar triangle



$$\frac{c'}{x_a - d_c} = \frac{\sigma_{cbc}}{x_a}$$

$c' = 5.666$

$MOR = 134.184 \times 10^6$ N.mm

$= 134.184 \times \frac{10^6}{10^6}$ N.m

so $MOR = 134.184$ N.m

BM > MR so section is not safe. Ans.

unit - I[st] - Part II

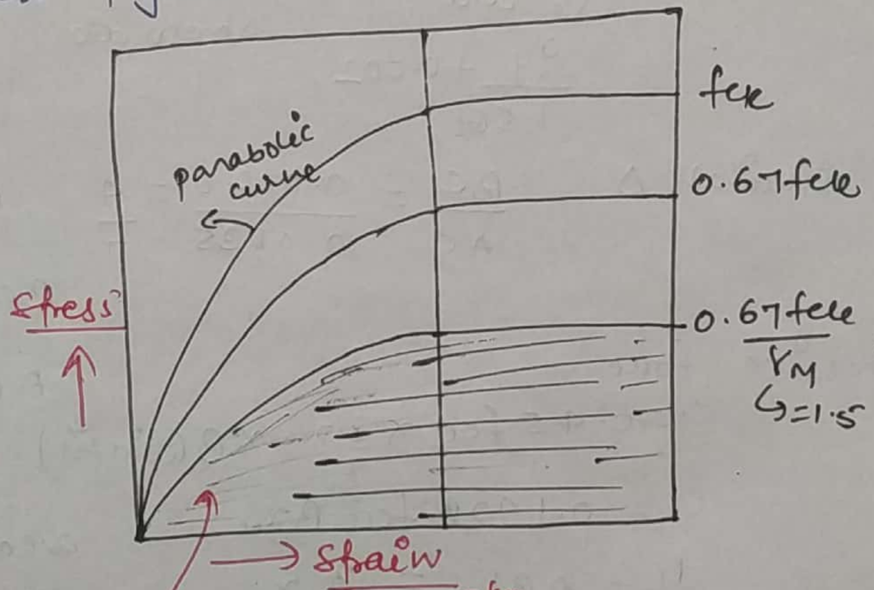
Limit state Method
(ultimate load theory)

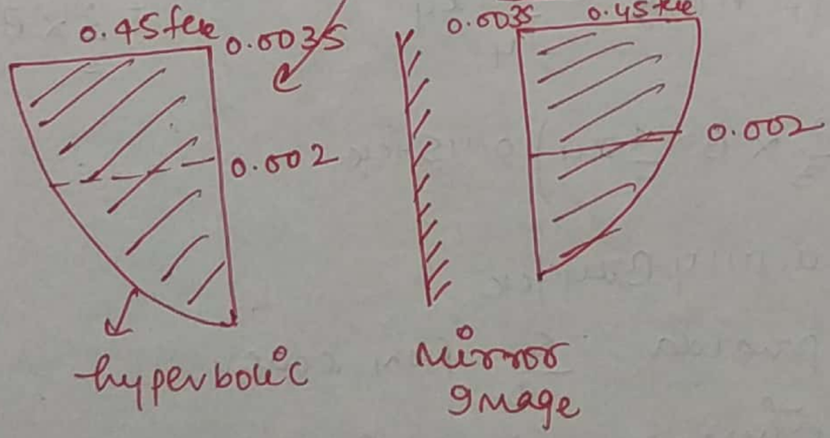
Assumptions in limit state design:-

(I) plane section before bending remain plane after bending. It means strain diagram is linear

(II) Max^m strain in outer most compression fiber in bending equal to 0.0035.

(III) An acceptable stress strain curve for a concrete is given in figure.





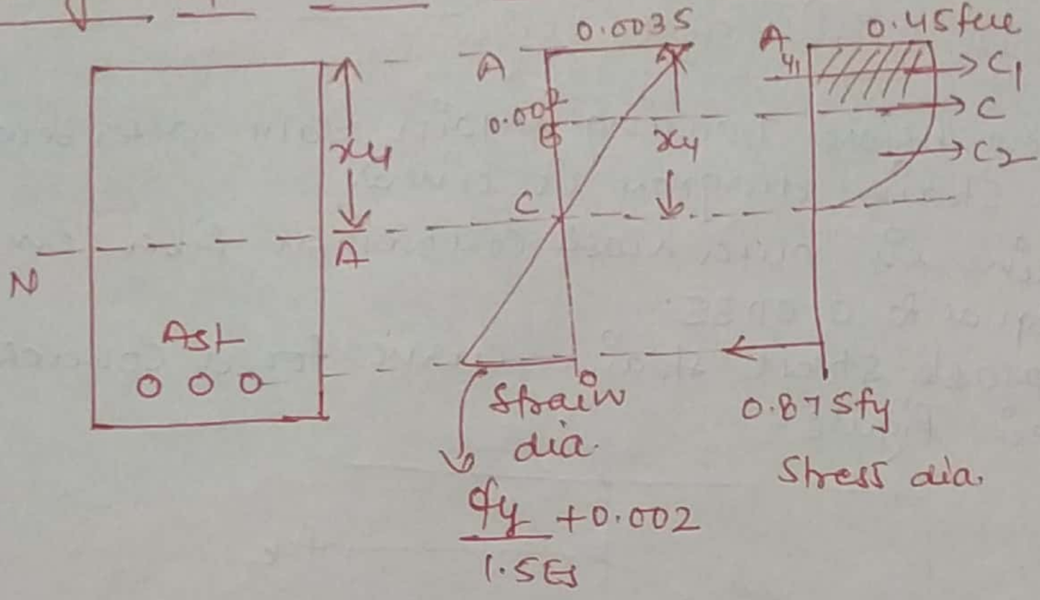
(IV). Tensile stress of concrete is ignore.

(V) Max^m strain in tension reinforcement in the section at failure shall not be less than $\left[\frac{f_y}{1.15} \times E_s + 0.002\right]$

$$= \frac{0.87 f_y}{E_s} + 0.002$$

VI. Permissible stress in concrete is considered .67 times of characteristic & partial F.O.S also considered.

Analysis of stress strain curve:-



$AC = x_u$

From similar Δ $\quad \frac{BC}{AC} = \frac{0.0020}{0.0035} = \frac{4}{7} \qquad BC = \frac{4}{7} AC$

$BC = \frac{4}{7} x_u$

Compressive force

$AB = x_u - \frac{4}{7} x_u = \frac{3}{7} x_u$

$C_1 = 0.45\, f_{ck} \times \frac{3}{7} x_u \times B$ (width)

$C_1 = 0.1928\, f_{ck} B x_u$

$y_1 = AB/2 = \frac{3}{14} x_u$

area of Parabola $= \frac{2}{3} \times$ Base $\times$ height

$C_2 = \left(\frac{2}{3} \times B \times \frac{4}{7} x_u\right) 0.45\, f_{ck}$

$C_2 = 0.1714\, B x_u f_{ck}$

Centroid of parabola $= \frac{5}{8}$ from corner

where C_2 act is 3/8 from top.

$y_2 = 8 \times \frac{3}{7 \times 8} x_u + \frac{3}{8} \cdot \frac{4}{7} (x_u) \qquad y_2 = \frac{9}{14} x_u$

Total compressive force $C = C_1 + C_2$

$= 0.1928\, f_{ck} B x_u + 0.1714\, B x_u f_{ck}$

$\{ C = 0.3642\, f_{ck} B x_u \}$

Lever arm → distance b/w compressive force & tensile force

$$\bar{y} = \frac{C_1 y_1 + C_2 y_2}{C_1 + C_2} = \frac{.1928 f_{ck} B x_u * \frac{3}{14} x_u + .1714 f_{ck} B x_u \times \frac{9}{14} x_u}{0.3642 f_{ck} B x_u}$$

$\bar{y} = .416 x_u$

$\bar{y} = 0.42 x_u$

Tensile force $\{T = 0.87 f_y A_{st}\}$

L.A. (Lever arm) $= (d - \bar{y})$

$\{L.A. = d - 0.42 x_u\}$

MOR :-

MR = Compressive force × L.A.

$\{MR = 0.36 f_{ck} B x_u (d - 0.42 x_u)\}$

MR = Tensile force × L.A.

$\{MR = 0.87 f_y A_{st} (d - 0.42 x_u)\}$ P|96|c

Actual depth of N.A. (x_u) :-

$C = T$

$0.36 f_{ck} B x_u = 0.87 f_y A_{st}$

$\left\{ x_u = \frac{0.87}{0.36} \frac{f_y}{f_{ck}} \cdot \frac{A_{st}}{B} \right\}$ P|96|c

Limiting depth of N.A. ($x_{u\,lim}$) :-

$x_{u\,lim} = \left(\frac{700}{(0.87 f_y + 1100)} \right) d$

$K = \frac{700}{0.87 f_y + 1100}$

$x_{u\,lim} = Kd$

For Fe 250 $K = 0.53$

Fe 415 $K = 0.479 \simeq 0.48$

Que: Calculate the MOR of RCC Rectangular section use M20 & Fe415

(I) 4 Nos – 16 ϕ (MM dia)

(II) 6 Nos – 25 ϕ (MM dia)

(III) Calculate Ast Just required for limiting section. Rectangular Beam of 600 × 400 MM and effective cover of 50 MM. D = 600 MM, B = 400 MM.

(I) For x_u $\quad C = T$ $\quad f_y = 415$, $f_{ck} = 20$

$$x_u = \frac{0.87}{0.36} f_y \frac{A_{st}}{f_{ck} \cdot B}$$

4 Nos – 16 ϕ

$A_{st} = 2412.743 MM^2$ $\quad x_u = 100.82 MM$

For $x_{u lim} = Kd$ $\quad K = 0.48$ for Fe415

$x_{u lim} = 264 MM$

$x_u < x_{u lim}$ under reinforced section

For compression

$MR = 0.36 \times 20 \times 400 \times 100.82 (550 - 0.42 \times 100.82)$

$MR = 147.105 \times 10^6$ N/MM Ans.

For Tension

$MR = 0.87 f_y A_{st} (d - 0.42 x_u)$

$= 0.87 \times 415 \times 804.25 (550 - 0.42 \times 100.82)$

$MR = 147.410 \times 10^6$ N.MM.

Ans.

(II) 6 Nos – 25 ϕ.

$$A_{st} = 6 \times \frac{\pi}{4} \times 25^2$$

$= 2945.24 MM$

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$$x_u = \frac{0.87}{0.36} \frac{f_y A_{st}}{f_{ck} B}$$

$x_u = 369.228\,mm$

$x_{u\,lim} = kd$

$= 0.48 \times 550$

$x_{u\,lim} = 264\,mm$

$x_u > x_{u\,lim}$

So over reinforced section

$MR = 0.36 \times f_{ck} \times B x_{u\,lim} (d - 0.42\, x_{u\,lim})$

$= 0.36 \times 20 \times 400 \times 264 (550 - 0.42 \times 264)$

$M_{u\,lim} = MR = 333.87 \times 10^6\ N.mm$ Ans.

(ii) A_{st} for the limiting section

$$A_{st} = \frac{B.M.}{0.87 f_y d J}$$

$J = (1 - 0.42k)$

$J = (1 - 0.42 \times 0.48)$

$J = 0.7984$

$M = 333.87 \times 10^6$

$A_{st} = 2405.84\,mm^2$

or IInd method

$C = T$

$0.36 f_{ck} B x_{u\,lim} = 0.87 f_y A_{st}$

$A_{st} = 2405.84\,mm^2$ Ans

Doubly reinforced section:-

Que:- Size of RC beam is restricted to 250mm x 500mm of carries a super impose load of 25 kN/m over a span of 6m determine the reinforcement for a beam of by LSM use M20 & Fe415 Effective cover of steel is 40mm

Soln: NOTE f_{yd} = design strength = $0.87 f_y$

self weight = $0.25 \times 0.5 \times 25$

= 3.125 kN/m

$W = 25 + 3.125$

$W = 28.125$ kN/m

using LSM $W_u = 1.5 \times 28.128 = 42.1875$

$BM_u = \frac{W_u l^2}{8} = \frac{42.2 \times 6^2}{8} = 189.9$ kN.m.

MOR of Balance section

$MR_1 = QBd^2$

$Q = .138 f_{ck}$

$Q = 2.76 \times 250 \times l^2$

$MR_1 = 146$ kNm

$BM_u > MR_1$

hence we provide doubly reinforced section

Fe415

$x_{ulim} = 0.48d$

$d = 460$

$x_{ulim} = 220.8$

$MR_1 = 0.87 f_y A_{st1} (d - 0.42 \times 220.8)$

$A_{st1} = 1101.05 mm^2$

$A_{st2} = MR_2 / 0.87 f_y (d - d_c)$

$$M_{R_2} = B.M - M_{R_1} = 43.9$$

$$A_{st_2} = \frac{43.9 \times 10^6}{0.87 \times 415 \, (460-40)}$$

$$A_{st_2} = 289.4975 \ mm^2$$

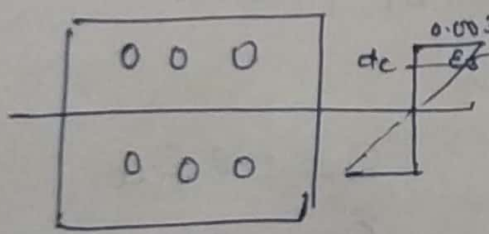
$$A_{st} = A_{st_1} + A_{st_2}$$

$$A_{st} = 1390.54 \ mm^2$$

$$A_{sc} = \frac{M_{R_2}}{(f_{sc} - 0.42 f_{ck})(d - d_c)}$$

en strain diagram

$$x_u = x_{ulim}$$



from similar triangle

$$\frac{0.0035}{x_{ulim}} = \frac{E_{sc}}{(x_{ulim} - d_c)}$$

$$E_{sc} = 0.00286659$$

strain		stress
0.00276	→	352
0.00286	→	f_{sc} 361
0.00380	—	

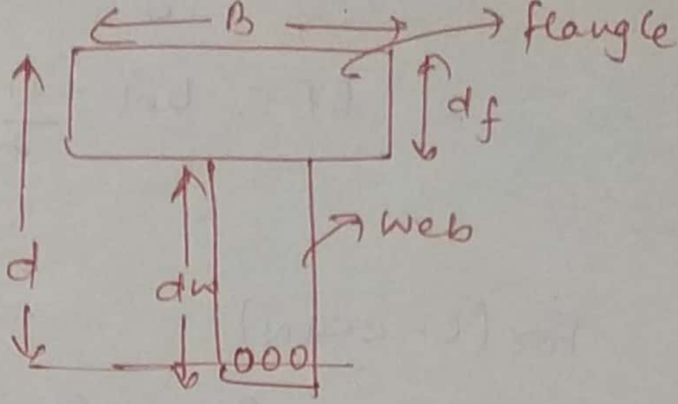
$$f_{sc} = 352 + \frac{(361-352) \times (0.00286 - 0.00276)}{(0.00380 - 0.00276)}$$

$$f_{sc} = 352.86 \ N/mm^2$$

$$M_{R_2} = (f_{sc} - 0.45 f_{ck}) A_{sc} (d - d_c)$$

$$A_{sc} = 303.97 \ mm^2$$

T- Beam / L-Beam



Effective width of flange:-

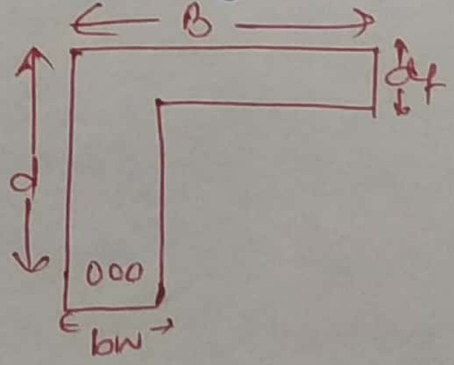
(I) For Isolated Beam - T Beam

$$B_f = \frac{l_o}{(l_o/B + 4)} + b_w$$

(II) For Isolated Beam - L Beam

$$B_f = \frac{0.5 l_o}{(l_o/B + 4)} + b_w$$

✡ if $B_f > B$ then B_f is taken B



Pg/37 - l_o is the effective span

For Isolated Beam → l_o = Effective span

NOTE-: continuous Beam l_o may be assumed 0.7 of the Effective span.

Pg/37 For Continuous Beam:- (For T-Beam)

$$B_f = \frac{l_0}{6} + b_w + 6d_f$$

$$B_f = b_w + \frac{l_1}{2} + \frac{l_2}{2}$$

in Both min. = B_f For T-Beam

For (L-Beam)

$$B_f = \frac{l_0}{12} + b_w + 3d_f$$

or

$$B_f = b_w + \frac{l_1}{2}$$

→ min^M of both || B_f (For L-Beam)

l_1 = clear distance