UNIT-I

UNIT - I

INTRODUCTION TO RCC

Concrete: is a product obtained artificially by hardening the mixture of cement, sand (FA) and gravel (CA) and water in a predetermined proportions. When these ingredients are mixed they form a plastic mass which can be poured in suitable moulds and set on standing into hard solid mass.

In concrete the voids between coarse aggregate is filled up by fine aggregate and the voids between fine aggregate is filled up by cement. Cement acts as a binder on hardening.

The chemical reaction of cement and water in the mix is relatively slow and requires time and favourable temperature for its completion. This time is known as setting time. It is divided into three phases. The phase known as initial setting time requires 30 min to 60 min for completion. During this phase concrete mix decreases its plasticity and develop resistance to flow. The second phase known as final setting time may vary b/w ... to 6 hours after the mix operation. During this

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this phase, concrete appears to be relatively soft solid without surface hardness. The third phase consists of progressive hardening and increase in strength.

Depending on the quality and proportions of the ingredients used in the mix, the properties of concrete vary. Concrete has enough strength in compression but has little strength in tension. Hence the use of plain concrete (P.C.C) is limited to applications where great compressive and weight are the principal requirement. However to use concrete for common structures such beams, slabs, retaining structures etc., steel ~~bar~~ reinforcement may be placed at tensile zones of the structure. This concrete is known as Reinforced cement Concrete (R.C.C)

Ingredients of concrete:

CEMENT:

It is the active ingredient of concrete, finely grounded material with cohesive and adhesive properties.

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Chemical Composition of Cement

i) Tricalcium silicate C_3S 30 to 50%
ii) Di calcium silicate C_2S 20 to 45%
iii) Tricalcium aluminate C_3A 8 to 12%
iv) Tetra calcium alumino Ferrite C_4AF 6 to 10%

Physical properties of Cement

① Fineness ② setting time ③ soundness
④ Compressive strength ⑤ Heat of hydration.

① **Fineness**: is the measure of the size of particles of cement. It is an important factor in determining the rate of gain of strength.

For fineness test Sieve test and Blaine's test are done on cement. As per BIS, when cement is sieved on 90 micron IS sieve the residue of cement should not exceed 10 percent.

③ **Soundness of Cement**:

The undesirable expansion of some of the constituents of cement after setting is referred as unsoundness of cement. The large change in volume results in disintegration and cracking. unsoundness

is due to the presence of free lime and magnesia in the Cement. This can be Reduced by i) Limiting MgO Content to less than 0.5%
ii) fine grinding
iii) Thorough mixing

Tests for unsoundness is done by

(a) Le-Chatlier mould : As per BIs the Expansion of the Pointer shall not be greater than 10mm.

(b) Auto Clave test : - permissible limits 0.8%

(4) Compressive Strength :

It is one of the important properties of Cement. Compressive test is carried on 1:3 Cement, sand mortar on a 50cm² cube. For OPC, compressive strength shall not be less than as follows -

3 days — 16 N/mm²
7 days — 22 N/mm²
28 days — 31 N/mm²

(5) Heat of Hydration : Hydration of Cement is Exo-thermic reaction with approximately 120cal/g

being liberated. For low heat of hydration
<66 and 75 cal/g for 7 & 28 days.

Properties of Concrete:

The important properties of ~~concrete~~ which governs the design of a concrete mix are
i) Strength (ii) Durability (iii) Workability
iv) Economy.

The aim of proportioning a concrete mix will be to find the economic proportions of Cement, coarse aggregate, fine aggregate and water so as to get a mix of given strength, proper workability and durability.

WORKABILITY: of Concrete is that property of concrete which determines the amount of internal work necessary to produce full compaction. The greatest factor affecting the workability is water (amount of) in the mix.

A workable Concrete does not ~~a~~ show any bleeding or seggregation

SLUMP TEST is the simplest test to measure the

D) i) Hard drawn steel wires fabricating confirming to IS: 1566-1967

ii) rolled steel made from structural steel confirming to IS:226-1975.

** The most important characteristic of a reinforcing bar is its stress-strain curve and the important property is the yield stress or 0.2% proof stress.

The permissible stresses in steel reinforcement as per IS: 456-2000 are give in Table 22 (pg 82). of IS 456.-2000.

Modulus of Elasticity (E) = $\frac{stress}{strain}$

'E' for steel may be taken as 2×10^5 N/mm².

Type (A) bars have yield strength of 250N/mm². Hence it is also referred as Fe250, having characteristic strength of 250N/mm².

Type (C) bars are high yield strength bars also known as HYSD bars. They are also known as cold twisted deformed bars (or) TOR steel and are available in two grades (i) Fe415 or Tor40

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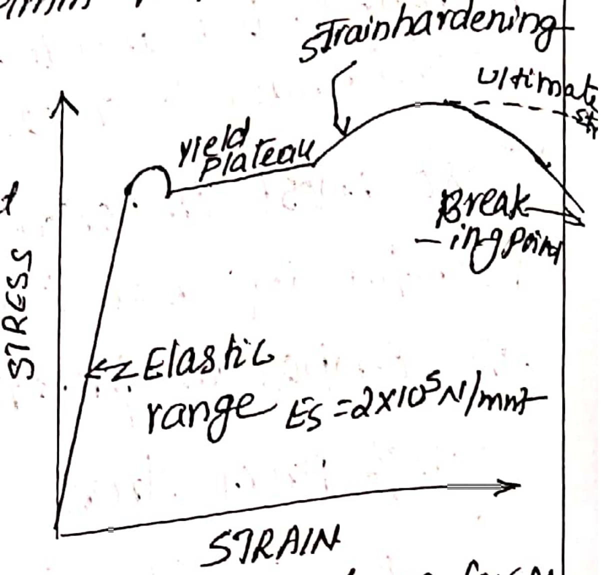
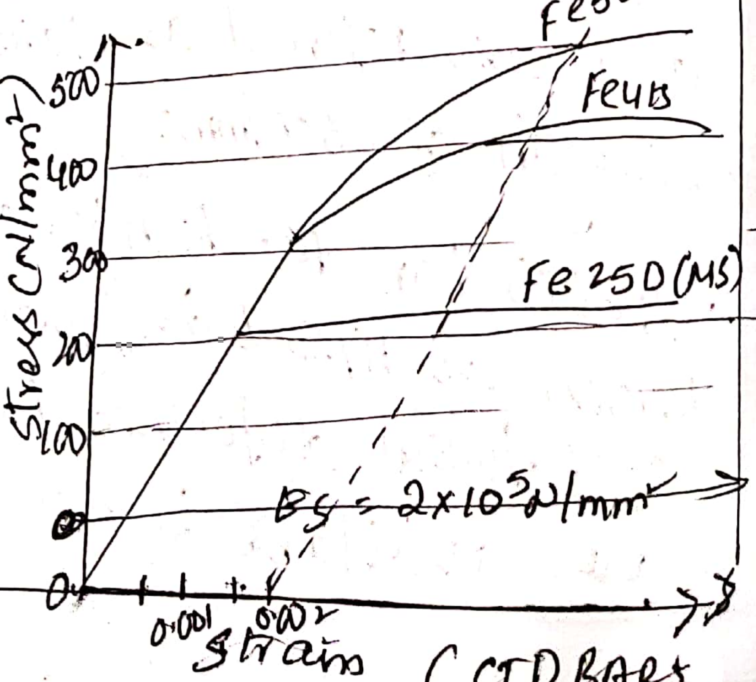
and (ii) Fe 500 or Tor 50 having 0.2% proof stress as 415 N/mm² and 500 N/mm² respectively.

→ Mild steel has low yield stress but has significant yield plateau having plastic strain nearly 10 times the limiting strain @ yield point



Stress strain curve for MS

The yield plateau can be eliminated by straining the bar beyond the yield plateau either by twisting or stretching. A twisted bar has considerable increased yield stress about 50% to 100% more than the ordinary mild steel. (i.e higher yield stress is achieved with much smaller strains)



(CTD BARS)

What is the need of proof stress?

~~The process of cold workin~~

Since cold worked bars lack a well defined yield plateau, yield stress is specified at 0.2% proof stress.

Characteristic strength of Steel Reinforcement:

The characteristic strength (f_y) means that value of strength below which not more than 5% of test results are expected to fall

DESIGN PHILOSOPHIES:

Design of RCC members is based on three theories

1. Working stress method
2. ultimate ~~stress~~ load method
3. Limit state method

Working stress method:

i) Both steel and concrete behave elastically

ii) The variation of stress is linear

iii) This method of design is based permissible stresses in concrete and steel

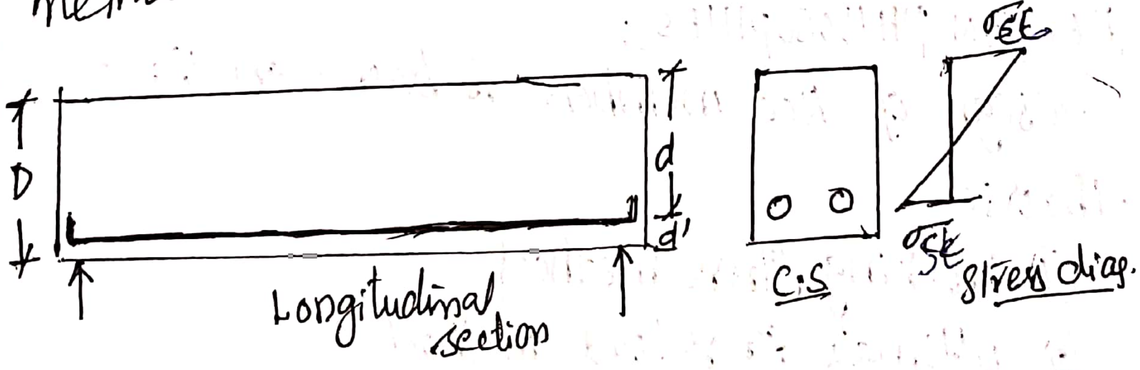
iv) The sections are designed as per elastic theory of bending, assuming both materials obeys Hooke's law.

→ Permissible stress = $\frac{\text{Yield stress}}{\text{Factor of safety (FS)}}$

F.S for steel = 1.79 in working stress method

F.S for Concrete ≈ 3 in " "

The draw back of this method was no consideration was given for variation of load in this method.



II. ULTIMATE LOAD METHOD

In this method, the stress condition at the state of impending collapse of structure is analysed. The concept of modular ratio is avoided in this method. The safety measure in the design is introduced ~~using~~ as load factor.

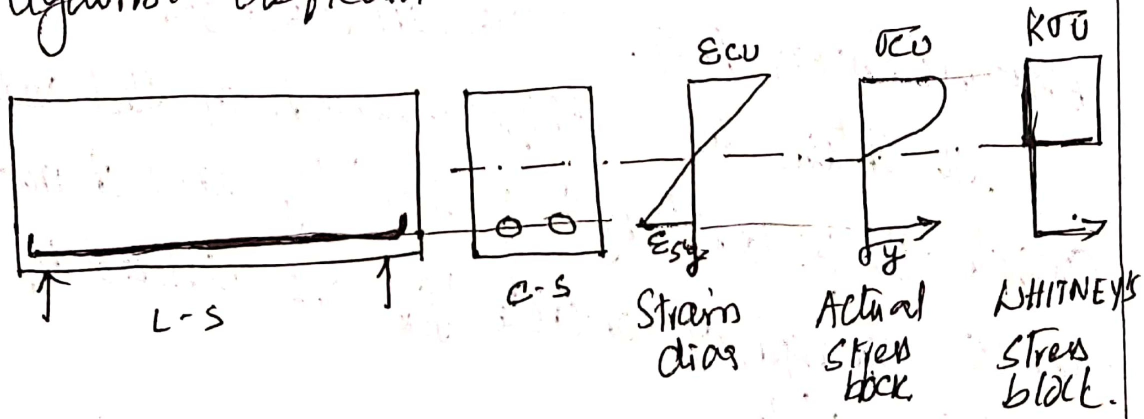
→ In this method working load (w) is increased by a factor 1.5 (Load factor) to obtain ultimate load w_u

$$W_U = 1.5W$$

→ This method takes into account the non linear behaviour of stress in ~~Concentration~~ Concrete.

→ Whitney's theory was popular ultimate load theory, it assumed max. strain in concrete as 0.003 and the corresponding stress is considered for design.

Drawback of this method is that it does not account for variation in behaviour of material and also there is complete disregard for control against deflection.



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III. 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 safety or serviceability.

There are two types of limit states:

1) ultimate limit states (or limit states of collapse) which deal with strength, overturning, sliding, buckling, fatigue fracture, etc.,

2) Serviceability limit states which deal with discomfort to occupancy caused by excessive deflection, crackwidth, vibration etc., (cont.-8)

PARTIAL SAFETY FACTOR & DESIGN STRENGTH:

To obtain the design strength of steel and concrete the yield strength of steel 'f_y' and characteristic strength of concrete 'f_{ck}' are divided by suitable factors.

→ For steel a partial safety factor of 1.15 is recommended by IS 456 in LSD.

Design strength of steel $f_{des} = \frac{f_y}{1.15} = 0.87 f_y$.

→ For Concrete partial safety factor 1.5 is taken twice?

Design strength of concrete = $f_{desc} = \frac{f_{ck}}{1.5} = 0.67 f_{ck}$

↳ back

$= \frac{0.67 f_{ck}}{1.5} = 0.446 f_{ck}$

ASSUMPTION IN LSD OF COLLAPSE (FLEXURE)

(Theory of bending in RC beams) II

1. Plane section normal to the axis remain plane after bending.

ii) The max. strain in concrete at the outer most compression fibre is taken as 0.0035 in bending.

iii) The design stress block parameter are as follows:

Area of stress block = $0.36 f_{ck} x_u$

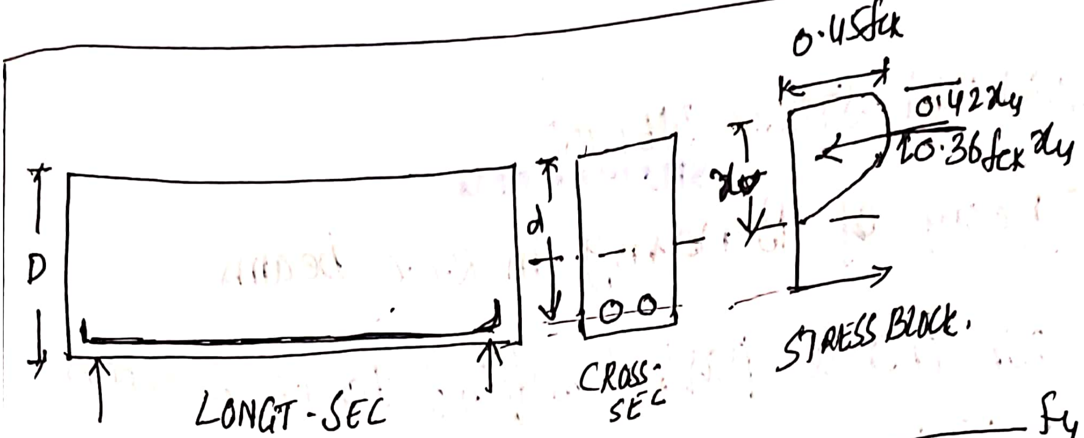
Depth of compressive force from extreme comp. fibre = $0.42 x_u$.

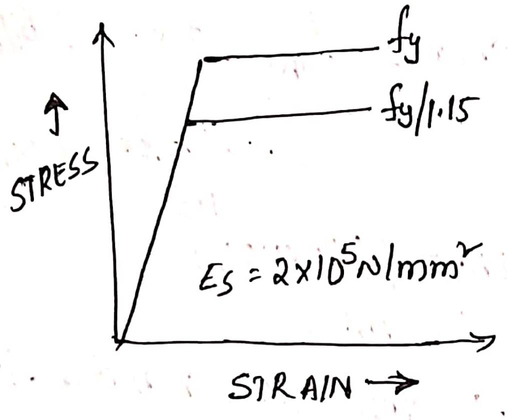
where x_u = Depth of NA

f_{ck} = Characteristic strength of concrete.

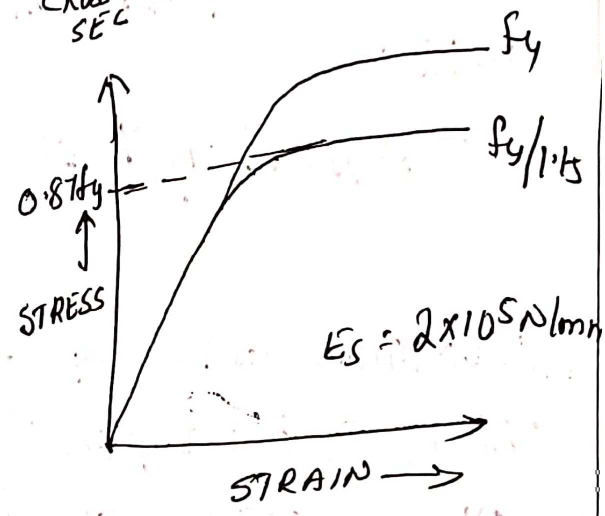
) The max. strain in the tension reinforcement in the section at failure shall not be less than

$\frac{f_y}{1.15 E_s} + 0.002$

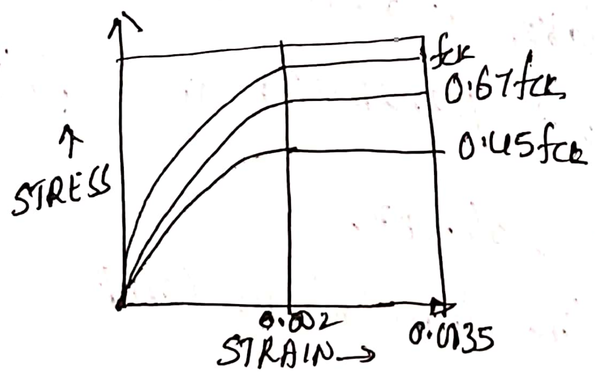




Stress-Strain Curve for MS



Stress-Strain Curve for CNDB



Stress-Strain Curve for Concrete.

(cont...6)

LIMIT STATE OF SERVICEABILITY (Deflection & Cracking.)

Depth of beams and slabs shall be limited to (IS 456 2000) 23.2

* Cantilever

S NO	Beam/slab	span/depth ratio
1.	Cantilever	7
2.	Simply Supported	20
3	continuous	26

B) Limit State of cracking :

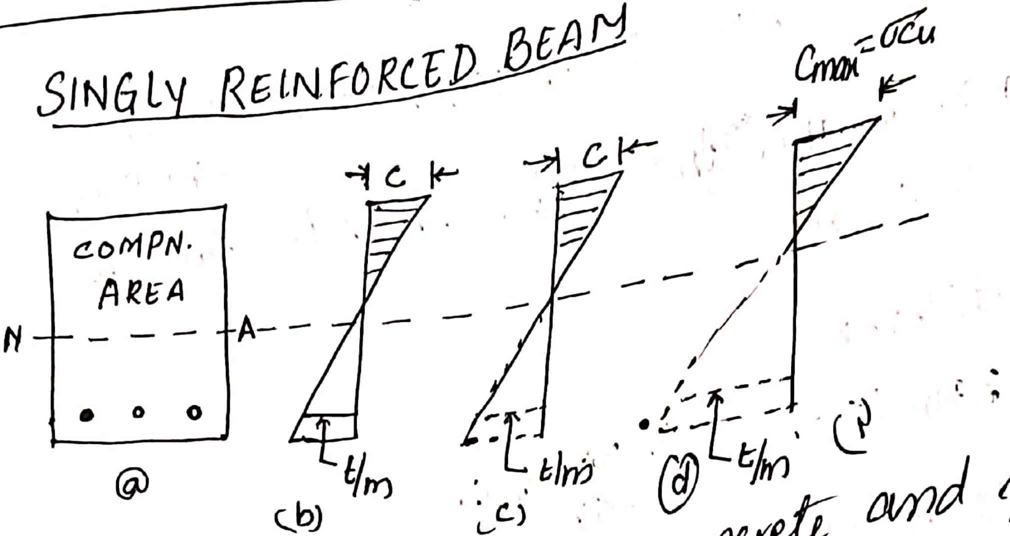
crack width ≯ 0.3mm where cracking is not harmful
≯ 0.2mm where members are subjected to weather or moisture
≯ 0.1mm in aggressive environment i.e in sea water.

* LIMITING DEPTH OF NEUTRAL AXIS :

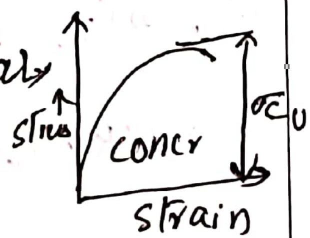
The limiting depth of NA for different grades of steels are as follows : (Pg 70)

Yield strength of steel fy	x_{umax}/d	Depth of NA x_{max}
250 N/mm²	0.53	0.53d.
415 N/mm²	0.48	0.48d
500 N/mm²	0.46	0.46d

SINGLY REINFORCED BEAM



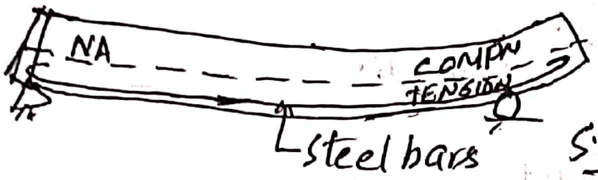
At very small loads both concrete and steel, resist tension. However as the load increases, the concrete at the bottom of the section will reach a tensile stress at which crack occurs and thus the steel bars alone resist the tension.



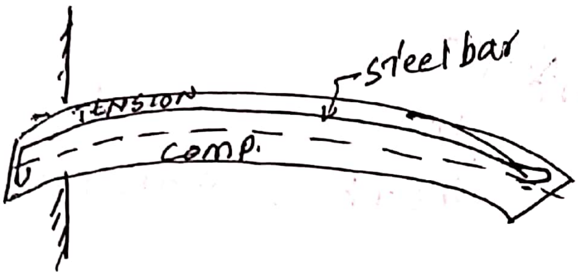
Stress-strain in concrete is not linear. the stress in concrete do not increase in proportion to increase in strain.

When the load increase further so that max. compressive stress occurs @ the top of the section, the concrete flows plastically (fig d) σ_{cu} represents the ultimate compressive strength of concrete. At such a stage, the beam may continue to deform without offering proportionately increased resistance and small increase in load may cause completely

Fig: shows a S.S. RCC beam subjected to transverse load, bending it downwards



S.S. R.C.C. beam



R.C. cantilever.

In both the cases, the reinforcement consist of steel bars are provided at a suitable depth below 'Neutral Axis' and only in tensile zone. Such beams are known as "Singly Reinforced beams".
However if reinforcement is provided in compression zone also to carry the compressive stresses, it is known as "doubly reinforced" section.

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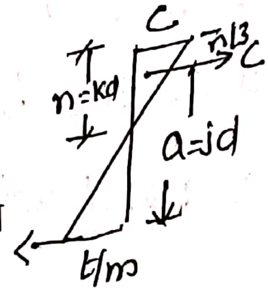
Modular ratio (m)

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



S.R.B cont..)

9(ii) $\frac{A_{st}}{bd} = k \cdot \frac{c}{2t}$

from dia.

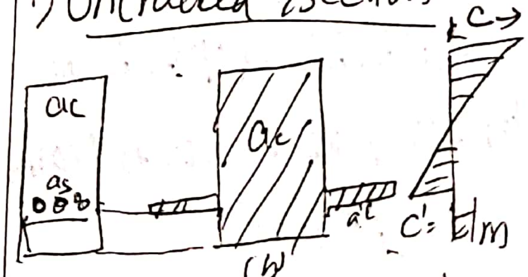
$\Rightarrow \frac{c}{kd} = \frac{t}{m} \cdot \frac{1}{d - kd}$

on solving ~~k~~

$$k = \frac{mc}{mc + t} = \frac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}}$$

Equivalent Area

i) Uncracked Section



If the load on the beam is small so that the tensile stresses setup in the conc. below the N.A is smaller than the permissible, the conc. area below N.A will not crack. In that case

$e_s = e_c$

$\frac{t}{E_s} = \frac{c'}{E_c}$

$\therefore t = c' \cdot \frac{E_s}{E_c} \Rightarrow t = m \cdot c'$

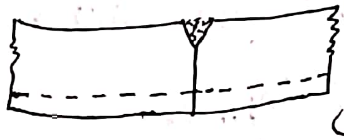
or $\boxed{c' = t/m}$ i.e stress in concr. surrounding steel.

i.e stress in steel is m times stress in conc.

Fig (b) a_c' is the addl area of conc. equivalent to steel area.

~~However for un~~

failure of beam with out sufficient warning.

(fig ii) 

(ii)

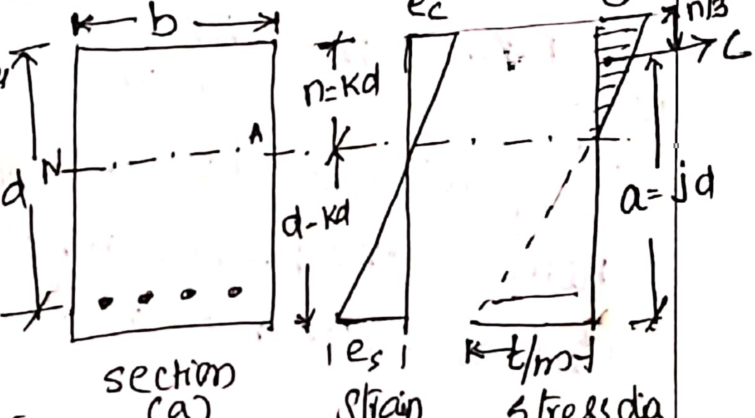
However if the tensile stress in steel reaches its ultimate value first, the beam would(?) [fig iii] and the beam will fail in tension or by local crushing of concrete at top of the concrete. However upto elastic limit of steel, the reinforcing bar resist tension in proportion to their strain.

(iii)

NEUTRAL AXIS OF BEAM SECTION

To determine NA, consider two cases

(A) Stresses in concrete and steel are known.



S.R. Section

Let c = Comp stress in extreme fibre of conc.

t = tensile stress in steel reinf..

b = breadth of beam

d = depth of beam to the centre of reinforcement (Eff. depth)

n = kd = depth of NA below the top of the beam

K = NA depth factor = n/d

A_{st} = Area of tensile Reinforcement

Since there is no resultant force across the section

Total Comp = Total Tension

$\frac{1}{2} c \times b \cdot kd = t \cdot A_{st}$

$\Rightarrow \frac{A_{st}}{bd} = K \cdot \frac{c}{2t}$ [$c' = \frac{t}{m}$ equivalent conc. area)

If t (or σ_{st}) is the stress in steel & c' is the equivalent conc-area $= t/m$ cont...)

on solving

(NA depth factor) $K = \frac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}}$ i.e $\frac{mc}{mc+t}$

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

σ_{cbc} = Per. Comp stress in conc.

σ_{st} = per. tensile stress in reins.

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

Note
K' gives the location of neutral axis when stresses in steel and concrete are known.

(B) When dimension (b & d) of the beam are known: (reinforcement is also known)

$K = \sqrt{2mp' + (mp')^2} - mp'$, where $p' = \frac{A_{st}}{bd}$ (reinf. ratio)

m = mod. ratio

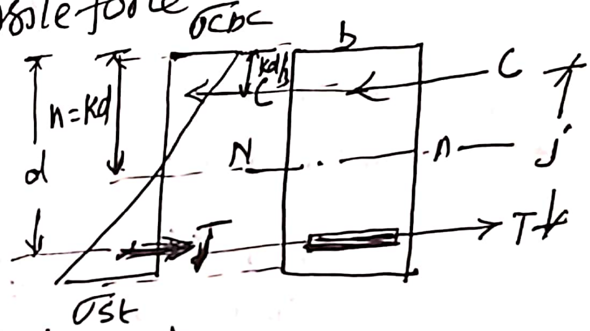
* equating the moment of area in Comp. to moment of equivalent area in tension about N.A.,

$b \cdot kd \cdot \frac{kd}{2} = mA_{st}(d - kd)$

* MOMENT OF RESISTANCE (MR)

The total Compressive force acting at the centre of gravity of the compressive ~~forces~~ area is equal to the total tensile force acting at the c.g of the steel reinforcement.

Hence the M.R of RC beam section is equal to the moment of couple consisting of the compressive force & tensile force.



Total Compressive force

$C = \frac{1}{2}\sigma_{cbc} \times k \cdot bd$

acts @ $\frac{kd}{3}$ from top of the section

Similarly Total tension $T = \sigma_{st} \cdot A_{st}$ acts at a dist. 'd' from top of section.

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Dist' b/w C & T is lever arm 'a'

$a = j \cdot d = d - \frac{kd}{3} = d(1 - k/3)$

$\therefore j = 1 - k/3 =$ Lever arm factor

$\therefore M.R = \text{Force} \times L.A$

$= C (or) T \times LA = \frac{1}{2}\sigma_{cbc} \cdot k \cdot bd(a) = \frac{1}{2}\sigma_{cbc} \cdot kb \cdot d \cdot jd$

$$MR = \frac{1}{2}\underbrace{\sigma_{cbc} \cdot j \cdot k}_{Q} \cdot bd^2$$

$= Q \cdot bd^2$ where $Q = \frac{1}{2}\sigma_{cbc} \cdot j \cdot k$.

$$\therefore M.R = Q \cdot bd^2$$

ex: $\sigma_{st} = 140 N/mm^2$ (Fe 250) & M_{15}

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

$$m = \frac{280}{3 \times 5} = 18.67$$

$$k = \frac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}}$$

$$= \frac{18.67 \times 5}{18.67 \times 5 + 140} = 0.40$$

$$j = 1 - k/3 = 1 - \frac{0.4}{3} = 0.867$$

$$\therefore Q = \frac{1}{2} \times 5 \times 0.867 \times 0.4 = 0.867$$

(OR)

$$M.R = \sigma_{st} \cdot A_{st} \cdot j \cdot d \Rightarrow A_{st} = \frac{M.R}{\sigma_{st} \cdot j \cdot d} = \frac{M}{\sigma_{st} \cdot j \cdot d}$$

Where M - External B.M.

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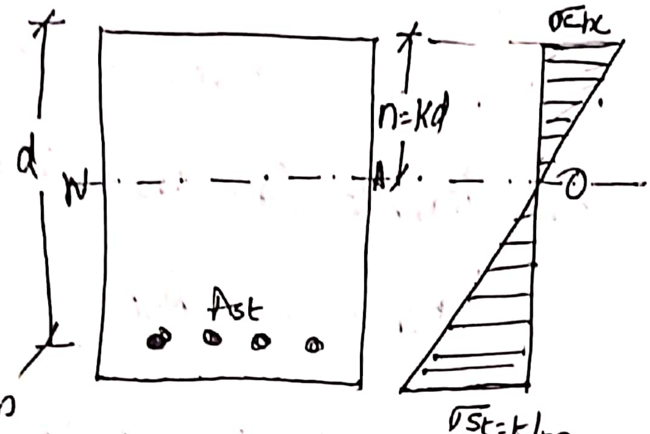
BALANCED, UNDER REINFORCED AND OVER REINFORCED SECTION.

(A) BALANCED SECTION

If the area of steel reinforcement A_{st} is of such magnitude that the permissible stresses in conc. & steel (σ_{cbc} & σ_{st}) are ~~developed~~ developed simultaneously, the section is known as **BALANCED SECTION**; OR **CRITICAL SECTION** OR **ECONOMICAL SECTION**. The N.A of bal. section is called critical N.A

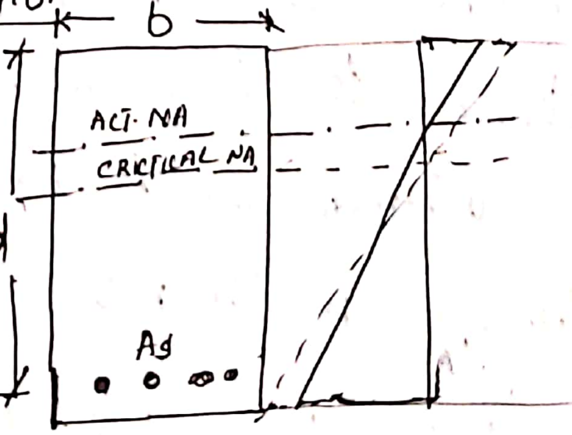


BAL. Sec.

$$M.R_c = M.R_T.$$

(B) UNDER REINFORED SECTION

An U-R section is the one in which the percentage of steel provided is less than a bal. R.C section.



In this section ~~Critical N~~ Actual N.A is above the critical N.A. of a bal. sec.

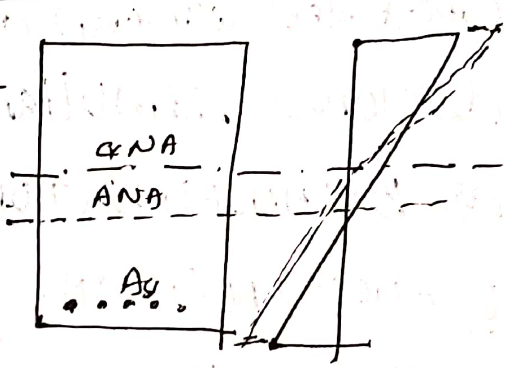
→ In a under reinforced section, the concrete is not fully stressed to its permissible value when stress in steel reaches its max value of σ_{st}.

- Therefore M.R is computed on the basis of the tensile force in steel

$$MR = \sigma_{st} \cdot A_{st} \cdot j\, d$$

(c) OVER REINFORCED SECTION

In OR section, the reinforcement provided is more than critical one and therefore actual NA is below the critical N.A.



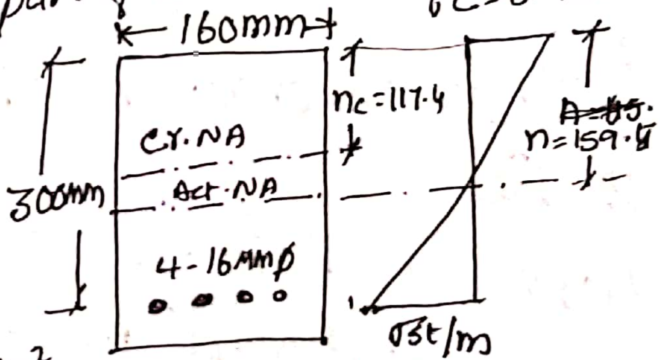
In OR Section steel reinforcement is not fully stressed to its permissible value and the M.R is determine on the basis of compressive force developed in concrete

$$M.R = \frac{1}{2} \sigma_{cbc} \cdot j \cdot k \cdot bd^2$$

SINGLY RC BEAMS

→ Determination of M.R of the given section
→ Determination of stresses in the given section
→ Design of section to resist a given B.M.

1) Determine the M.R of a SRCB 160mm x 300mm deep to the centre of reinforcement. If the stresses in steel & concrete are not to exceed 140N/mm² & 5N/mm². The reinforcement consists of 4 bars of 16mm ϕ. Take m=18. Also find the max. load the beam can carry if the beam is used over an eff. span of 5m.



$A_{st} = \frac{4\,\pi(16)^2}{4} = 804\,mm^2$

$\sigma_{cbc} = 5N/mm^2$; $\sigma_{st} = 140N/mm^2$

$m = 18$.

Equating the moment of area in compression to the moment of the equivalent area in tension about the N.A, we get

$b \times n \times \frac{n}{2} = m A_{st}(d-n)$

(Note:- Stress is steel is much higher say m times than conc. /* mA_{st} = Equivalent area of concr. */)

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$$\frac{160 \times n^2}{2} = 18 \times 804 (300 - n)$$

$$n^2 + 181n - 54287 = 0$$

$$\Rightarrow \boxed{n = 159.5\,mm}$$

If n_c is the depth of critical neutral axis, we have

$$n_c = k_c \cdot d = \frac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}} \times d$$

$$= \frac{18 \times 5}{(18 \times 5 + 140)} \times 300 = 117.4\,mm^2$$

Since act. depth of N.A > critical N.A depth, the section is <u>over reinforced</u>.

<u>Thus</u> concrete reaches the max. stress earlier to steel.

<u>Hence</u> M.R is found on the basis of compressive force developed in concrete.

$$C \times L.A$$

$$\therefore M.R = \frac{1}{2} \sigma_{cbc} \times n \times b \left(d - \frac{n}{3}\right)$$

$$= \frac{1}{2} \times 5 \times 159.5 \times 160 \left(300 - \frac{159.5}{3}\right) \times 10^{-6}$$

$$\boxed{M.R = 15.75\,KN\text{-}m}$$

$$M = \frac{wl^2}{8} \Rightarrow 15.75 = \frac{w \times 5^2}{8} \Rightarrow w = \frac{15.75 \times 8}{25} = 5.04\,kN/m$$

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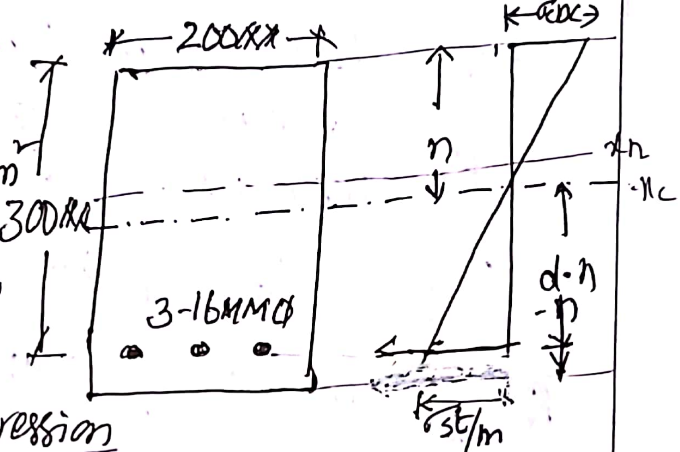
(2)

The C.S of a S.S. RC beam of 200mm × 300mm to the centre of reinforcement which consists of 3 bars of 16mm φ. Determine from the first principles the depth of N.A and the max. stresses in concrete when steel is stressed to 120 N/mm².

Take m = 19.



Sol

$A_{st} = \frac{3\pi(16)^2}{4} = 603.2\,mm^2$

Let the depth of N.A be 'n'

Equating Moment of Compression area to moment of Equivalent area of steel about N.A, we get

$b \cdot n \cdot \frac{n}{2} = m A_{st}(d-n)$

$100n^2 = 19 \times 603.2(300-n)$

$\Rightarrow n^2 + 114.6n - 34382 = 0$

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$\Rightarrow \boxed{n = 136.8\,mm}$

From stress diag:- $\frac{\sigma_{cbc}}{n} = \frac{\sigma_{st}/m}{d-n}$

$\Rightarrow \sigma_{cbc} = \frac{136.8 \times 120}{19(300-136.8)} = 5.29\,N/mm^2$

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#3 Design a RC beam subjected to a BM of 20kN-m use M20 Conc. and Fe415 reinforcement. Keep width of beam equal to half the Eff. depth.

Sol For M_{20} concr., $\sigma_{cbc} = 7 N/mm^2$ & $m = 13.33$.

For Fe415 Steel, $\sigma_{st} = 230 N/mm^2$.

For a balanced Section

$$K_c = \frac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}} = \frac{13.33 \times 7}{13.33 \times 7 + 230} = 0.289$$

$$j = 1 - K/3 = 1 - \frac{0.289}{3} = 0.904$$

$$Q = \frac{1}{2}\sigma_{cbc} \cdot j \cdot K = \frac{1}{2} \times 7 \times 0.904 \times 0.289 = 0.914$$

$$\therefore M.R = Q \cdot b \cdot d^2 = 0.914 \times \frac{d}{2} \cdot d^2 = 0.457 d^3 \text{ N-mm}$$

Given B.M = $M = 20 \times 10^6$ N-mm

$$\therefore 20 \times 10^6 = 0.457 d^3 \Rightarrow d = 352.4 mm$$

$$b = 176.2 mm$$

Area of Steel: $A_{st} = \frac{M}{\sigma_{st} \cdot j \cdot d} = \frac{20 \times 10^6}{230 \times 0.904 \times 352.4}$

$A_{st} = 273 mm^2$

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SHORT-ANSWER QUESTIONS (UNIT-I)

1) Differentiate between balanced, U-R & O-R sections in working stress method of design.

2) Name the compound present in cement.

3) What is the function of an admixture : To improve desirable qualities of concrete like comp. strength, density, durability etc.

4) Differentiate b/w bleeding, Honey combing and segregation of concrete. (bleeding → separation of water from conc.; honey combing → formation of voids in conc. mass; segregation → separation of CA)

5) Define workability

6) What do you mean by characteristic load and partial safety factors ? (IS 456 pg 67) Ans:- The load which has more than 95% probability of not exceeding its value during life of structure. (yield st / work st)

7. What is the limit state of serviceability.

8) What are the merits of limit state method over working stress method.

9) What is critical neutral axis.

10) Draw the stress-strain curve of HYSD bars and explain the concept of 0.2% strain. IS 456 fig 23 (70)

11) How does water cement (w/c) ratio effect the strength of concrete ? Explain. → Abrahm's w/c law: Increase in w/c ratio, crushing strength reduces

12) Nominal size of concrete is 12mm, when most of it passes through and retained on

Ans:→ 12mm & 10mm

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12) Based on which assumption in working stress method, strain in concrete surrounding the steel is taken equal to strain in steel.

Ans: ~~To improve the desi~~r It is based on the assumption that steel and concrete are well bounded.