Notes by-

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Properties of materials

① Concrete :-

IS. 456-2000/Pg. 15/Cl.6

Concrete is stone like hard matl. obtained by mixing
① sand
② ~~Fine~~ & coarse aggregates
③ water – for hydration & ~~workmanship~~. workability.
④ cement

Concrete ⇒ High compressive strength
Low Tensile strength.

This shortcoming of weak tension carrying capacity is offseted by providing steel to take tension & known as Reinforced cement concrete.

Constituent materials of concrete :-

① Cement
② Aggregate
③ water.

① Cement :-

(IS : 456 : 2000 – Pg – 13/ Cl.5.1) – [Details - see MCCT Notes]

cement is a material having property of binding ~~material~~ the mineral fragment in to a solid mass on its chemical combination with water.

Since binding & hardening actions are due to presence of water such cement is known as "Hydraulic Cement"

* cement used in constⁿ: Portland cement.
* Ingradients: ① Calcareous matls – e.limestone, chalk, marl
② Argillaceous matls – silicates of alumina.
③ Admixtures (if any)
* Process of cement manufacturing: (Detail MCCT Notes)
① Mixing in proper proportion.
② Grinding
③ Blending
④ Fusion in kiln
⑤ Crushing to fine powder
⑥ Dispatching.
* Main compounds in ordinary cement :-
① Tricalcium silicate : $3CaO\,SiO_2$
② Dicalcium silicate : $2CaO\,SiO_2$
③ Tricalcium aluminate $3CaO\,Al_2O_3$
④ Tetra calcium alumino-ferrite – $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$

* Chemical reaction of cement & water (exothermic), by virtue of which cement becomes a bonding agent is known as hydration of cement.

* Product of hydration - aluminates & silicates + Heat of hydration.
* The heat of hydration should be dissipated or controlled especially in mass constn to avoid cracking & weakening of concrete, which is done by circulating cool air or water throughout body of dam. [Notes of Hydraulic structures.]

* Cement absorbed moisture from atmosphere & gets hardened before used in constn, due to careless storing. If water absorption is more than 5% then it loses binding property.
(Types of cement: Given in IS code)

② Aggregates : (IS:456-2000/Pg.14/Cl.5.3] → (Highway Engg. Notes]

Vol. of concrete = 75% Vol. of aggregate.

* Aggregates used in concrete should be hard, durable, strong, chemically inert & well graded → [GE Notes]

Classification of aggregates:-

- Fine (Passing throug 4.75 mm sieve)
  - min. size ⇒ No limit
  - Max. size ⇒ 4.75mm
  - → (well graded.) → very important 'word'.
- Coarse (Retained on 4.75 mm sieve)
  - Min. size - 4.75 mm
  - Max. size - Govened by (IS:456-2000 Pg-14/5.3.3)
  - (Interview Que) The nominal max. size of coarser aggregate is governed by workability & size, spacing, & cover in case of reinforcement.
  - ∴ Max. size ≯ $\frac{1}{4}$ (Min. size of member) (bord) (20mm) (40 mm)
  - ≯ Min. clear dist. betn main bar - 5 mm
  - ≯ min. cover - 5 mm. [Except SLAB]
- Normal wt
  - Natural
  - artificial.
- light wt

* specific gravity = 2.6
* Unit wt = 1700 kg/m^3.

③ Water :- (IS: Pg 14/(Cl. 5.4)

① Should be clean & free from oil, acid, alkali, salt, sugar, organic matls.

Interview criteria:
② Avg. cube compression test of concrete at 28 days (by using available water) ≮ 90% of avg. strength of same grade concrete after 28 days prepared by using distilled water.

pH = 6, Sea water is not permitted.

* Properties of concrete :- [Pg. 15/6.2]

① structural Properties
  a) compressive strength
  b) Tensile strength
  c) stress-strain Relation, Modulus of elasticity.

② serviceability / Performance properties -
  a) creep
  b) shrinkage.

a] Compressive strength :-

compressive strength is defined as, " a load, at which standard specimen fails when subjected to uniaxial compression under a specified rate of loading, divided by area of c/s."

Aptitude Que

Standard Specimen ① cube (150mm) - IS Recommendation.
② cylinder
③ Prism.

The compressive strength calculated by above 3 types of specimen is not same, but it depends on size & shape of specimen.

This dependence is known as "Specimen Effect."

* compressive strength is done at 3, 7, 28 day after casting.

Interview

The compressive strength of cube at 28 day age is about 90%. the total strength, so this value is generally taken in design. i.e. M15, M20 ... etc.

* Water Cement Ratio :- $\frac{\text{wt of water}}{\text{wt of cement}}$.

for hydration, 38% water cement Ratio is Reqd.

$$0.25\% \Rightarrow \text{Hydration Reaction}$$
$$+\ 13\% \Rightarrow \text{Filling in the voids of pores.}$$
$$= 38\% \Rightarrow \text{Total}$$
$$+\ xx\% \Rightarrow \text{Workability}$$
$$= 0.5 \text{ to } 0.6 \Rightarrow$$

Aptitude que -

This is very critical constituent as -

If $w/c < 0.38 \Rightarrow$ Incomplete hydration

$w/c > 0.38 \Rightarrow$ Excess voids after hardening due to evaporation of water.
$\Rightarrow$ Less f_c

② **Tensile strength of concrete** [IS- cl. 6.2.2 / Pg.15)

Ultimate tensile strength of concrete is very low; hence it is usually not taken in to account in RCC. But it is important property that greatly affects the 'extent & width of cracking'.

* The tensile strength of concrete is reqd. for analysis of structure such as tanks for storage of liquids, pressure water pipes).

* The tensile strength of concrete in direct tension can be obtained by "split cylinder strength Test".

Interview

Split Tensile strength = $\left(\frac{1}{8} \text{ to } \frac{1}{12}\right)$ Cube compressive strength.

f_{cr} = Max. Tensile stress = Modulus of rupture = $\frac{M}{I} \cdot y = \frac{M}{Z}$

Where, M = Bending moment at rupture.
Z = Modulus of section.

"cr" ⇒ cracking.

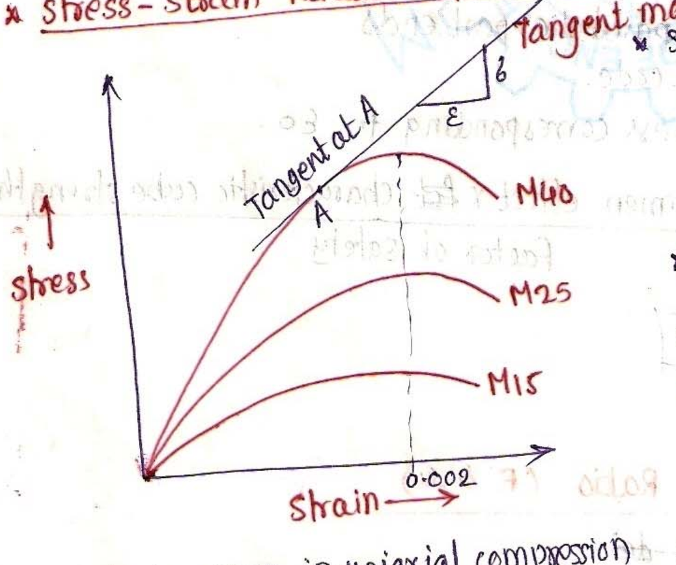
f_{cr} = Flexural cracking strength = Flexural tensile strength.

If, f_{ck} = ~~flexural~~ Cube compressive strength

then, $f_{cr} = 0.7\sqrt{f_{ck}}$

ⓒ * **stress-strain Relationship for concrete:-**

Tangent modulus :- E_c = tangent modulus = $\frac{6A}{\varepsilon A}$



stress-strain curve in uniaxial compression for cube of concrete.

* stress-strain Relationship is "NON-LINEAR."

∝ f(Grade of concrete, rate of loading, duration of loading)

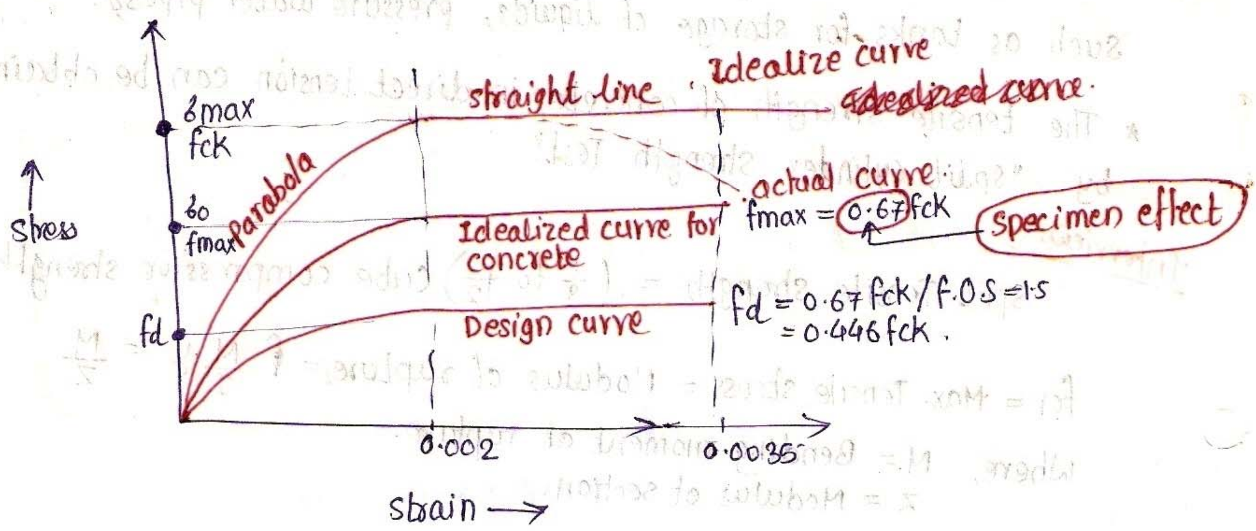
* GATE

* Max. comp. stress = 0.002 strain.
* failure strain (Low grade concrete) > Failure strain (High grade concrete)
* Ultimate or failure strain = 0.003 to 0.005.
= 0.002 — axial compression
= 0.0035 — Bending compression

* Idealized stress-strain curve :- (V.V. Imp. Basic)

In design calculation, stress-strain curve is assumed to be a parabola up to strain of 0.002 followed by a straight line terminating at ultimate strain.

i.e.



Eqⁿ for idealized stress-strain curve :-

$$\sigma = \left[\frac{2\varepsilon}{\varepsilon_0} - \left(\frac{\varepsilon}{\varepsilon_0}\right)^2\right] \cdot \sigma_0 \qquad [0 < \varepsilon < \varepsilon_0] \rightarrow \text{Parabola}$$

$$\sigma = \sigma_0 \qquad [\varepsilon_0 < \varepsilon < \varepsilon_{cu}] \rightarrow \text{straight line.}$$

Where, ε = strain at any point
σ = stress at any point
ε_0 = strain at which parabolic part ends
= 0.002 as per I.S. code.
σ_0 = Idealized max. stress corresponding to ε_0.

∴ Design stress = fd = $\dfrac{\text{Specimen effect} \times \text{characteristic cube strength}}{\text{Factor of safety}}$

∴ $fd = 0.45\, fck$

(GATE)

* Modulus of elasticity & Poission's Ratio (E & μ)

$E_c = \dfrac{\text{stress}}{\text{strain}}$ ~~Not uniquly del~~ ~~Not unique for~~

as stress-strain curve is not linear, for concrete.

E is not unique for concrete; it changes point to point.

∴ It is preferable to calculate E from test result. ~~than Given~~ Given formula than

∴ $E_c = 5000\sqrt{fck}$ N/mm² —— IS : 456/2000 - Pg. Cl. 6.2.3.1.

· μ = Poissions Ratio = 0.15 to 0.2 → Uniaxial comp. ~~lov~~ $\mu = 0.15$ → strength design.
$\mu = 0$ → Neglected.

(a) Creep of concrete :- [Cl. 6.2.5]

Creep is defined as plastic deformation under constant load or stress.

Concrete under load or stress ⇒ Rapid deformation up to highest intensity. } 3-4 months.
⇒ Gradual increase up to limiting value } 5 years.

(Interview) As creep increase rapidly at early periods (3-4 months); the construction of walls on newly casted & hardened concrete should be prolonged otherwise cracks will be develop after period of 6-12 months.

* Factors affecting creep :-

① Creep ∝ stress or load.
∝ Age of concrete.
∝ Rate of loading
$\propto \frac{1}{\text{Humidity}}$
∝ W/C Ratio
$\propto \frac{\text{Cement content}}{\text{Unit volume}}$

∝ ⇒ ~~Dirt~~ Directly proportional

* Estimation of Creep : [See PCAD Notes]

"Creep strain" is obtained from creep ~~coe~~ coefficient.

"Creep coefficient (θ)" :- $= \frac{\text{Creep strain } (\varepsilon_{cc})}{\text{Elastic strain } (\varepsilon_i)}$, at the age of loading.

$$\therefore \theta = \frac{\varepsilon_{cc}}{\varepsilon_i}$$

In absense of data,

	Ultimate creep coeff.		
Age at loading in days	7	28	365
Creep Coeff. (θ)	2.2	1.6	1.1

Pg. 16 Cl. 6.2.5.1

(Interview)
* Long Term modulus of elasticity of concrete

As, $E = \frac{\text{stress}}{\text{strain}}$

Due to creep, strain increases.
∴ E decreases.

As effect of creep is a long term process & hence corresponding E is known as "Long Term modulus of Elasticity of concrete".

as $E = \frac{\sigma}{\varepsilon_{ic}} = \frac{E_c \cdot \varepsilon_i}{\varepsilon_i + \varepsilon_{cc}} = \frac{E_c}{1 + \varepsilon_{cc}/\varepsilon_i} = \frac{E_c}{1+\theta}$ ∴ $\boxed{E = \frac{E_c}{1+\theta}}$

σ = stress in concrete
ε_{ic} = Initial elastic strain + Creep strain
E_c = Short term E
E_{ce} = Long term E

(b) * shrinkage (Cl.- 6.2.4) (आकुंचन पावणे)

(Interview) Reduction in "Volume" of concrete during process of hardening is known as shrinkage. [Opposite to swelling]

[Creep strain → Deformation due to (load.)
[shrinkage → Deformat^n of VOLUME due to (hardening process.)

* Factors affecting shrinkage :-

① Environmental condition (Temp. & Humidity)
② w/c Ratio
③ Volume - surface Ratio
④ Duration of explosure (NOT DURATION OF LOADING)
⑤ %age of steel

Greater the percentage of steel, lesser will be shrinkage.

Shrinkage is time dependent process.

Ultimate shrinkage of 50% ⇒ 1st one month.
Remaining 50% ⇒ in 6 months from commencement of drying.

In absence, of data,

Total shrinkage = 0.0003 ⟶ IS : 456 / Pg. 16 / Cl. 6.2.4.1

Creep & shrinkage occurs simultaneously.

In LSM ⇒ Deformat^n due to creep & shrinkage is considered from LS of serviceability consideration.

In WSM ⇒ It is not considered.

* Modular Ratio (m) [Cl. B-2.1.2 / Pg. 80]

$$\text{Modular Ratio} = \frac{\text{Modulus of Elasticity of steel}}{\text{Modulus of Elasticity of concrete}} = \frac{E_s}{E_c}$$

I.S. 456-2000 gives following expression for "Long term modular Ratio" as :-

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

σ_{cbc} = Permissible compressive stress due to bending in concrete (N/mm^2).

* Workability (Cl.7)

"Workability is defined as, useful internal work necessary to produce full compaction."

Workability of concrete is determined by –

① Slump test
② Compacting factor test
③ Vee-Bee consistometer test.

Workable concrete should not show bleeding or segregation.

* Durability: [Cl.8]

"Durability of concrete is its ability to resist its disintegration & decay."

Factors affecting durabilility are –

① Exposure conditions. (Mild, moderate, serve, very serve & extreme)
② w/c Ratio & cement per unit vol. content.
③ Type & quality of constituent materials.
④ Workability Requirement.
⑤ Cover to embeded reinforcement steel.
⑥ Curing
⑦ Size & shape of member.
⑧ Life span of member.
⑨ Permeability of concrete.
⑩ Void Ratio.

(Interview)

Too high cement content increases the risk of cracking due to drying shrinkage or to early thermal cracking & increased risk of damage due to "alkali-silica Reactions". ~~The fo~~ Therefore max. cement content is given as

530 kg/m³.

Based upon exposure conditions min. nominal cover & min. grade of concrete is given in IS: 456- Table ~~Sec~~ 5 / Pg. 20.

* Temperature effect. (Cl.27 / Pg-50) (Detail- see Highway (Bridge Engg.))

Concrete expands with rise in temp. & contracts. This effect of change in length due to change in temp. is reduced by provision of "expansion joints". The break betⁿ joint should be complete & reinforcement shall not ~~exce~~ extened across expansion joint. It is recommended that, structure adjacent to expansion joint should be supported on seperate column or wall but not necessarily on seperate foundation.

Coeff. of Thermal expansion $= 0.6\times10^{-5}$ to 1.3×10^{-5} /°C → for diff. types of aggergates.
$= 1.1\times10^{-5}$ /°C → for liquid storage structure and design of chimneys etc.

* Unit wt. of concrete (γ_c) (cl.19.2.1)

(Interview)

$\gamma = \frac{wt}{vol.}$

γ for plane concrete = 22 - 25 kN/m^3 } depending upon type of aggregate & grading (Void Ratio)

γ for RCC = 23 - 26 kN/m^3

According to IS code, γ = 24 kN/m^3 → plain concrete
= 25 kN/m^3 → RCC

* Concrete Proportioning (cl. 9)

In RCC, concrete is known by its "grade" as M15, M20 .. etc.

M ⇒ Mix
15, 20, ... ⇒ characteristics comp. strength of 15 cm cube at 28 days (N/mm^2)

Grades in RCC ⇒ M20, M25
Grades in ~~Precas~~ Prestressed concrete : M30, M35, M40, M45, M50, M60.

* Proportioning & mixing of cement, aggregate & water is done by –
  a] Design Mix Concrete
  b] Nominal mix concrete.

a] Nominal mix concrete :- Used in small works. up to M20 grade.

M15 : (1:2:4)
M20 : (1:1½:3) } Nominal max. size of aggregate = 20 mm

Types : ① Volume Batching
② Weight Batching :- Very common at site [see "site Notes"]

b] Design mix concrete :-

Design mix is always preferred to nominal mix.

Mtds :- ① Road Research Lab. (RRL) mtds.
② American Concrete Institution mtd
③ Dept. of environment, London.
④ IS method

* Production of concrete & quality control :-

Production : ① Batching : [Wt. batching is preferred)
② Mixing (Mechanical mixing is preferred)
③ Placing, compacting [Vibrator is preferred)
④ Curing

(GATE) * **Design strength of concrete :-**

Type of stress (N/mm²)	Grade of concrete		
	M15	M20	M25
Cht. comp. stress	15	20	25
Design stress in			
① Direct compression [0.4 fck]	6.0	8.0	10.0
② Bending comp. [0.446 fck]	6.69	8.92	11.15
③ Flexural Tension [0.7 √fck]	2.71	3.13	3.5
④ Avg. bond for plain bar in Tension	1.0	1.2	1.4
⑤ Bearing [0.45 fck]	6.75	9.0	11.25

(①) → for axially loaded short colᵐ considering min. eccentricity ~ (see colᵐ Notes)
(⑤) → Axially loaded short colᵐ considering eccentricity.
(④) → 60 % increase for deformed bars bond stress
25 % increase for bars in tension.

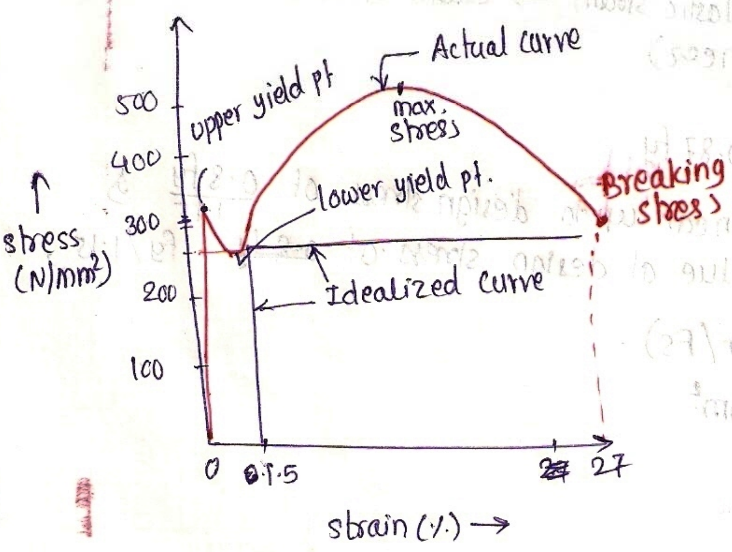
* **Reinforcing steel :-**

Types :
① Plain round bars of MS [Fe 250]
② High Yield Strength Deformed (HYSD) bars = Fe415, Fe500
③ Steel wire fabric.

(Interview)
Fe ⇒ Ferrous metal
250, 415, 500 ⇒ Yield stress (N/mm²)

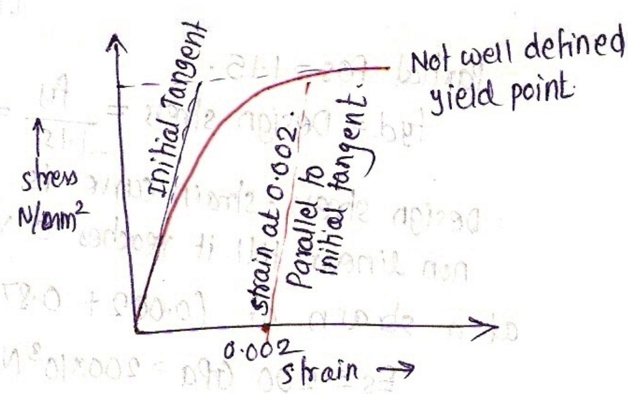
① **Plain round bars of MS :-**

① It has "well defined" yield point giving lower point yield stress of 250 N/mm².



② **High Yield strength Deformed bar**

① It has high yield point but it is not well defined.
Therefore yield stress or characteristic stress is given by 0.2 % proof stress.

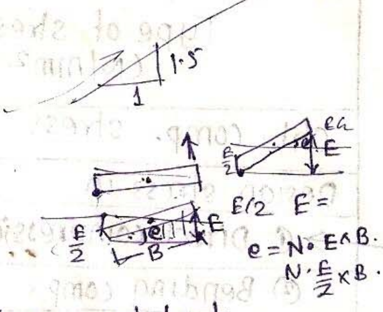


HYSD bars are either -

① Hot rolled from steel billets

② cold working — cold Twisted → "TORSTEEL"

coeff $f = \frac{V^2}{127R(1 \pm 0.0n)}$



TOR 40 ⇒ Fe415

TOR 50 ⇒ Fe500.

(Aptitude)

Advantages of HYSD bar over MS bar

① Ast reqd. for HYSD bar < that of MS bar. ∴ Economical.

② Good bond with concrete & can be placed without end hook, smaller anchorage length, ⇒ Economical.

③ During twisting process, the defect (if any) is noticed & steel is rejected ∴ Each bar is tested for defects.

★ **Disadvantages :-**

① Limiting use for further high stress. i.e. Fe550 -

② Due to reduction in Ast, design shear strength is also reduces.

HYSD Bar ⇒ symbol #
MS Bar ⇒ symbol ϕ } According to SP.

Use : bar of 8mm dia as ⇒ ϕ8 or #8 ;

NOT [8ϕ ; 8#] — (wrong)

Idealized stress - strain curve for Fe415 grade of steel :

stress - is proportional to strain up to stress of 0.8 fy. ⇒ i.e. linear.
Thereafter stress strain relationship is non-linear.

∴ Yield stress attains at $\left[0.002 + \frac{f_y}{E_s}\right]$

0.002 → Inelastic strain (Linear); $\frac{f_y}{E_s}$ → Elastic strain

Partial FOS = 1.15.

∴ f_{yd} = Design stress = $\frac{f_y}{1.15} = 0.87 f_y$.

∴ Design stress - strain curve is linear up to design stress of $\frac{0.8 f_y}{1.15}$ & non linear till it reaches a value of design stress of ~~0.8 fy~~ $f_y/1.15$, at a strain of $(0.002 + 0.87 f_y/E_s)$.

$E_s = 200$ GPa $= 200 \times 10^3$ N/mm².

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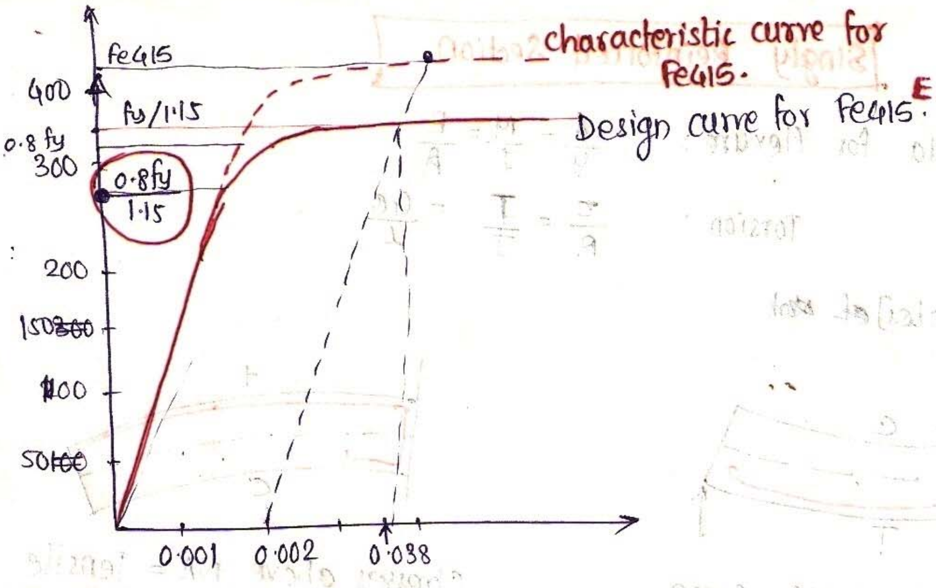

* Properties of Round Bars :-

- Unit wt. of steel = 7850 kg/m³.

Interview

Wt. of steel bar in kg/m length = $\frac{\phi^2}{162.2}$

ϕ = dia. of bar.