DESIGN OF REINFORCED CONCRETE STRUCTURES

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Head Office:

HYDERABAD

GATE MASTER'S ACADEMY
3rd Floor, S.S. Towers, Beside Kamala Hospital,
Dilsukhnagar, Hyderabad.
Tel: 040-6662 3032
Mobile:+91 8125303032

GM Publications

Address : #303, 3rd Floor, SS Towers, Beside Kamala Hospital,
Dilsukh Nagar, Hyderabad - 60

Phone : 040-66623032

Mobile : +91 8125303032

e-mail : info.gmpublication@gmail.com

web : www.gatemasterspublication.com

Authors

Subject Experts of Gate Master's Academy, Hyderabad.

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INDEX

DESIGN OF REINFORCED CONCRETE STRUCTURES

TSPSC AEE SYLLABUS

Concrete Structures: Materials, permissible stresses and IS Specifications; Working stress methods; Limit State Method - Stress Blocks parameters, design of Beams, Slabs, Columns and Footing; Design for Shear and Torsion; Design of Retaining Walls, Water tanks, and T-Beam Slab bridges; Yield line theory.

Pre-Stressed Concrete: Basic concepts, material for pre-stressing, losses in Prestress, classification of pre-stressing system; Analysis of PSC Sections.

APPSC AEE SYLLABUS

Limit state design for bending, Shear, Axial compression, and combined forces. Code provision for slabs, Beams, Columns, and footings. Principles of prestressed concrete design, Materials, Methods of prestressing, losses. Design of simple members and determinate structures. Design of brick masonry as per IS codes.

SSC-JE SYLLABUS

RCC beams-flexural strength, shear strength, bond strength, design of singly reinforced and double reinforced beams, cantilever beams. T-beams, lintels. One way and two way slabs, isolated footings. Reinforced brick works, columns, staircases, retaining wall, water tanks (RCC design questions may be based on both Limit State and Working Stress methods).

1 INTRODUCTION TO RCC, MATERIALS & DESIGN METHODS

INTRODUCTION

- Concrete is one of the most common building materials used for construction of civil engineering structures like buildings, bridges, pavements, dams, hydraulic structures, water tanks, auditorium, swimming pools,….etc.

Types of Concrete

- **Plain concrete:**
  - It consists of any binding material, sand, gravel & water, with or without admixtures

Why concrete is essentially used?

- It has high compressive strength.
- It can be easily moulded into any shape & size
- It can resist fire & corrosion.
- It is relatively cheaper & widely available.

- **Drawbacks:**
  - It cannot resist the significant tension. The tensile strength of concrete is about 10% of its compressive strength.
  - It is used where tensile stresses/ strains never develop.

Ex: Pedestals, Mass concreting in dams.

Reinforced Concrete:

Reinforce: Strengthening of any material

- We know that, concrete has high compressive strength, but its tensile strength is very low. In any situation where tensile stresses are developed is resisted by Steel bars forming a composite material which is known as Reinforced Cement Concrete.

Properties of Hardened Concrete

- **Compressive strength of concrete:**
  - The characteristic compressive strength of 150mm size cube at the age of 28 days $\pm$ 2hrs expressed in N/mm^2.
- **Characteristic strength of cube:**
  - The strength below which not more than 5% of test results are expected to fall.

Note : As per IS456:2000, the minimum grade of concrete to be used in RCC

- M20 [General construction works not for constructions]

- M30 [Sea construction works]

  M-Mix
- 20-Compressive strength of concrete @ 28 days

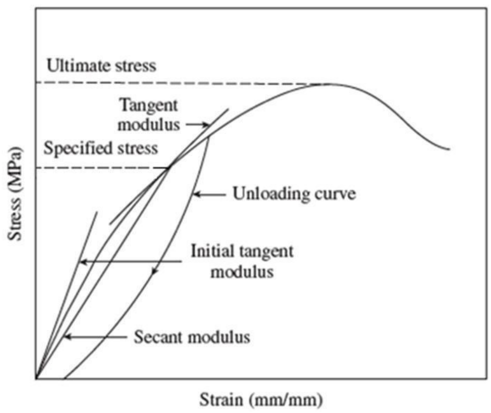
- **Grade of concrete:**

Ordinary concrete	M10 to M20
Standard concrete	M25 to M55
High strength concrete	M60 to M80

Note : Minimum grade of concrete is based on durability to which the structure is exposed.

- **Tensile strength:**
  - Tensile strength of concrete is very low, usually varying from 10 to 20% of its compressive strength.
  - It is measured in terms of Splitting tensile strength of cylindrical specimens.
  - As per code: $f_t = 0.7\sqrt{f_{ck}}$. (flexural tensile strength of concrete)
- **Bond strength:**
  - It is shear stress at interface of reinforcement of concrete developed to resist the slippage of bar relative to its surrounding concrete.
- **Modulus of Elasticity/Young's modulus (E)**
  - It is required for computations of deflection for R.C members.
  - In laboratory calculation of E, a cylinder is loaded/unloaded for three/four cycles, stress-strain is plotted, average slope of stress strain curve is taken.
- **Initial tangent modulus of elasticity:**

  Slope of stress strain curve at origin



- **Tangent Modulus :** Slope of tangent at any point on stress strain curve
- **Secant modulus of elasticity:**

  Slope of line joining any point on stress-strain curve to origin.

  Short term modulus of elasticity $=(E_c)=5000\sqrt{f_{ck}}$
- **Long term modulus of elasticity:** Considered effects of creep and shrinkage.

$$E_{long} = \frac{E_c}{1+\theta}$$

$$\text{Where, } \theta = \text{creep coefficient} = \frac{\text{Ultimate creep strain}}{\text{Elastic strain}}$$

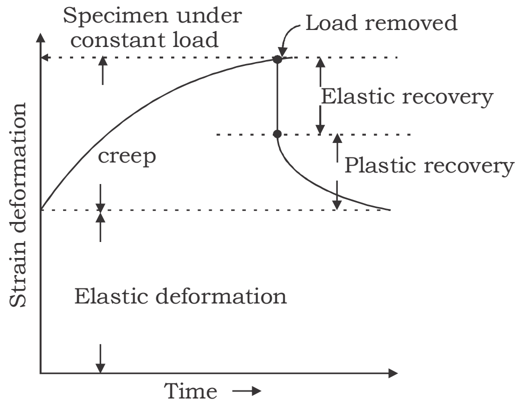
Days	θ
7 days	2.2
28 days	1.6
1 year	1.1

Note : Higher the value of "θ" lower will be the Elong and Higher will be the deflection.

- **Poissons ratio (μ):** It is the ratio of Lateral strain to longitudinal strain. (μ)
  - μ = 0.1 (High strength concrete)
  - μ = 0.2 (Weak concrete)
  - μ = 0.15 (Design purpose)
  - μ = 0.2 (Serviceability criteria)
- **Shrinkage**:
  - It is the Decrease in volume during the process of drying & hardening of concrete
  - Depends upon ingredients of concrete and environmental conditions.

Note : Shrinkage strain is independent of stress condition.

  - If restrained, shrinkage strains can cause cracking of concrete. 0.0003 shrink age strain is taken for design purpose.
- **Creep of Concrete:**
  - It is defined as the Plastic deformation (time dependent) under constant load or sustained loads.
  - If the load is removed, the part of the strain which is immediately recovered is called Elastic Recovery.



Reinforcement

- Generally, steel bars are used to reinforce the concrete to resist tensile stresses which are resulting from the applied loads.
- **Properties :**
  - High strength.
  - High modulus of elasticity.
  - Ability to develop a good bond with concrete.
  - Easy availability.
- **Types:**
  - Mild Steel (Fe-250 N/mm^2)
  - HYSD bars (Fe-450 & Fe-500) (TOR Steel)

    Fe $\rightarrow$ ferrous

    250, 450, 500 ; Yield stress (N/mm^2)
- **Advantages:**
  - Tensile strength is very high
  - It can develop good bond with concrete.
- **Functions:**
  - To resist the bending of beams, Slabs, water tanks etc.
  - To increase the load carrying capacity of compression members.
  - To resist the diagonal tension developed due to shear
  - To reduce the shrinkage of concrete.

Requirement of concrete covers:

- Protection against corrosive materials like chlorides, sulphates, etc
- Protection to steel against corrosion.

Exposure Condition	Description	Minimum Nominal Cover	Minimum Cement	Minimum Grade of Concrete	Maximum W/C Ration
Mild	Protected from rainfall	20 mm	300kg/m^3	M 20	0.55
Moderate	- Exposed to normal rain - Permanently submerged into normal water	30 mm	300kg/m^3	M 25	0.50
Severe	- Coastal area - Alternate drying and wetting - Exposed to heavy rainfall	45 mm	320kg/m^3	M 30	0.45
Very Severe	- Sea water spray - Alternate drying and wetting in sea water - Permanently submerged into sea water	50 mm	340kg/m^3	M 35	0.45
Extreme	- Subjected to tidal zone - Subjected to aggresive chemicals	75 mm	360kg/m^3	M 40	0.40

DESIGN PRINCIPLES

INTRODUCTION

Any member should be designed to satisfy the following two requirements

- Strength Criteria [Max. load carrying capacity]
- Serviceability Criteria [Should not undergo excessive deflections]

Strength (safety)

Note : Collapse may leads to various reasons such as exceeding the load carrying capacity, overturning etc. It should resist the max load carrying capacity, overturning, sliding, fatigue,....etc

- **Serviceability:**
  - Satisfactory performance of structure under service load, without discomfort to user due to excessive deflections, cracking, vibrations.
- **Analysis:** Calculation of Axial forces, Shear force, Bending moment and Twisting moments.etc
- **Design:**

  The main aim of Design is to decide the size of members [Beam column, slab] and amount of reinforcement is required so that the structure will perform satisfactorily during its life period with minimum cost.

Requirements of a Structure:

- To sustain all types of loads.
- To sustain deformation during & after construction.
- Should have adequate durability.
- Should resist secondary stresses [Temperature, creep, etc].

Basic Methods of Design

- Working Stress method (IS 456 : 1964)
- Ultimate Load method
- Limit State method (IS 456 : 2000)

Working Stress Method

- First method accepted by all national codes
- Based on elastic theory, assumes that the *Structural material behaves in a linear* elastic manner $\sigma \propto \varepsilon$[for both materials]
- At any cross-section, plane sections before bending remain plane after bending. This means that unit strain above and below the neutral axis are proportional to the distance from the neutral axis.
  - The concrete and steel reinforcement are well bonded. This means that the tensile strain in concrete surrounding the steel is equal to the tensile strain in the steel reinforcement.
  - All tensile stresses are taken by the reinforcement alone and none by the concrete. This means that while calculating the moment of resistance of the beam, the contribution of the concrete in the tensile zone is to be completely neglected.
  - Modulus of elasticity of conrete is constant at all stresses and is not a function of duration of stress. Young's modulus of concrete is generally found by secant method from the stress-strain curve.
  - Steel reinforcement is free from initial stresses when it is embedded in concrete.

Material	FOS
Concrete	3 to 4
Steel	$1.78 \simeq 1.80$

- $$\text{FOS} = \frac{\text{Strength of material}}{\text{Allowable stress / Permissible / Design stress}}$$
- Members are designed only for working loads.

Note : "FOS" taken accounts for any uncertainities involved in estimation loads and material properties.

- Strength criteria only considered.

Drawbacks

- Failure criteria is stress but strain criteria is reliable

Ultimate Load Method

- Improvement over the WSM
- Structural members are designed for ultimate loads only.

  Ultimate or Design loads = Load factor × Service load
- Safety in the design of structure taken care by load factor.
- *Non-linear stress-strain curve* accounted for stress induced in the structure at the verge of failure.
- It gives more economical sections, i.e slender sections of beams & columns as compared to WSM
- Slender section sometimes result in excessive deflection or crack width under service loads

Limit State

It the state of about to collapse", beyond which the structure is not in practical use, i.e either the structure collapse/becomes unserviceable.

Limit state of collapse:

It is the state which is able to withstand design loads against collapse. Collapse may arise from i) Rupture of one/more critical sections, ii) loss of static equilibrium due to overturning/sliding.

It deals with

- Flexure
- Shear
- Torsion
- Compression

Limit state of serviceability:

It is the state which is able to perform under service load without discomfort to user.

- Deflection
- Cracking
- Vibrations

- **Limit State of Collapse (Safety Requirements):** It is the limit state at which the structure as likely to collapse. The limit state of collapse of the structure or part of the structure could be assessed from rupture of one or more critical sections and from buckling due to elastic or plastic instability or overturning.

  The following limit states of collapse are considered in design:

  - Limit state of collapse in flexure
  - Limit state of collapse in compression
  - Limit state of collapse in shear
  - Limit state of collapse in torsion

- **Limit state of serviceability:** Limit state of serviceability relate to the performance of the structure at working loads. The limit states of serviceability consists of

  - Excessive deflection

- Premature or excessive cracking
- Other limit states (Like Vibration, Durability, Fire Resistance)

Loads

Dead loads (IS 875 - Part - I)

For beams: B x D x γ

γ = Unit weight of concrete

For slabs: D x γ

Live loads or Super imposed loads (IS 875 - Part-II)

Residential buildings: $2kN/m^2$

Hospital & hostels: $3kN/m^2$

Class rooms, Restaurants: $4kN/m^2$

Wind loads (IS 875 - Part-III)

Horizontal loads caused by wind.

Design of wind velocity } $V_z = k_1k_2k_3V_y$

Where,

k_1= Probability (or) Risk factor

K_2= Based on terrain, height

k_3=Torography factor

Design wind (P_z) = 0.6 V_z^2

Snow loads (IS 875 - Part-IV)

- Important for in areas having snow fall
- **Special Loads (IS 875 - Part-V)**
- Special loads and load combinations

IS456:2000 Codal Recommendations

- **Characteristic strength:**

  It is the strength below which not more than 5% of the test results are expected to fall.

Ex: **For concrete :** Characteristic strength of concrete

For steel : Yield strength.

- **Characteristic load:**

  It is the load which has 95% probability of not being exceeded during the life of structures.

Characteristic load = Working load /service load.

- **Partial safety factors**
- For Materials (division)
- For Loads (multiplication)

Note : The factors by which characteristic strength values are divided to get design strength are termed as the partial safety factor.

Limit State	Concrete	Steel
Collapse	1.50	1.15
Serviceability	1.0	1.0

- **Loads:** It is multiplying factor used to ↑ the characterisic load to obtain the design load.

Design load $F_D = \gamma_f F$ γ_f - Partial safety factor F - Characteristic load

Values of partial safety factor γ_f for various limit state based nature of loading.

Load Combination	Limit State of Collapse			Limit State of Serviceability		
	DL	LL	WL	DL	LL	WL
DL+LL	1.5	1.5	-	1.0	1.0	-
DL+WL+EL	1.5 or 0.9*	-	1.5	1.0	-	1.0
DL+LL+WL/EL	1.2	1.2	1.2	1.0	0.8	0.8

Note : 0.9* is applicable when stability against overturning stresses is critical Design load or factoral load

Design strength of material

- Actual strength of concrete: 0.67 f_{ck}

Design strength of concrete $= \dfrac{0.67 f_{ck}}{1.5} = 0.45 f_{ck}$

- Steel: f_y (yield stress)

Design stress $= \dfrac{f_y}{1.15} = 0.87\ f_y$

CLASSWORK

1. Consider the following statements related to both the working stress design and ultimate strength design of reinforced concrete:

   1. Plane section before bending remains plane after bending
   2. The tensile strength of concrete is ignored.

   Which of these statements is/are correct?

   a) 1 alone b) 2 alone
   c) Both 1 and 2 d) Neither 1 nor 2

2. In limit state design of reinforced concrete, deflection is computed by using

   a) Initial tangent modulus
   b) Secant modulus
   c) Tangent modulus
   d) Short and long-term values of Young's modulus

3. What should be the minimum grade of reinforced concrete in and around sea coast construction?

   a) M35 b) M30 c) M25 d) M20

4. What is the value of flexural strength of M25 concrete ?

   a) 4.0MPa b) 3.5MPa
   c) 3.0MPa d) 1.75MPa

5. Grade of steel is designated as Fe415, if

   a) The upper yield stress of the steel is 415N/mm^2
   b) The ultimate stress of the steel is 415N/mm^2
   c) The partial safety factor is 1.15
   d) The characteristic strength is 415N/mm^2

6. Factor of safety is the ratio of

   a) Tensile stress to working stress
   b) Compressive stress to working stress
   c) Bending stress to working stress
   d) Yield stress to working stress

7. What is the pH value of potable water, as specified by IS 456: 2000?

   a) Equal to 7. b) Between 6 and 9
   c) Less than 6 d) Not less than 6

8. Long term elastic modulus in terms of creep coefficient (θ) and 28-day characteristic strength (f_{ck}) is given by

   a) $\frac{5000\sqrt{f_{ck}}}{1+\theta}$ MPa b) $\frac{50000\sqrt{f_{ck}}}{1+\theta}$ MPa
   c) $\frac{5000f_{ck}}{1+\sqrt{\theta}}$ MPa d) $\frac{5000\sqrt{f_{ck}}}{\sqrt{1+\theta}}$ MPa

9. As per IS456-2000, which one of the following correctly expresses the modulus of elasticity of concrete? (read with the relevant units)

   a) $E_c = 0.7\sqrt{f_{ck}}$ b) $E_c = 500\sqrt{f_{ck}}$
   c) $E_c = 5000\sqrt{f_{ck}}$ d) $E_c = 5700\sqrt{f_{ck}}$

Practice Questions

Level - 1

1. A concrete mix of good workability should have a minimum water cement ratio of **(APPSC AEE 2003)**

a) 0.20 b) 0.40 c) 0.60 d) 0.80

2. M 120 grade concrete indicates a compressive strength of 120.0 MPa of **(APPSC AEE 2003)**

a) 200 mm cubes at 28-days

b) 150 mm cylinders a 28-days

c) 150 mm cubes at 28-days

d) 200 mm cubes at 56-days

3. Flexural tensile strength of M25 grade concrete is **(APPSC AEE 2003)**

a) 3.5 MPa b) 5.0 MPa

c) 2.5 MPa d) 1.5 MPa

4. The maximum cement content in concrete should not exceed **(APPSC AEE 2004, AEE 2011)**

a) 350.0 kg/m^3 b) 450.0 kg/m^3

c) 500.0 kg/m^3 d) 550.0 kg/m^3

5. Water used for mixing of concrete should be **(APPSC AEE 2004)**

a) Slightly acidic b) Free from bacteria

c) Distilled d) Potable

6. The minimum quantity of cement content needed in one m^3 of a reinforced concrete which is exposed to sea weather conditions is (in kg) **(AEE 2011)**

a) 250 b) 350 c) 450 d) 550

7. The relation between modulus of rupture (f_{cr}) and characteristic compressive strength (f_{ck}) is given by **(TSPSC AEE 2015)**

a) $f_{cr}=0.7\ f_{ck}$ b) $f_{cr} = 0.7\sqrt{f_{ck}}$

c) $f_{cr}=0.75\ f_{ck}$ d) $f_{cr} = \frac{0.7}{\sqrt{f_{ck}}}$

8. The grade of concrete generally not used in the reinforced concrete is **(TSPSE AE 2015)**

a) M40 b) M25 c) M20 d) M10

9. One of the following is not used in RCC members design **(PH & Municipality 2001)**

a) Working stress method

b) Limit state method

c) Ultimate method

d) Plastic analysis

10. Characteristic load on a structure has a probability of being **(APPSC AEE 2003)**

a) Exceeded 95 percent

b) Not exceeded 5 percent

c) Exceeded 5 percent

d) Not exceeded 99 percent

11. Partial safety factor of the material considered for concrete is**(TSPSC AE 2015)**

a) 0.87 b) 1.15 c) 1.50 d) 2.00

12. The partial safety factor for Steel as per IS 456-2000 is taken as**(TSPSC AE 2015)**

a) 1.15 b) 1.35 c) 1.50 d) 1.65

13. According to IS 456-2000, the maximum strain in concrete at the outermost compression fibre in the limit state design of flexural members is **(TSPSC AE 2015)**

a) 0.0020 b) 0.0035

c) 0.0050 d) 0.0065

14. Mean target strength [f_t] is given by (where f_{ck} is 28 day Characteristic compressive strength and 'S' is Standard deviation.) **(TSPSC AEE 2015)**

a) $f_t=f_{ck}-0.65$ s b) $f_t=f_{ck}+1.65$ s

c) $f_t=f_{ck}+0.65$ s d) $f_t=f_{ck}-1.65$ s

15. The minimum grade of concrete for moderate environment is

(APPSC AEE 2019)

a) M15 b) M20 c) M25 c) M30

16. Minimum cement content for severe exposure and corresponding minimum grade of concrete as per IS 456 are

(APPSC AEE 2019)

a) 240 kg and M25 b) 250 kg and M25

c) 250 kg and M20 d) 250 kg and M30

17. The ultimate strain in concrete in bending is assumed in the IS code as

(APPSC AEE 2019)

a) 0.002 b) 0.0035

c) 0.003 d) 0.004

18. The characteristic strength of concrete is

a) Higher than the average cube strength

b) Lower than the average cube strength

c) The same as the average cube strength

d) Higher than 90% of the average cube strength

19. The cylinder strength of the concrete is less than the cube strength because of

a) The difference in the slenderness

b) The difference in the slenderness ratio of the specimens

c) The friction between the concrete specimens and the steel plate of the testing machine

d) The cubes are tested without capping but the cylinders are tested with capping

20. The characteristic strength of concrete is defined as that compressive strength below which not more than

a) 10% of results fall

b) 5% of results fall

c) 2% of results fall

d) None of the above

21. As per IS 456:2000 recommend actions the total shrinkage strain is

a) 0.003 b) 0.0003

c) 0.67 d) 0.05

22. The property of a fresh concrete which makes the mixing water rise up to the surface while placing and finishing is called **[TS Transco-2018]**

a) Segregation b) Bleeding

c) Bulking d) Slumping

23. In working stress design the shape of the stress block is assumed to be

[TS Transco-2018]

a) Rectangular b) Triangular

c) Parabolic d) Parabolic Rectangular

Level - 2

1. Reinforced cement concrete is equally strong in taking **(TS TRANSCO 2015)**

a) Tensile and compressive stresses

b) Compressive and shear stresses

c) Tensile, compressive and shear stresses

d) Tensile and shear stresses

2. If characteristic compressive strength at 28 days is 40 N/mm^2 and the standard deviation is 5 N/mm^2, the target strength at 28 days for concrete mix proportion's. **(APPSE AEE Mains-2016)**

a) 40 N/mm^2 b) 48.25 N/mm^2

c) 43.25 N/mm^2 d) 45 N/mm^{2+}

3. Creep is _______ dependent deformation due to _____ load.

(APGENCO Trainee AE-2017)

a) Stress, dead b) Strain, live

c) Time, sustained d) Time, dead

4. Nominal concrete over in a beam of section 300.0×600.0 mm, span 12.0 m and reinforced with 20 mm diameter bars should not be less than

(APPSE AEE 2003)

a) 20.0 mm in mild exposure

b) 30.0 mm in mild exposure

c) 40.0 mm in very severe exposure

d) 30.0 mm in very severe exposure

5. In limit state method, the characteristic load is defined as mean load plus 'k' times the deviation. If the characteristic load is not to exceed only 5% times the expected life of the structure, the value of 'k' should be : **(AEE 2008)**

a) Zero b) 0.72

c) 1.64 d) None of the above

6. Euler-Bernoulli's bending theory assumes that the beam section is :

(AEE CE/ME 2008)

a) Symmetric about its vertical axis

b) Rectangular

c) Symmetric about the neutral axis

d) Symmetric about vertical and horizontal axes through the centroid

7. Modulus of elasticity of M25 concrete as determined by formula of IS-456 is :

(AEE 2009)

a) 1,24,500 MPa b) 90,125 MPa

c) 25,000 MPa d) 16,667 MPa

8. In the limit state design of concrete structures, the strain distribution is assumed to be **(TSPSc AEE 2015)**

a) Linear b) Non-linear

c) Parabolic d) Rectangular

9. In the designation of a concrete mix, the letter 'M' and the number stand for

(TSPSC AE 2015)

a) Mix and characteristic compressive strength of 100 mm cube at 28 days

b) Mix and characteristic compressive strength of 75 mm cube at 28 days

c) Mix and characteristic compressive strength of 150 mm cube at 28 days

d) Mix and characteristic compressive strength of 125 mm cube at 28 days

10. As a designer, what would be your estimate (in N/mm^2) of the flexural tensile strength of a concrete, whose characteristic cube compressive strength is 25 N/mm^2 **(TSPSC AEE 2018)**

a) 3.0 b) 4.0 c) 2.5 d) 3.5

11. How many cube specimens from a sample ?

a) 5 consecutive non-overlapping

b) 3 consecutive non-overlapping

c) 4 consecutive non-overlapping

d) 2 consecutive non-overlapping

12. The standard deviation suggested by IS 456-2000 for design of grade M20 concrete is **(APPSC AEE 2019)**

a) 3.5N/mm^2 b) 5 N/mm^2

c) 4 N/mm^2 d) 4.5 N/mm^2

13. The preliminary test is repeated if the difference, of compressive strength of three test specimens, exceeds _______

(APPSC AEE 2019)

a) 5 kg/cm^2 b) 15 kg/cm^2

c) 8 kg/cm^2 d) 10 kg/cm^2

14. Characteristic strength of M20 concrete is 20MPa. What is the number of cubes having 28days compressive strength

greater than 20MPa out of 100cubes made with this concrete?

a) All b) 95 c) 80 d) 50

15. Modulus of elasticity of concrete is increased with

a) Higher W/C ratio

b) Shorter curing period

c) Lesser vibration

d) Increase in age

16. What is unit weight of plain concrete and reinforced concrete

a) 25 and 24 b) 24 and 25

c) 24 and 78.5 d) 25 and 78

17. Combination of partial safety factors for loads under limit state of collapse and limit state of serviceability will be

a) 1.5(DL+LL) (or) (DL+WL) (or) 1.2(DL +LL+WL) and DL+0.8(LL+WL)

b) 1.5(DL+LL) and DL+0.8(LL+WL)

c) 1.5(DL+LL) (or) 1.5(DL+WL) (or) of 1.2(DL+LL+WL) and 1.0 (DL+LL) (or) 1.0(DL+WL) (or) DL+0.8(LL+WL)

d) 1.2(DL+LL+WL) and 1.0 (DL+LL) (or) 1.0(DL+WL) (or) DL+0.8(LL+WL)

18. Partial safety factor for concrete and steel are 1.5 and 1.15 respectively, because

a) Concrete is heterogenous while steel is homogeneous

b) The control on the quality of concrete is not as good as that of steel

c) Concrete is weak in tension

d) Voids in concrete are 0.5% while those in steel are 0.15%

19. Modular ratio given in the assumptions of working stress method **[TS SPDCL-2018]**

a) Is the same as the ratio of moduli of steel and concrete

b) Fully takes care of the long term effects such as creep

c) Partially takes care of the longterm effects such as creep

d) Is the reciprocal of Poisson's ratio

20. Which of the limit states takes care of deflections, vibrations and cracking in concrete structures **[TS SPDCL-2018]**

a) Limit state of collapse

b) Limit state of serviceability

c) Limit state of durability

d) Durability

Level - 1

KEY

01. b	02. c	03. a	04. b	05. d	06. d	07. b	08. d	09. d	10. c
11.c	12. a	13. b	14. b	15. c	16. d	17. b	18. b	19. b	20. b
21. b	22. b	23. b							

Level - 2

KEY

01. c	02. b	03. c	04. a	05. c	06. d	07. c	08. a	09. c	10. d
11. c	12. c	13. b	14. b	15. d	16. b	17. c	18. b	19. c	20. b

2 SINGLY REINFORCED BEAMS

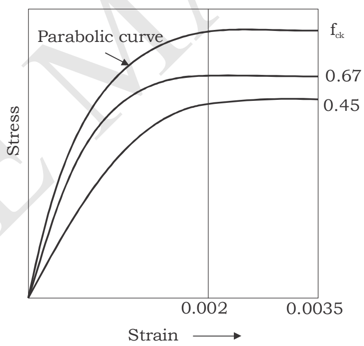
INTRODUCTION

- It deals with proportioning of beams which are primarly subjected to flexural action. The beam can be of any shape. However, rectangular shaped beams being most commonly used.

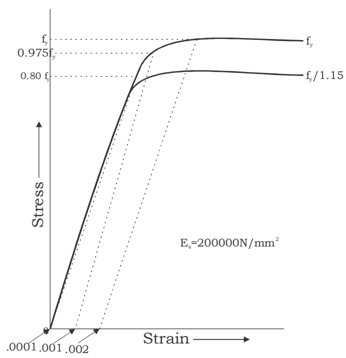
Assumptions in Limit State of Collapse in Flexure

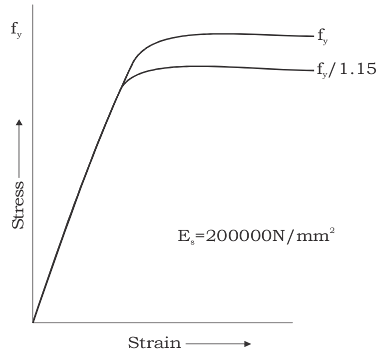
- Plane sections normal to axis remains plane even after bending
- The maximum strain in concrete at the outermost compression fibre is 0.0035 in bending
- The tensile strength of concrete is ignored.
- The steel area is assumed to be concentrated at the centroid of steel.
- The stress-strain curve for design purpose may be assumed to be rectangular, trapezium, parabola, other shape which results in prediction of strength in substantial agreement with the test results
- The maximum strain in the tension reinforcement in the section at failure should not be less than $0.002+\dfrac{0.87f_y}{E_s}$

- **Stress-strain curve for concrete**

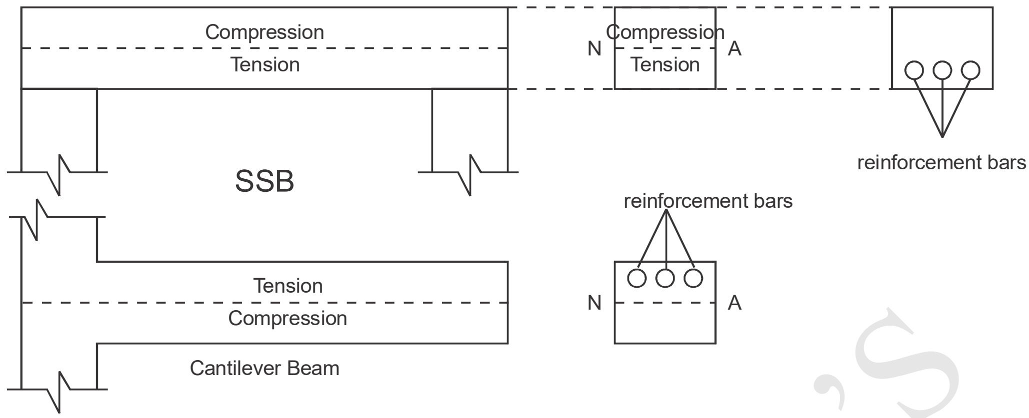


- **Stress-strain curve for HYSD bars**

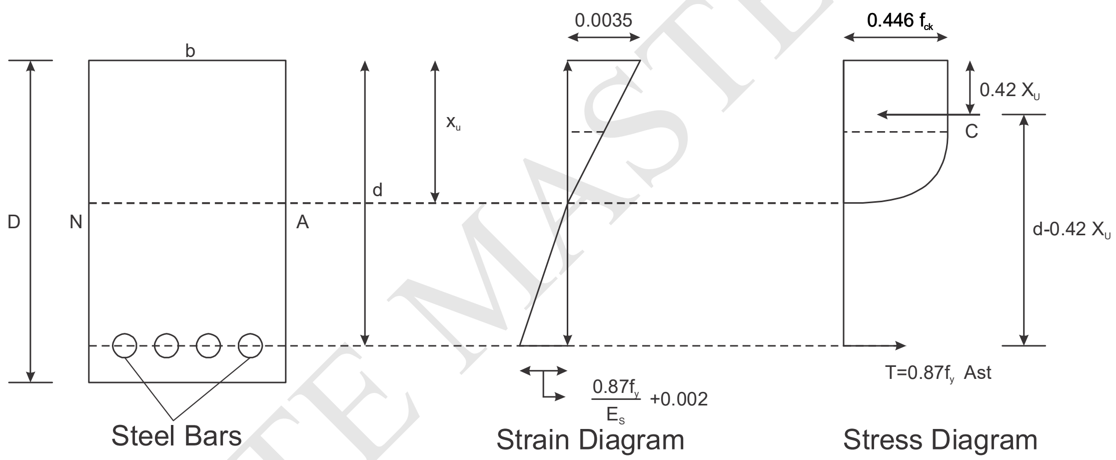




Definition: The amount of steel that is provided only in tension zone, which is known as singly reinforced rectangular beam



Stress-Block Parameters:



Depth of Neutral Axis

- **From the stress block parameters:**
  - Compressive force = C = $0.36f_{ck}bx_u$ (Note: for Balanced Section $x_u = x_{umax}$)
  - Tensile force = T = $0.8\ f_yA_{st}$

$$x_u = \frac{0.87f_yA_{st}}{0.36f_{ck}.b}$$

To find x_u: C=T → for limiting/Balanced section.

f_y	250	415	500
$\frac{x_{u(max)}}{d}$	0.53 (0.531)	0.48 (0.479)	0.46 (0.456)