Chapter 5

Prestressed Concrete

CHAPTER HIGHLIGHTS

- *Introduction*
- *Materials used*
- *Prestressing system*
- *Analysis of prestress*
- *Losses of prestress*

Introduction

This chapter outlines the concept of prestressed concrete. It gives a brief introduction to materials used in prestressed concrete, and analysis of prestressed concrete. The various losses occur during prestressing are also discussed in this chapter.

Definition

Prestressed concrete is the one in which internal stresses of such magnitude and distribution are introduced so that the stresses resulting from given external loadings are counteracted to a desired degree.

- By using prestressed concrete, the entire cross-section of concrete is fully utilized, whereas in RCC, the concrete in compressive zone is only utilized.
- Use of high-tension steel in RCC leads to formation of wider cracks, whereas the prestressed concrete has no cracks due to use of high-tensile steel.

Advantages of Prestressed Concrete

1. Cross-section is more efficiently used in case of fully-prestressed members.
2. Reduced dead weight of structure results in saving the cost of foundation.
3. The use of curve tendons and the precompression of concrete help to resist shear.
4. Improved resistance to impact, reversal of stress, and vibration.
5. Prestressed concrete beams usually have low deflections.

Materials Used

High Strength Concrete (As per IS:1343)

- Minimum grade of concrete: M40 for pretensioned members and M30 for post-tensioned members.
- Minimum cement content of 300 to 360 kg/m^3 is prescribed to meet the durability requirements.
- Maximum cement content in the mix should not exceed 530 kg/m^3.

High Tensile Steel

- High tensile steel generally consists of wires, bars or strands.
- High tensile steel usually contains 0.6–0.85 per cent carbon, 0.7–1 per cent manganese, 0.05 per cent sulphur and phosphorous with traces of silicon.
- Because of superior bond characteristics, high tensile steel wires, indented or crimped, are preferred.
- Small diameter wires of 2–5 mm are mostly used in the form of strands.

- Diameter of high tensile steel bars commonly employed in prestressing are of 10 mm, 12 mm, 16 mm, 20 mm, 22 mm, 25 mm, 28 mm and 32 mm.
- The 0.2 per cent proof stress for high-tensile wires and bars should not be less than 85 and 80 per cent of the minimum specified tensile strength.
- The IS code prescribes a minimum percentage elongation varying from 2.5–10 per cent for bars.
- For strands, the percentage elongation measured on a gauge length of not less than 600 mm should not be less than 3.5 per cent.
- IS:1343 specifies the values of modulus of elasticity of high tensile wires, bars and strands as 210, 200 and 195 kN/mm^2, respectively.

Need for High-Strength Steel and Concrete

- The normal loss of stress in steel is generally about 100–240 N/mm^2. If mild steel is used, the stress in steel is more or less completely lost due to elastic deformation, shrinkage and creep of concrete. Hence, the high strength steel is used to meet the loss of stress in steel.
- High strength concrete has high resistance in tension, bond, shear and bearing and is less liable to shrinkage cracks, smaller ultimate creep strain, higher modulus of elasticity resulting in a smaller loss of prestress in steel. Due to high strength concrete, there is a reduction in the cross-sectional dimensions which, in turn, reduces the dead weight of the material.

Prestressing System

Pretensioning System

- In the pretensioning system, the tendons are first tensioned between rigid anchor blocks and with the form in place, the concrete is cast around the stressed tendon.
- Prestress is mainly transferred to the concrete by bond and no special anchorages are required in pretensioned members.
- For mass production of pretensioned elements, the long line process developed by Hoyer is used.

Post-tensioning System

- In post-tensioning system, the concrete units are first cast by incorporating ducts or grooves to the house of tendons and, when the concrete attains sufficient strength, the high-tensile wires are tensioned by means of jack bearing on the end face of the member and anchored by wedges or nuts.
- Forces are transferred by means of end anchorages and when the cable is curved through radial pressure between cable and duct.
- The post tensioning system based on wedge action includes the Freyssinet, Grifford–Udall, Anderson and Magnel–Blaton anchorages.
- The main advantage of Freyssinet system is that a large number of wires or strands can be simultaneously tensioned using double-acting hydraulic jack.
- Grifford–Udall system is used for tensioning the wires separately.
- In Lee–McCall system, the tendons comprise of high-tensile bars which are threaded at end. After tensioning, each bar is anchored by screwing a nut and washer tightly against the end plates. Lee–McCall system is based on direct bearing.

Applications

Post-tensioning

- Ideally suited for medium to long-span on-site work.
- Most of the long-span bridges are constructed using post-tensioning systems.

Analysis of Prestress

Assumptions

1. Concrete is a homogenous elastic material.
2. Within the range of working stresses, both concrete and steel behave elastically, not withstanding the small amount of creep which occur in both the materials under sustained loading.
3. A plane section remains plane even after bending.

The following notations and sign conventions are used for analysis of prestress:

P = Prestressing force (positive when producing direct compression)

e = Eccentricity of prestressing force

$M = P \cdot e$ = Moment

A = Cross-sectional area of the concrete member

I = Second moment of area of section about its centroid.

Z_t and Z_b = Sections modulus of the top and bottom fibres.

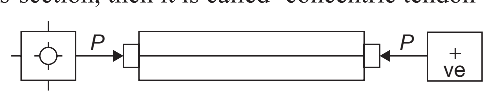
f_t and f_b = Prestress in concrete developed at the top and bottom fibers (positive when compressive and negative when tensile in nature).

y_t and y_b = Distance of the top and bottom fibers from centroid of the section.

r = Radius of gyration.

Concentric Tendon

- If a prestressing force passes through the centroid of the cross-section, then it is called 'concentric tendon'.



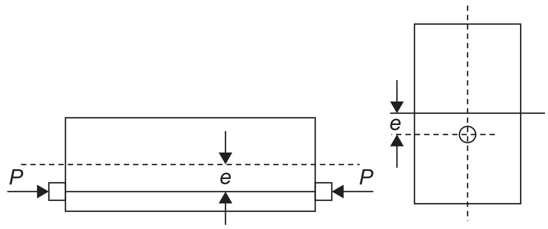
(A) Cross–section (B) Longitudinal stress section = $\frac{P}{A}$

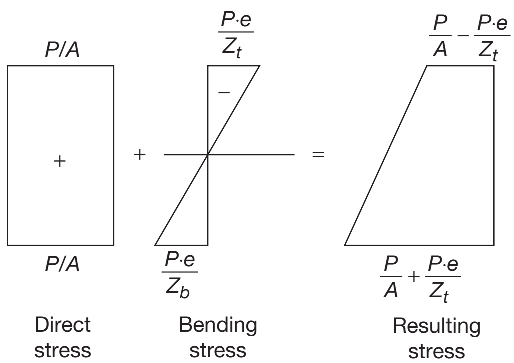
- In case of concentric tendon, a uniform compressive prestress of magnitude P/A develops across the depth of the beam.

Eccentric Tendon

- If a prestressing force is applied at an eccentricity to the centroid of the cross-section, then it is called 'eccentric tendon'.

  The following figure shows a concrete beam subjected to an eccentric prestressing force of magnitude 'P' located at an eccentricity 'e'.





Eccentric prestressing

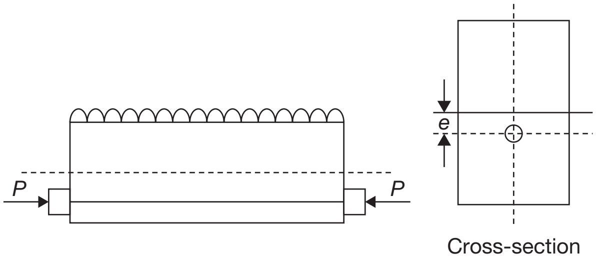
Stresses developed at the top and bottom fibers of the beam are obtained by the relations.

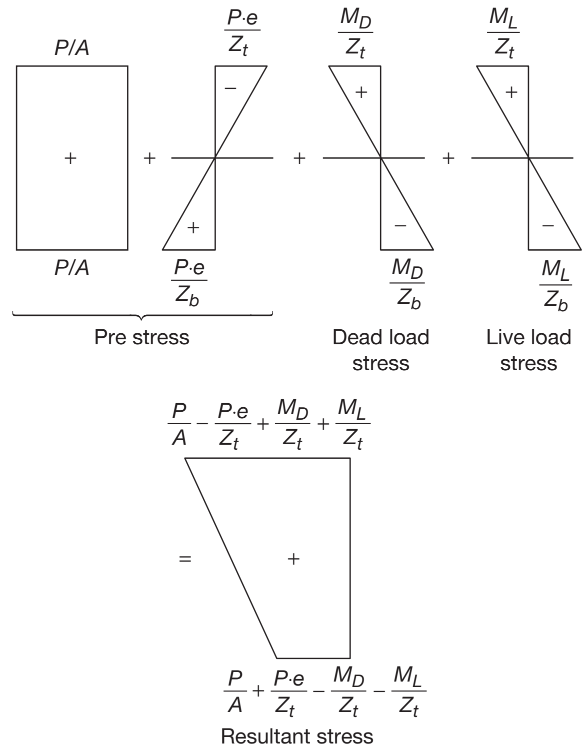
$$f_b = \left(\frac{P}{A} + \frac{P \cdot e}{Z_b}\right) = \frac{P}{A}\left(1 + \frac{ey_b}{r^2}\right)$$

$$f_t = \left(\frac{P}{A} - \frac{P \cdot e}{z_t}\right) = \frac{P}{A}\left(1 - \frac{ey_t}{r^2}\right)$$

Resultant Stress at a Section

- Consider a concrete beam subjected to uniformly distributed live loads (w_L) and dead loads (w_D) is prestressed by a straight tendon carrying prestressing force at an eccentricity 'e'.





- The resultant stresses at the top and bottom fibres of concrete at any given section are:

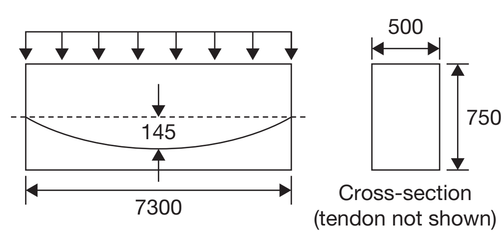
$$f_t = \left(\frac{P}{A} - \frac{P \cdot e}{Z_t}\right) + \left(\frac{M_D}{Z_t}\right) + \left(\frac{M_L}{Z_t}\right)$$

$$f_b = \left(\frac{P}{A} + \frac{P \cdot e}{Z_b}\right) - \left(\frac{M_D}{Z_b}\right) - \left(\frac{M_L}{Z_b}\right)$$

SOLVED EXAMPLE

Example 1

A concrete beam prestressed with a parabolic tendon is shown in the sketch. The eccentricity of the tendon is measured from the centroid of the cross-section. The applied prestressing force at service is 1620 kN. The uniformly distributed load of 45 kN/m includes the self weight. The stress (in N/mm^2) in the bottom fibre at mid-span is **[GATE, 2012]**



All dimensions are in mm

(A) tensile 2.90 (B) compressive 2.90
(C) tensile 4.32 (D) compressive 4.32

Solution

$$f_b = \frac{P}{A} + \frac{P_e}{Z_b} - \frac{M_{DL} + M_{LL}}{Z_b}$$

$$= \frac{1620\times10^3}{500\times750} + \frac{1620\times10^3\times145}{\left(\frac{500\times750^2}{6}\right)} - \frac{\left[\frac{45\times(7.3)^2}{8}\right]\times10^6}{\left(\frac{500\times750^2}{6}\right)}$$

$$f_b = 2.9\text{ MPa }(+)$$

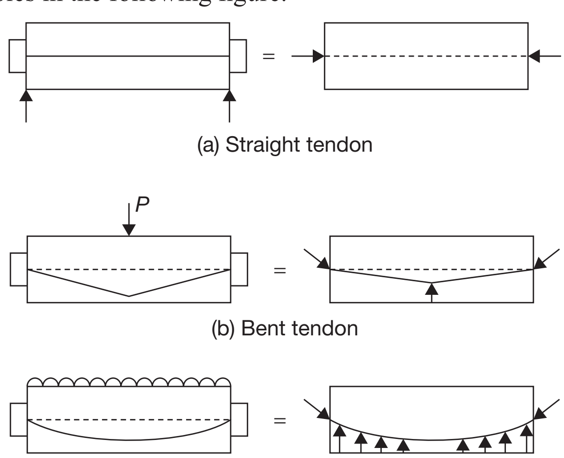
Hence, the correct answer is option (B).

Pressure Line or Thrust Line

- The locus of points of application of the resultant force in any structure is called the 'pressure line' or 'thrust line'.
- In case of prestressed concrete members, the location of pressure line depends upon the magnitude and direction of the moments applied at the cross-section and magnitude and distribution of stress due to the prestressing force.
- A change in the external moments in the elastic range of a prestressed concrete beam results in a shift of the pressure line rather than in an increase in the resultant force in beam.
- Therefore, P-line or thrust line follows the bending moment diagram.

Concept of Load Balancing

- The concept of load balancing is based on that the transverse component of cable forces balances the given type of external loads.
- The requirements will be satisfied if the cable profile in a prestressed member corresponds to the shape of the bending moment diagram resulting from external loads.
- The concept of load balancing is useful in selecting the tendon profile.
- The principle of load balancing is shown with the examples in the following figure.



(a) Straight tendon

(b) Bent tendon

(c) Curved tendon

Losses of Prestress

Loss of prestress is generally referred to gradual reduction of the initial prestress in concrete with time due to various causes.

Types of Losses of Prestress

Pre-tensioning	Post-tensioning
Elastic deformation of concrete	No loss due to elastic deformation if all the wires are simultaneously tensioned. If the wires are successively tensioned, there will be loss of prestress due to elastic deformation of concrete.
Relaxation of stress in steel	Relaxation of stress in steel
Shrinkage of concrete	Shrinkage of concrete
Creep of concrete	Creep of concrete
	Friction
	Anchorage slip

Loss Due to Elastic Deformation of Concrete

The loss of prestress due to elastic deformation of concrete depends on the modular ratio and average stress in concrete at the level of steel.

Loss of stress in steel due to elastic deformation = mf_c

Where

$$m = \text{Modular ratio } = \frac{E_s}{E_c}$$

f_c = Prestress in concrete at the level of steel.

Loss Due to Shrinkage of Concrete

- The primary cause of drying shrinkage is the progressive loss of water form concrete resulting in change in volume of concrete members.
- Surface cracks may develop due to differential shrinkage between the interiors and surface of members.
- The shrinkage of concrete is influenced by the type of cement and aggregates and the method of curing used.
- For example, use of high-strength concrete with low water-cement ratios results in reduction in shrinkage and consequent loss of prestress.
- Loss of stress in steel due to shrinkage of concrete is estimated as $\varepsilon_{cs} \times E_s$.
- Where, ε_{cs} – total residual shrinkage strain having values of 300 × 10^{-6} for pretensioning and $\left[\frac{200\times10^{-6}}{\log_{10}(t+2)}\right]$ for post tensioning

  t = Age of concrete at transfer in days

  E_s = Modulus of elasticity of steel

Loss Due to Creep of Concrete

- Creep of concrete in prestressed member is due to the sustained prestress in concrete resulting in reduction of stress in high tensile steel.
- The various factors influencing the creep of concrete are: relative humidity, stress level, strength of concrete, age of concrete at loading, duration of stress, water/cement ratio and type of cement and the aggregate in concrete.
- Loss of stress in steel due to creep of concrete is estimated by two methods.
- Ultimate creep strain method:

$$\boxed{\text{Loss to creep of concrete} = \varepsilon_{cc}\ f_c\ E_s}$$

Where

ε_{cc} = Ultimate creep strain for a sustained unit stress.

f_c = Compressive stress in concrete at the level of steel.

E_s = Modulus of elasticity of steel.

- Creep coefficient method:

$$\boxed{\text{Loss of strees in steel} = \phi m f_c}$$

Where

$$\phi = \text{Creep coefficient} = \left(\frac{\text{Creep strain}}{\text{Elastic strain}}\right) = \frac{\in_c}{\in_e}$$

m = Modular ratio

f_c = Stress in concrete

Loss Due to Relaxation of Stress in Steel

- Loss of stress due to relaxation of steel is generally taken as a percentage of initial stress in steel.
- The IS code recommends a value varying between 0–90 N/mm^2 for stress in wires varying between 0.5–0.8 f_y.
- Relaxation losses for prestressing steel at 1000 h at 27 ± 2°C for various initial stress are given below.

Initial Stress	Relaxation Stress, MPa
0.5 f_y	0
0.6 f_y	35
0.7 f_y	70
0.8 f_y	90

- This loss is generally taken as the order of 2–8% of the initial stress.

Loss of Stress Due to Friction

- Occurs in post-tensioned members only.
- Loss of stress occurs in post-tensioned members due to the friction between the tendons and surrounding concrete ducts.
- The magnitude of this loss is due to the loss of stress due to curvature effect and also loss of stress due to the Wobble effect (length effect).

$$\boxed{P_x = P_0 e^{-(\mu\alpha + kx)}}$$

Where

P_0 = Prestressing force at the jacking end.

μ = Coefficient of friction between cable and duct (0.25–0.55).

α = The cumulative angle in radians through which the tangent to the cable profile has turned between any two points under consideration.

K = Friction coefficient for wave effect

$(15 \times 10^{-4}$ to $50 \times 10^{-4})e = 2.7183$

For small values of $(\mu\alpha + kx)$, we can write:

$$\boxed{P_x = P_0[1 - (\mu\alpha + kx)]}$$

$$\boxed{\text{Loss of stress} = P_0(\mu\alpha + kx)}$$

Loss Due to Anchorage Slip

- In most post-tensioning systems, slip over a small distance occurs before the wires are firmly fixed between the wedges.
- The magnitude of the slip depends on the type of wedge and the stress in the wires.

$$\boxed{\text{Loss of stress due to anchorage slip} = \left(\frac{P}{A}\right) = \left(\frac{E_s\Delta}{L}\right)}$$

Where

Δ = Slip of anchorage, mm

L = Length of the cable, mm

A = Cross-sectional area of the cable, mm^2

E_s = Modulus of elasticity of steel, N/mm^2

P = Prestressing force in cable, kN.

Exercises

1. In a pre-stressed member, it is advisable to use
(A) low-strength concrete.
(B) high-strength concrete.
(C) high-strength concrete and high-tension steel.
(D) high-strength concrete and low-tension steel.

2. The loss of prestress due to elastic shortening of concrete is least in
(A) one wire pre tensioned beam.
(B) one wire post tensioned beam.
(C) multiple wire pre tensioned beam with sequential cutting of wires.
(D) multiple wire post-tensioned beam with subject to sequential pre-stressing.

3. A uniformly distributed load intensity, w, acting on a simply supported prestressed concrete beam of span, L, producing a bending moment, M, at its mid span is to be balanced by a parabolic tendon with zero eccentricity at ends and eccentricity e, at mid span. The prestressing force required depends on?
(A) w and e (B) w and L
(C) L and e (D) M and e

4. Let jd be the lever arm between the resultant tensile force T in the reinforcing/prestressing steel and the resultant compressive force 'c' in concrete of a reinforced/prestressed concrete beam. When subjected to increase in the external bending moment, which one of the following statements is true in reinforced and prestressed concrete beam?
I. In reinforced concrete beams
(A) T increases at a faster rate than jd.
(B) Both T and jd increases at the same rate.
(C) jd increased at a faster rate than T.
(D) Neither T nor jd decreases.
II. In pre stressed concrete beams
(A) T increases at a faster rate than jd.
(B) Both T and jd increases at the same rate.
(C) jd increases at a faster rate than T.
(D) Neither T nor jd increases.

5. IS:1343–1980 limits the minimum characteristic strength of pre-stressed concrete for post tensioned work and pre-tensioned work as
(A) 25 Mpa, 30 Mpa respectively
(B) 25 Mpa, 35 Mpa respectively
(C) 30 Mpa, 35 Mpa respectively
(D) 30 Mpa, and 40 Mpa respectively

6. As per Indian standard code of practice for pre stressed concrete (IS:1343–1980) the minimum grade, of concrete to be used for post-tensioned and pre-tensioned structural elements are respectively
(A) M20 for both (B) M40 and M30
(C) M15 and M20 (D) M30 and M40

7. A rectangular simply supported prestressed concrete beam of span 'L' is subjected to a prestressing force of P acting centrally at end sections and the prestress tendons are parabolicaly draped with maximum eccentricity of e_{max} at mid span section. The uniformly distributed upwards load (w) on the beam due to prestresing force will be
(A) $16\,P \cdot e_{max}/L^2$ (B) $4\,P \cdot e_{max}/L^2$
(C) $12\,P \cdot e_{max}/L^2$ (D) $8\,P \cdot e_{max}/L^2$

8. A prestressed concrete beam has a cross section with the following properties Area $A = 46,400$ mm^2, $I = 75.8 \times 10^7$ mm^4, $Y_{bottom} = 244$ mm, $Y_{top} = 156$ mm. It is subjected to a prestressing force at an eccentricity 'e' so as to have a zero stress at the top fibre. The value of 'e' given by
(A) 66.66 mm (B) 66.95 mm
(C) 104.72 mm (D) 133.35 mm

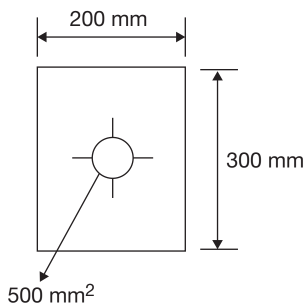
9. A prestressed concrete rectangular beam of size 300 mm × 900 mm is prestressed with an initial prestressing force of 700 kN at an eccentricity of 350 mm at mid span. Stress at the top of the due to prestress alone, in N/mm^2 is
(A) –3.46 (tension)
(B) 2.59 (compression)
(C) zero
(D) 8.64 (compression)

10. A concrete column carries an axial load of 450 kN and a bending moment of 60 kN-m at its base. An isolated footing size 2 m × 3 m side along the plane of the bending moment is provided under the column centers of gravity of column and footing coincide. The net maximum and the minimum pressures in kN-m^2 on soil under the footing are respectively.
(A) 95 and 55 (B) 95 and 75
(C) 75 and 55 (D) 75 and 75

11. A simply supported prestressed concrete beam is 6 m long and 300 mm wide. Its gross depth is 600 mm. It is prestressed by horizontal cable tendons at a uniform eccentricity of 100 mm. the prestressing tensile force in the cable tendons is 1000 kN. Neglect the self weight of beam. The maximum normal compressive stress in the beam at transfer is
(A) zero (B) 5.55 N/mm^2
(C) 11.11 N/mm^2 (D) 15.68 N/mm^2

12. A concrete beam of rectangular cross-section of 200 mm × 400 mm is prestressed with a force of 400 kN at eccentricity 100 mm. The maximum compressive stress in concrete is
(A) 12.5 N/mm^2 (B) 17.5 N/mm^2
(C) 5.0 N/mm^2 (D) 2.5 N/mm^2

13. The cross-section of a pre tensioned pre stressed concrete beam is shown in figure. The reinforcement is place concentrically. If the stress in steel at transfer is 1000 MPa, compute the stress in steel immediately after transfer. The modular ratio is 6.



14. A beam with a rectangular cross-section of size 250 mm wide and 350 mm deep is prestressed by a force of 400 kN. Using 8 number 7 mm ϕ steel cables located at an eccentricity of 75 mm. Determine the loss of prestress due to creep of concrete. Grade of concrete is M40. Coefficient of creep is 2; stress at transfer is 80%, modulus of elasticity of steel (E_s) is 2×10^5 MPa.

15. For prestressed structural elements, high strength concrete is used primarily because
(A) both shrinkage and creep are more.
(B) shrinkage is less but creep is more.
(C) modulus of elasticity and creep values are higher.
(D) high modulus of elasticity and low creep.

16. The magnitude of loss of prestress due to relaxation of steel is in the range of
(A) zero to 1% (B) 2 to 8%
(C) 8 to 12% (D) 12 to 14%

17. The ultimate strength of the steel used for prestressing is nearly
(A) 250 N/mm^2 (B) 415 N/mm^2
(C) 500 N/mm^2 (D) 1500 N/mm^2

18. Match List I (post-tensioning system) with List II (type of anchorage) and select the correct answer using the codes given below the lists:

	List I		List II
a.	Freyssinet	**1.**	Flat steel wedges in sandwich plates
b.	Gifford–Udall	**2.**	High strength nuts
c.	Lee–McCall	**3.**	Split conical wedges
d.	Magnel–Blaton	**4.**	Conical serrated concrete wedges

Codes:

	a	b	c	d
(A)	2	1	4	3
(B)	4	3	2	1
(C)	2	3	4	1
(D)	4	1	2	3

Direction for questions 19 and 20:

A post tensioned concrete beam 120 mm wide and 300mm deep is prestressed by three cables each with a cross-sectional area of 60 mm^2 and with an initial stress of 1100 MPa. All the three cables are straight and located 100 mm from the sofit of the beam. If the modular ratio is 6, the loss of stress due to elastic shortening in the beam

19. When simultaneous tensioning and anchoring of all the three cables is done will be
(A) 24.51 MPa (B) 43.92 MPa
(C) 78.26 MPa (D) zero

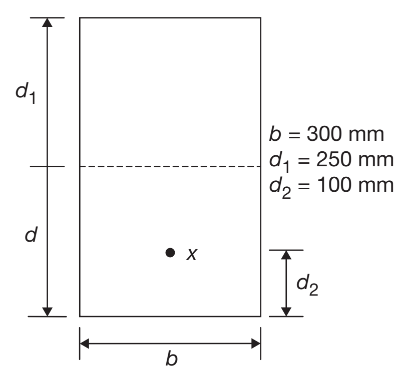
20. When successive tensioning of the three cables are done (one at a time)
(A) 24.51 MPa (B) 43.92 MPa
(C) 78.26 MPa (D) zero

21. As per Indian standard code of practice for pre-stressed concrete (IS:1343–1980) the minimum grades of concrete to be used for pre-tensioned and post tensioned structural element are respectively
(A) M40 and M30 (B) M30 and M40
(C) M30 for both (D) M40 for both

22. Which of the following is categorized as a long term loss of pre-stress in a pre-stressed concrete member?
(A) Loss due to friction
(B) Loss due to elastic shortening
(C) Loss due to anchorage slip
(D) Loss due to relaxation of strands

23. A pre-stressed concrete beam of size 300 mm × 900 mm is pre stressed with an initial pre-stressing force of 800 kN at an eccentricity of 400 mm at mid span. Stress at top of the beam due to pre stress alone, (in N/mm^2) is ______.
(A) 2.86 (B) 3.94
(C) –4.94 (D) 10.863

24. In a prestressed concrete beam section shown in figure, the net loss is 10% and the final pre-stressing force applied at x is 800 kN. The initial fiber stresses (in N/mm^2) at the top and bottom of the beam were

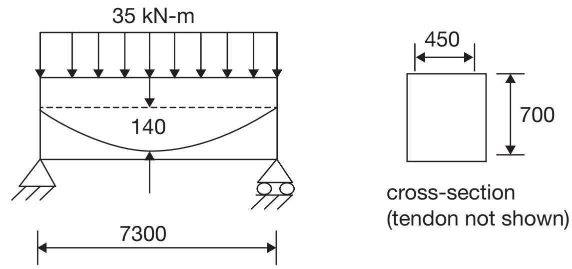


(A) 4.736 and –16.576
(B) –5.736 and 16.576
(C) –4.736 and 16.576
(D) –5.736 and –16.576

25. The percentage loss of presstress due to anchorage slip of 3 mm in a concrete beam of length 25 m which is post-tensioned by a tendon with an initial stress of 1000 N/mm^2 and modulus of elasticity is equal to 2.1×10^5 N/mm^2, is

(A) 2.5
(B) 3.5
(C) 4.5
(D) 3

26. A concrete beam prestressed with a parabolic tendon is shown in the sketch. The eccentricity of the tendon is measured from the centroid of the cross-section. The applied pre-stressing force at service is 1500 kN. The uniformly distributed load applied is 35 kN-m, includes its self-weight.



(All dimensions are in mm)

The stress (in N/mm^2) in the bottom fibre at mid-span is

(A) 4 (B) 10.4
(C) 3 (D) 5.4

Previous Years' Questions

1. The percentage loss of prestress due to anchorage slip of 3 mm in a concrete beam of length 30 m which is post tensioned by a tendon with an initial stress of 1200 N/mm^2 and modulus of elasticity equal to 2.1×10^5 N/mm^2 is **[GATE, 2007]**

(A) 0.0175 (B) 0.175
(C) 1.75 (D) 17.5

2. A concrete beam of rectangular cross-section of size 120 mm (width) and 200 mm (depth) is pre stressed by a straight tendon to an effective force of 150 kN at an eccentricity of 20 mm (below the centroidal axis in the depth direction). The stresses at the top and bottom fibers of the section are **[GATE, 2007]**

(A) 2.5 N/mm^2 (compression), 10 N/mm^2 (compression)
(B) 10 N/mm^2 (tension), 2.5 N/mm^2 (compression)
(C) 3.75 N/mm^2 (tension)
(D) 2.75 N/mm^2 (compression), 3.75 N/mm^2 (compression)

3. A pre-tensioned concrete member of section 200 mm × 250 mm contains tendons of area 500 mm^2 at center of gravity of the section. The prestress in the tendons is 1000 N/mm^2. Assuming modular ratio as 10, the stress (N/mm^2) in concrete is **[GATE, 2008]**

(A) 11 (B) 9
(C) 7 (D) 15

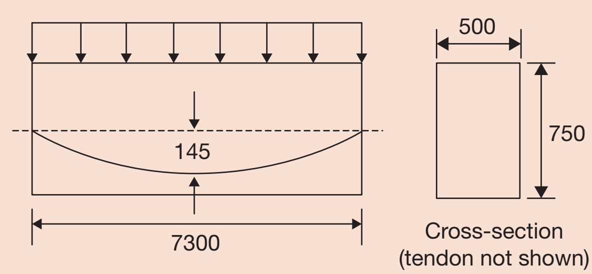
4. A rectangular concrete beam of width 120 mm and depth 200 mm is prestressed by pretensioning to a force of 150 kN at an eccentricity of 20 mm. The cross sectional area of the prestressing steel is 87.5 mm^2. Take modulus of elasticity of steel and concrete as 2.1×10^5 MPa and 3.0×10^4 MPa respectively. The percentage loss of stress in the pre stressing steel due to elastic deformation of concrete is **[GATE, 2009]**

(A) 8.75 (B) 6.125
(C) 4.81 (D) 2.19

5. Which of the following is categorized as a long term loss of prestress in a pre stressed concrete member? **[GATE, 2012]**

(A) Loss due to elastic shortening
(B) Loss due to friction
(C) Loss due to relaxation of strands
(D) Loss due to anchorage slip

6. A concrete beam prestressed with a parabolic tendon is shown in the sketch. The eccentricity of the tendon is measured from the centroid of the cross-section. The applied prestressing force at service is 1620 kN. The uniformly distributed load of 45 kN/m includes its selfweight. The stress (in N/mm^2) in the bottom fibre at mid-span is **[GATE, 2012]**

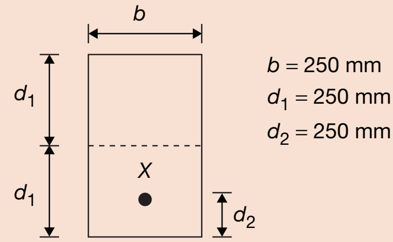


All dimensions are in mm

(A) tensile 2.90
(B) compressive 2.90
(C) tensile 4.32
(D) compressive 4.32

7. Creep strains **[GATE, 2013]**
(A) caused by dead loads only.
(B) caused by live loads only.
(C) caused due to cyclic loads only.
(D) independent of loads.

8. In a pre-stressed concrete beam section shown in the figure, the net loss is 10% and the final pre-stressing force applied at X is 751 kN. The initial fiber stresses (in N/mm^2) at the top and bottom of the beam were **[GATE, 2015]**



(A) 4.166 and 20.833
(B) –4.166 and –20.833
(C) 4.166 and –20.833
(D) –4.166 and 20.833

Answer Keys

Exercises

1. C	**2.** B	**3.** D	**4.** (i) A (ii) C	**5.** D	**6.** D	**7.** D	**8.** C	**9.** A
10. A	**11.** C	**12.** A	**13.** 950 MPa	**14.** 63 MPa		**15.** D	**16.** B	**17.** D
18. B	**19.** D	**20.** B	**21.** A	**22.** D	**23.** C	**24.** C	**25.** A	**26.** A

Previous Years' Questions

1. C	**2.** A	**3.** B	**4.** B	**5.** C	**6.** B	**7.** A	**8.** D