Applied Mechanics Department,

Shantilal Shah Engineering College, Bhavnagar

2970611: Design of Prestressed Concrete structures

Tutorial:1: Introduction

1 What is the basic principle of prestressed concrete?

2 Why did the early attempts in prestressing using ordinary mild steel fail?

3 Bring out the difference between concentric and eccentric prestressing.

4 What is the minimum concrete strength requirements prescribed for prestressed concrete members in IS: 1343 code?

5 Distinguish between pretensioned and post-tensioned members.

6 Explain the principle of post-tensioning.

7 Write advantages and disadvantages of prestressed concrete

8 What is the necessity of using high-strength concrete and high tensile steel in prestressed concrete?

9 Distinguish between the terms (a) uniaxial (b) biaxial and (c) triaxial pre-stressing?

10 Differentiate between full prestressing and partial prestressing.

11 What is non-distortional prestressing?

12 What is the necessity of using supplementary or untensioned reinforcement in prestressed concrete members?

Tutorial:2: Losses in Prestress

1 A pretensioned beam of rectangular cross-section, 150 mm wide and 300 mm deep, is prestressed by eight, 7 mm wires located 100 mm from the soffit of the beam. If the wires are initially tensioned to a stress of 1100 N/mm^2, calculate their stress at transfer and the effective stress after all losses, E_s = 210 kN/mm^2, E_c = 31.5 kN/mm^2 given the following data:

	Up to time of transfer	Total
Relaxation of steel	35 N/mm^2	70 N/mm^2
Shrinkage of concrete	100 x 10^{-6}	300 x 10^{-6}
Creep coefficient	—	1.6

[Ans: 977.5 N/mm^2, 793.6 N/mm^2]

2 In a post-tensioned beam of length 12 m, a cable is laid symmetrically, with its central 6 m length horizontal and the two straight end-portions sloping up at an angle with the horizontal whose tangent is equal to 0.075. The cable is tensioned by jacking at one end and is anchored at the remote end of the beam. At the jacking end the measured stress is 1040 N/mm^2. The 'wobble' coefficient K may be assumed as 0.004/m. Calculate the stress in the cable at the remote end and at the two points where the alignment of the cable changes. Assume the coefficient of friction between cable and duct as 0.40. What is the percentage loss of prestress between the jacking end and the anchored end?

[Ans: Stress at first kink = 996 N/mm^2
Stress at second kink = 972 N/mm^2
Stress at anchored end = 928 N/mm^2
Percentage loss = 10.8%]

3 A prestressed concrete girder is post-tensioned using a cable concentric at supports and having an eccentricity of 400 mm at the centre of span. The effective span of the girder is 25 m. The initial force in the cable is 400 kN at the jacking end A. Determine the loss of force

in the cable due to friction and wave effect and the effective force in the cable at the farther end B. Assume coefficient of friction m = 0.30 and coefficient for Wave effect K = 0.0043/m.

[Ans: Loss of prestressing force = 28 kN:
Prestressing force at B = 372 kN]

4 A cylindrical water tank having an external diameter of 50 m is to be prestressed circumferentially by means of high tensile wire cables jacked at four points, 90 degrees apart. If the minimum stress in the cable wires immediately after tensioning is 500 N/mm^2 and the coefficient of friction is 0.5, estimate (a) the maximum stress to be applied to the wires at the jacking end, (b) the expected extension at the jack. Assume the modulus of elasticity of steel as 210 kN/mm^2.
Assume the modulus of elasticity of steel as 210 kN/mm^2.

[Ans: Stress in wires at jacking end = 1102 N/mm^2;
Extension at the jacking end = 149.7 mm]

5 A post-tensioned cable of a beam 10 m long is initially tensioned to a stress of 1000 N/mm2 at one end. If the tendons are curved so that the slope is 1 in 15 at each end with an area of 600 mm2, calculate the loss of prestress due to friction, given the following data:

- Coefficient of friction between duct and cable = 0.55
- Friction coefficient for wave effect = 0.0015/m
- During anchoring, if there is a slip of 3 mm at the jacking end, calculate the final force in the cable and the percentage loss of prestress due to friction and slip.

[Ans: 526.6 kN; 12.3 per cent]

Tutorial:3: Flexural Design of Prestressed Concrete Elements

1	The cross-section of a symmetrical I-section prestressed beam is 300 mm by 750 mm (overall), with flanges and web 100 mm thick. The beam is post-tensioned by cables containing 48 wires of 5 mm diameter high-tensile steel wires at an eccentricity of 250 mm. The 28-day strength of concrete in compression is 40 N/mm2 and the ultimate tensile strength of wires is 1700 N/mm2. Assuming that the grouting of the tendons is 100 per cent effective, determine the ultimate moment of the section. **[Ans: 571 kN m]**
2	A post-tensioned prestressed concrete T-beam with unbonded tendons is made up of a flange 300 mm wide and 150 mm thick and the width of the rib is 150 mm. The effective depth of the section is 320 mm. The beam is prestressed by 24 wires each of 5 mm diameter having a characteristic strength of 1650 N/mm^2. The effective stress after all losses is 900 N/mm^2. If the cube strength of concrete is 56 N/mm^2, estimate the flexural strength of the section. Assume (L/d) ratio = 20. **[Ans: 185.2 kN m]**
3	A double T-section having a flange 1200 mm wide and 150 mm thick is prestressed by 4700 mm2 of high-tensile steel located at an effective depth of 1600 mm. The ribs have a thickness of 150 mm each. If the cube strength of concrete is 40 N/mm2 and tensile strength of steel is 1600 N/mm2, determine the flexural strength of the double T-girder. **[Ans: 9069 kN m]**
4	An unsymmetrical I-section has an overall depth of 2000 mm. The top flange width and depth are equal to 1200 and 300 mm, respectively, and the bottom flange width and depth are equal to 750 and 200 mm, respectively. The thickness of the web is 300 mm. The tendons having a cross-sectional area of 7000 mm^2 are located 200 mm from the soffit. If the ultimate compressive strength of concrete and the tensile strength of steel are 42 and 1750 N/mm^2 respectively, and the tendons are effectively bonded to concrete, estimate the flexural strength of the section.

	[Ans: 15366 kN m]
5	An unsymmetrical I-section bridge girder has the following section properties: Width and thickness of top flange = 1200 and 360 mm, respectively, thickness of web = 240 mm, centroid of section located at 580 mm from the top, the girder is used over a span of 40 m, and the tendons (bonded) with a cross-section of 7000 mm^2 are parabolic with an eccentricity of 1220 mm at the centre of span and zero at the supports. Given f_{cu} = 45 N/mm^2 and f_{pu} = 1700 N/mn^2, estimate the ultimate flexural strength of the centre-of-span section. **[Ans: 17416 kN m]**
6	A concrete beam with a rectangular section 100 mm wide and 300 mm deep, is stressed by three cables, each carrying an effective force of 240 kN. The span of the beam is 10 m. The first cable is parabolic with an eccentricity of 50 mm below the centroidal axis at the centre of span and 50 mm above the centroidal axis at the supports. The second cable is parabolic with zero eccentricity at the supports and an eccentricity of 50 mm at the centre of span. The third cable is straight with a uniform eccentricity of 50 mm below the centroidal axis. If the beam supports a uniformly distributed live load of 5 kN/m and Ec = 38 kN/mm^2, estimate the instantaneous deflection at the following stages: (a) Prestress + self-weight of beam. (b) Prestress + self-weight + live load. **[Ans: (a) 32.9 mm (upward); (b) 43.6 mm (downward)]**
7	A prestressed concrete highway tee beam and slab bridge has the following design parameters: • Overall depth of slab = 200 mm Effective depth = 165 mm • Reinforcements: 10 mm diameter bars at 125 mm c/c • fck = 25 N/mm^2, fy = 415 N/mm^2 • At the service load moment, the stress in steel is 228 N/mm^2 • Depth of neutral axis = 41 mm • Modulus of elasticity of steel = 200 kN/mm^2 Using the IS: 456-2000 code method, estimate the width of crack in the slab. **[Ans: 0.13 mm]**

8	A Freyssinet anchorage (125 mm diameter), carrying 12 wires of 7 mm diameter stressed to 950 N/mm2, is embedded concentrically in the web of an I-section beam at the ends. The thickness of the web is 225 mm. Evaluate the maximum tensile stress and the bursting tensile force in the end block using IS 1343 method. Design the reinforcement for the end block. **[Ans: 5 N/mm^2; 125 kN; 550 mm^2]**
9	A high-tensile cable comprising 12 strands of 15 mm diameter (12 K15 of PSC Freyssinet system) with an effective force of 2500 kN is anchored concentrically in an end block of a post-tensioned beam. The end block is 400 mm wide by 800 mm deep and the anchor plate is 200 mm wide by 260 mm deep. Design suitable anchorage zone reinforcements using Fe-415 grade HYSD bars using IS: 1343 code provisions. **[Ans: Bursting tension = 425 kN, Ast = 1177 mm^2, 10 mm-diameter bars spaced at 100 mm centres both ways over a length of 400 mm from the end face]**

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Tutorial:4: Shear and Torsional Strength Design

1	The horizontal prestress at the centroid of a concrete beam of rectangular crosssection 120 mm and 250 mm, is 7 N/mm^2 and the maximum shearing force on the beam is 70 kN. Calculate the maximum principal tensile stress. What is the minimum vertical prestress required to eliminate this principal tensile stress? **[Ans: 1.4 N/mm^2; 1.75 N/mm^2]**
2	A prestressed concrete beam having an unsymmetrical I-section, has a fibre stress distribution of 13 N/mm2 (compression) at the top edge and linearly reducing to zero at the bottom. The top flange width and thickness are 2400 and 400 mm, respectively, the bottom flange width and thickness are 1200 and 900 mm, respectively, and the depth and thickness of the web are 1000 and 600 mm, respectively. The total vertical service-load shear in the concrete at the section is 2350 kN. Compute and compare the principal tensile stress at the centroidal axis and at the junction of the web with the lower flange. **[Ans: At centroidal axis, tensile stress = 0.7 N/mm^2 At junction of web and bottom flange = 0.85 N/mm^2]**
3	The support section of a prestressed concrete beam, 100 mm wide by 250 mm deep, is required to support an ultimate shear force of 80 kN. The compressive prestress at the centroidal axis is 5 N/mm^2. The characteristic cube strength of concrete is 40 N/mm^2. The cover to the tension reinforcement is 50 mm. If the characteristic tensile strength of stirrups is 415 N/mm^2, design suitable shear reinforcements in the section using IS code recommendations. **[Ans: 8 mm diameter two-legged stirrups at 150 mm centres]**
4	A post-tensioned bonded prestressed concrete beam of rectangular section 350 mm wide by 700 mm deep, is prestressed by an effective force of 180 kN acting at an eccentricity of 190 mm. At service-load conditions, a section of the beam is subjected to a bending moment of 250 kN m, a torsional moment of 100 kN m and a transverse shear force of 100 kN. If

	fck = 40 N/mm^2, fy = 415 N/mm^2, fp = 1600 N/mm^2, design suitable longitudinal and transverse reinforcements in the section. **[Ans: Longitudinal reinforcement: three bars of 25 mm diameter Transverse reinforcement: 12 mm diameter two-legged stirrups at 100 mm centres]**
5	A tee beam section has a flange width and thickness of 500 mm and 200 mm, respectively. The web is 200 mm thick and 600 mm deep. The beam spanning over 16 m is prestressed using a cable carrying an effective force of 2000 kN. The cable is parabolic with an eccentricity of 600 mm at centre of span and 300 mm at supports. Estimate the ultimate shear resistance at the support section. Also, evaluate the maximum permissible uniformly distributed working load on the beam assuming a load factor of 2 and characteristic compressive strength of concrete as 40 N/mm^2. **[Ans: V_{cw} = 541 kN, w_w = 33.8 kN/m]**

Tutorial:5: Prestressed Compression and Tension Members

1	Design the prestressing force required for the tie member of reinforced concrete truss. The service-load tension in the tie member is 360 kN and the thickness of the member is fixed as 150 mm. The permissible compressive stress in concrete at transfer is 15 N/mm^2 and tension is not permitted under service loads. The loss ratio is 0.8. High-tensile wires of 7 mm diameter, tensioned to a stress of 1000 N/mm^2 and having an f_{pu} = 1500 N/mm^2 are available for use. The tensile strength of concrete is 2.5 N/mm^2. A load factor of 1.7 at the limit state of collapse and 1.2 against cracking is to be provided in the design. **[Ans: Section 150 mm by 200 mm; Prestressing force = 450 kN; Number of 7 mm wires = 12]**
2	A prestressed concrete compression member with a square cross-section of 400 mm a side is reinforced with four strands of 12.7 mm diameter at each corner with an effective cover of 50 mm. If fps = 1650 N/mm^2, fck = 40 N/mm^2, fpe = 1000 N/mm^2 and Eps = 200 kN/mm^2, construct the load-moment interaction diagram and determine the maximum moment capacity of the section and the corresponding axial load. Assume suitable data regarding the strains in concrete and steel. **[Ans: P_u = 2000 kN, M_u = 220 kN m]**
3	What are the advantages of prestressing in the design of concrete members subjected to axial tension? What are the load factors generally specified against cracking and collapse in such members?