

Precast and Prestressed Concrete Structures (315317)

MSBTE K-Scheme · Civil Engineering Semester 5 · Model Question Paper — Set B · Model Answers

Q.1 Attempt any FIVE of the following: (10 M)

a) Structural precast elements

2 M

Structural precast concrete elements:

1. Fencing and electric transmission poles
2. Paver blocks (interlocking)
3. Door and window frames
4. Manhole covers and frames
5. Precast welded mesh (fabric) panels
6. Slab panels, beams, columns, lintels, chajjas and staircase flights

(Any four, $\frac{1}{2}$ M each)

b) Types of concrete for precast elements

2 M

Types of concrete (any four):

1. Plain cement concrete (PCC)
2. Reinforced cement concrete (RCC)
3. Prestressed concrete (PSC)
4. Self-compacting concrete (SCC)
5. Ferro-cement
6. Autoclaved aerated concrete (AAC)

($\frac{1}{2}$ M each)

c) Module and basic module

2 M

Module: A module is a standard unit of length used as the basic increment for coordinating dimensions of buildings and their components, so that components fit together without cutting.

Basic module M = 100 mm (multi-modules 3M = 300 mm, 6M = 600 mm, 12M = 1200 mm are used for planning).

(Definition 1 M, value 1 M)

d) Prestressed concrete; types of prestressing steel

2 M

Prestressed concrete is concrete in which internal stresses of suitable magnitude and distribution are deliberately introduced (by stretched high-tensile steel) so that the stresses produced by external loads are counteracted to a desired degree.

Types of prestressing steel: high-tensile wires (plain / indented), strands (2-, 3- and 7-wire), cables (groups of wires/strands) and high-tensile alloy bars.

(Definition 1 M, types 1 M)

e) Assumptions in analysis of PSC beam

2 M

1. Concrete is a homogeneous, elastic material.
2. Within the range of working stresses, both concrete and steel behave elastically (small creep is ignored).
3. A plane section before bending remains plane after bending, i.e. strain varies linearly with depth.

(Any two, 1 M each)

f) Eccentric straight and parabolic cable profiles

2 M

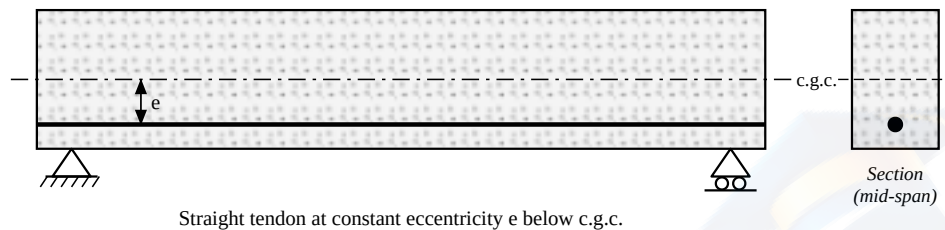


Fig.: Eccentric straight cable (constant e)

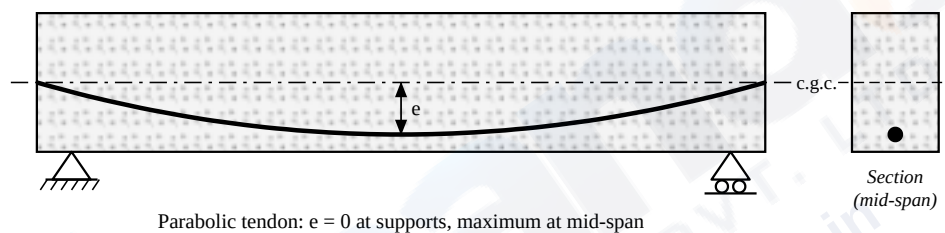


Fig.: Parabolic cable ($e = 0$ at supports, maximum at mid-span)

(Each sketch 1 M)

g) Types of losses of prestress

2 M

1. Loss due to elastic deformation (shortening) of concrete
2. Loss due to shrinkage of concrete
3. Loss due to creep of concrete
4. Loss due to relaxation (creep) of steel
5. Loss due to friction (post-tensioning)
6. Loss due to anchorage slip (post-tensioning)

(Any four, $\frac{1}{2}$ M each)

Q.2 Attempt any THREE of the following: (12 M)

a) Advantages and disadvantages of precast concrete

4 M

Advantages

1. Faster construction – casting and site work go on simultaneously.
2. Better quality, accurate dimensions and good surface finish (factory control).
3. Formwork and scaffolding at site are reduced; moulds are reused.

4. Economical for repetitive, mass production of standard units.
5. Construction is possible in all seasons; site is cleaner with less wastage.
6. Members can be pre-tensioned (prestressed) easily in the factory.

Disadvantages

1. Heavy handling, transport and erection equipment (cranes, trailers) is required.
2. Joints between members need careful design and workmanship; they are weak points for leakage and continuity.
3. Members may get damaged (cracks, broken edges) during handling and transport.
4. Not economical for small or non-repetitive work; high initial cost of factory and moulds.
5. Less flexibility – late design changes are difficult; transport size limits member size.

(Any two advantages 2 M, any two disadvantages 2 M)

b) Precast door and window frame sections

4 M

Precast RCC door and window frames (IS 6523) are cast in steel moulds in place of timber frames.

- Section is about 100 mm × 60–75 mm with a **rebate** for the shutter; window frame has a sloping (weathered) sill.
- Reinforcement: 4 bars of about 6 mm Ø at the corners with 3–6 mm stirrups at about 150 mm c/c; cover about 15 mm.
- Holdfasts (3 on each side) are embedded for fixing into masonry; hinges/fixtures are fixed to embedded inserts or wooden plugs.
- Advantages: termite and fire proof, no warping, cheaper than good timber, long life.

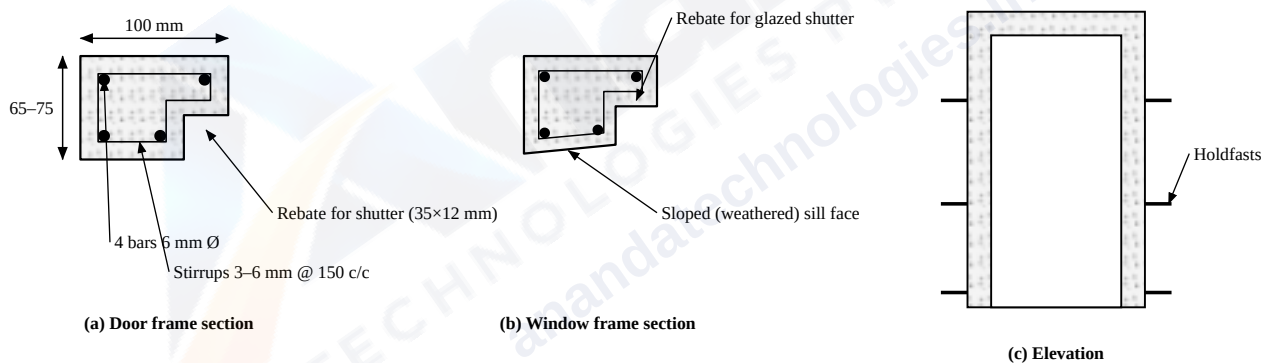


Fig.: Precast RCC door and window frame sections showing reinforcement

(Sketches with reinforcement 3 M, points 1 M)

c) Manhole cover and precast mesh

4 M

i) Manhole covers:

- Circular/rectangular precast RCC or steel-fibre reinforced concrete (SFRC) cover with a precast frame (IS 12592).
- Made in light, medium and heavy-duty grades depending on traffic; edge is protected by an MS ring.
- Lifting key holes are provided; frame is bedded on the chamber wall with mortar.
- Cheaper than cast iron, no theft value, corrosion free.

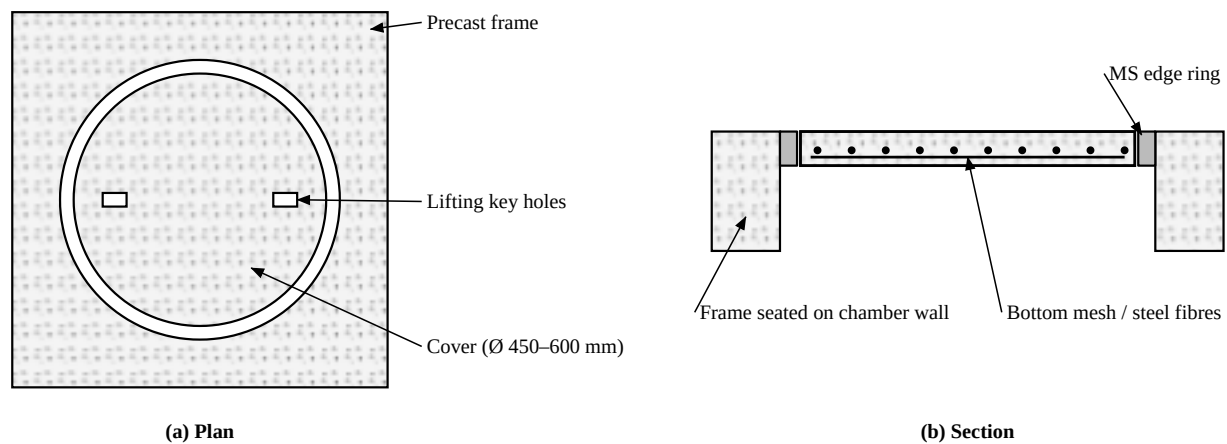


Fig.: Precast RCC / SFRC manhole cover with frame – plan and section

ii) Precast mesh:

- Welded wire fabric (IS 1566) – high-strength wires placed at right angles and electrically welded at every crossing.
- Supplied in rolls/sheets cut to size; used as reinforcement in precast slabs, wall panels, pipes, manhole covers and paver slabs.
- Saves time of tying bars, gives accurate spacing and good crack control.

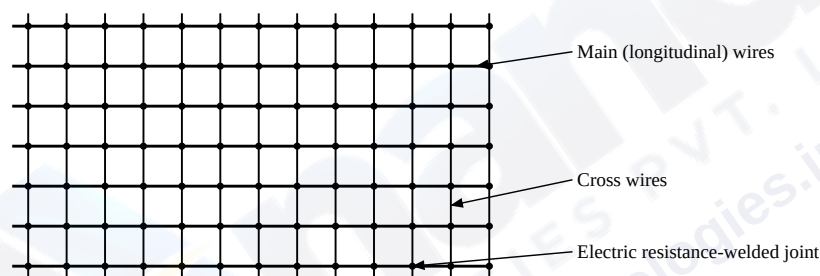


Fig.: Precast welded wire mesh (fabric) used in precast units

(Each element 2 M (description + sketch))

d) Tests on precast elements; load test

4 M

Tests to check quality of precast elements:

1. Dimensional check and visual inspection (size, squareness, cracks, honeycombing).
2. Compressive strength of concrete cubes cast with the units (at demoulding, transfer and 28 days).
3. **Load (flexural) test** on a sample unit.
4. Non-destructive tests – rebound hammer, ultrasonic pulse velocity, cover-meter for cover.
5. Water absorption and breaking load / tensile splitting test (paver blocks), abrasion test.

Load test (explained):

1. A sample unit (beam / slab panel) is placed on supports at its design span.
2. Load is applied in increments by a jack through a spreader beam (two-point loading) or by sandbags.
3. Deflection at mid-span is read with a dial gauge at every increment; cracks are observed.

4. The full test load is kept for 24 hours, deflection is recorded, then the load is removed and recovery is noted.
5. The unit is acceptable if there is no visible damage and the deflection/recovery satisfy the limits of the code (IS 456 load-test criteria).

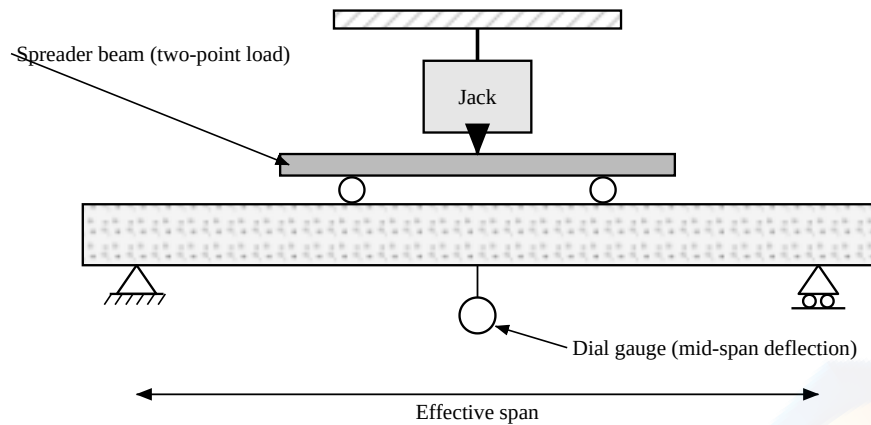


Fig.: Flexural (load) test on a precast beam / slab panel

(List 1 M, explanation of one test 3 M)

Q.3 Attempt any THREE of the following: (12 M)

a) Requirements of structural joints with sketch

4 M

Requirements:

1. **Strength:** the joint must safely transfer all forces (axial load, shear, bending moment) between the members.
2. **Ductility and stability:** it should deform without sudden failure (important in earthquakes).
3. **Durability:** steel inserts and bars in the joint must be protected from corrosion; good cover/grout.
4. **Water-tightness and weather resistance** (external joints sealed against rain and air).
5. **Accommodate tolerances and movements** due to temperature, shrinkage and creep.

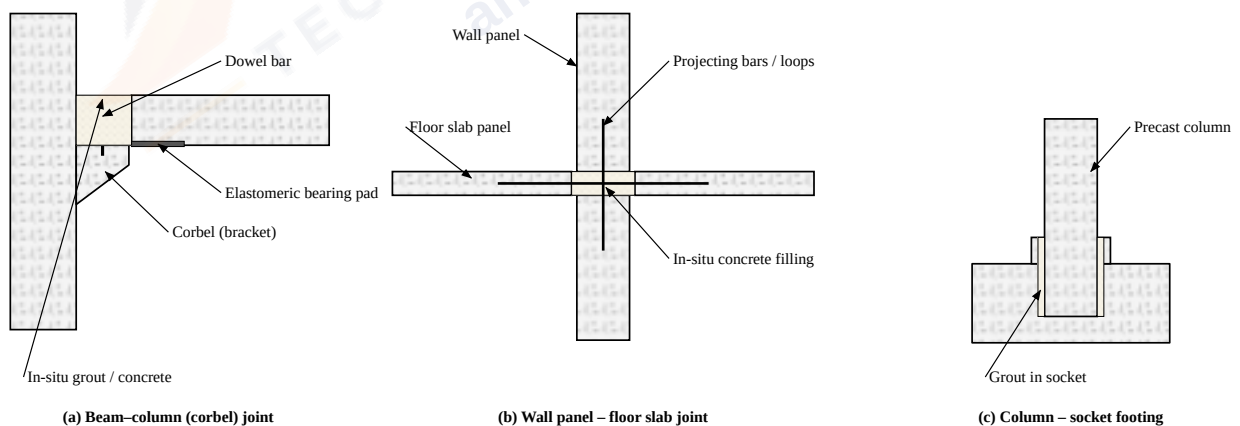


Fig.: Typical structural joints in prefabricated construction

Beam-column (corbel) joint: the precast beam is seated on the column corbel over an elastomeric bearing pad; a dowel bar from the corbel passes into a sleeve in the beam and the gap is filled with

non-shrink grout, so vertical load and horizontal shear are transferred.

(Requirements 2 M, sketch with explanation 2 M)

b) Mixed vs composite construction

4 M

Mixed construction	Composite construction
Two or more construction systems/materials are used in the same building, each acting separately .	Precast and cast-in-situ concrete (or steel and concrete) are bonded so that they act together as one unit .
E.g. precast slab panels resting on load-bearing brick walls; RCC frame with precast wall panels.	E.g. precast beam with in-situ deck slab connected by shear connectors (T-beam action).
No special shear connection between the parts.	Shear connectors / projecting stirrups / roughened surface are essential.
Each part is designed for its own load.	Section is designed as a composite section with larger depth and stiffness.
Simple, flexible, uses locally available materials.	Economical for bridges and long spans; reduces formwork (precast acts as form).

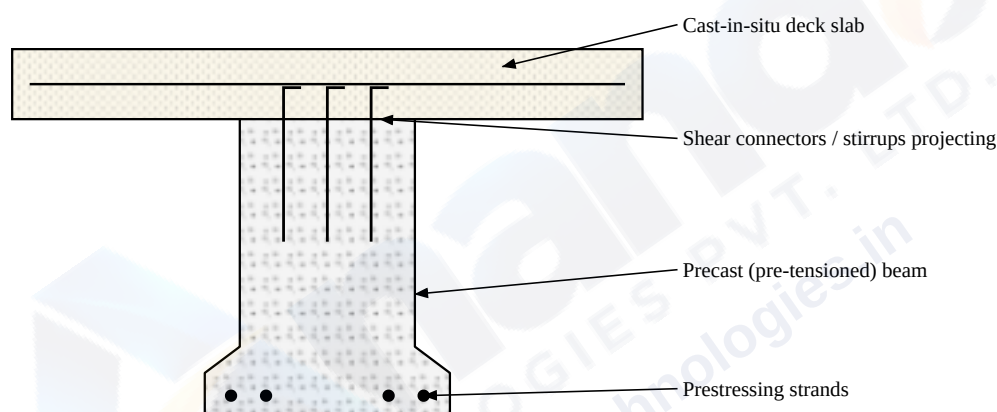


Fig.: Composite construction – precast beam with cast-in-situ slab acting together

(Any four points, 1 M each)

c) Prestressed concrete vs reinforced concrete

4 M

Prestressed concrete (PSC)	Reinforced concrete (RCC)
High-strength concrete (M30 and above; IS 1343: M30 post-tensioned, M40 pre-tensioned).	Normal concrete M20–M30.
High-tensile steel (1500–1900 N/mm ² wires/strands).	Mild steel / HYSD bars (Fe 250–Fe 550).
Steel is stretched (active) before load is applied.	Steel is passive – stressed only when load comes.
Whole concrete section is effective; no cracks under working load.	Concrete below neutral axis is cracked and neglected.
Smaller depth, lighter members; suitable for long spans.	Larger depth and self weight; suitable for short/medium spans.

Deflection is small (camber); good fatigue and shear resistance.	Deflection larger; cracks may lead to corrosion.
Needs jacks, anchorages and skilled workers.	Simple construction with ordinary skill.

(Any four points, 1 M each)

d) Use of wire, strand, cable and bar

4 M

Steel form	Situation where used	Justification
Wire (single, 3–8 mm)	Pre-tensioned small mass-produced members – railway sleepers, poles, hollow-core and plank slabs.	Small diameter gives large surface area for bond; indented wires anchor by bond alone.
Strand (7-wire)	Long-line pre-tensioning beds; post-tensioned slabs and girders.	Flexible, available in long lengths, high force per unit, good bond.
Cable (group of wires/strands in a duct)	Large post-tensioned bridge girders, box girders, long-span beams.	Very large prestressing force from one anchorage; can follow curved (parabolic) profiles.
Tendon as bar (10–40 mm)	Short members, vertical / transverse prestressing, ties, anchors, segmental joints.	Stiff; anchored by threads and nuts; easily coupled; low loss due to anchorage slip in short lengths.

Note: 'Tendon' is the general name for any stretched element (wire, strand, cable or bar) used to impart prestress.

(Each with justification, 1 M each)

Q.4 Attempt any THREE of the following: (12 M)

a) Loading stages of a prestressed member

4 M

A prestressed member passes through the following stages, and stresses must be checked at each:

- Initial stage (tensioning and transfer):** tendons are stretched; at transfer the full initial prestress P_i acts with only self weight – maximum compression at the bottom, possible tension at the top.
- Intermediate stage:** handling, transportation and erection of the member; dead loads of slabs/finishes are added; supports may differ from final ones.
- Final (service) stage:** after all losses the effective prestress P_e acts with dead + live load – check maximum compression at top and tension at bottom.
- Ultimate stage:** behaviour under overload up to collapse (cracking load, ultimate flexural and shear strength).

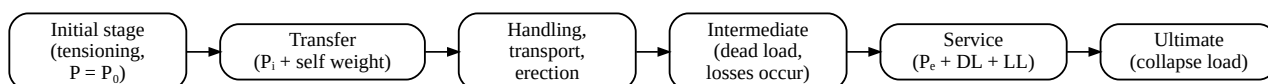


Fig.: Loading stages of a prestressed concrete member

(Stages with explanation 4 M)

b) Gifford-Udall system

In the **Gifford-Udall system (U.K.)** each wire is tensioned and anchored separately. Each wire passes through a tube unit and is gripped by a **split conical wedge (two halves)** seated in a **steel anchor barrel / thrust ring** which bears on a bearing plate at the end of the member. The wire is pulled by a light jack, the wedges are pushed into the barrel and the jack is released; the duct is then grouted.

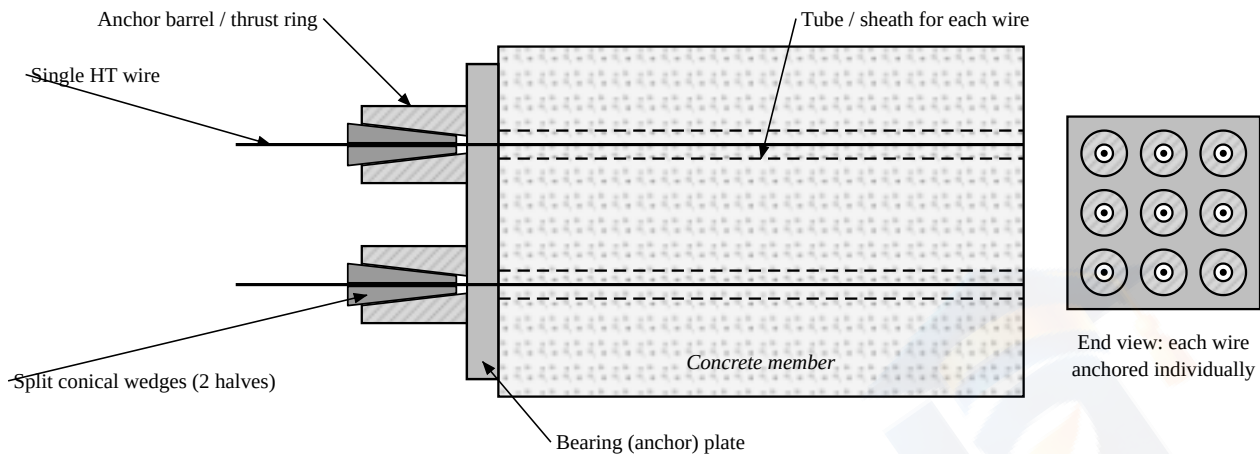


Fig.: Gifford-Udall system – split-cone wedge anchorage for single wire

Merits:

1. Each wire is stressed individually, so force in every wire is accurately controlled.
2. Light, portable jacks are enough.
3. Anchorages are simple and cheap; same grips also used for pre-tensioning.
4. Suitable for any number of wires; flexible arrangement.

Demerits:

1. Slow – each wire tensioned and anchored separately.
2. Large number of anchorages for big cables; more space required at the ends.
3. Not economical for very large prestressing forces.
4. Wedge slip loss can be significant in short members.

(Explanation with sketch 2 M, merits 1 M, demerits 1 M)

c) Friction and anchorage-slip losses (numerical)

Given: cable length $L = 20$ m, parabolic with central dip $h = 400$ mm, $\mu = 0.35$, $k = 0.0015$ per m, stress at jacking end $f_{pi} = 1200$ N/mm², tensioned from one end, anchorage slip $\Delta = 5$ mm, $E_s = 200$ kN/mm².

Step 1 – Total angle change α

For a parabola $y = 4h \cdot x(L - x)/L^2$, slope at each end $= 4h/L = 4 \times 0.4/20 = 0.080$ rad.

Total change of angle from one end to the other $\alpha = 2 \times 4h/L = 8h/L = \mathbf{0.160 \text{ rad}}$

Step 2 – Loss due to friction (curvature effect + wave/wobble effect)

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

$$\mu\alpha + kL = 0.35 \times 0.160 + 0.0015 \times 20 = 0.0560 + 0.0300 = 0.0860$$

Stress at far end = $1200 \times e^{-0.0860} = 1200 \times 0.9176 = 1,101.11 \text{ N/mm}^2$

Friction loss = $1200 - 1,101.11 = 98.89 \text{ N/mm}^2$ (8.24 %)

Step 3 – Loss due to anchorage slip

$\Delta f = E_s \cdot \Delta / L = 200,000 \times 5 / 20,000 = 50.00 \text{ N/mm}^2$ (4.17 %)

Total (friction at far end + slip) = $98.89 + 50.00 = 148.89 \text{ N/mm}^2 = 12.41 \%$ of the jacking stress.

(α 1 M, friction loss 2 M, slip loss 1 M)

d) Cable profile for central concentrated load

4 M

For a simply supported beam with a **central concentrated load W**, the bending moment diagram is **triangular** – zero at the supports and maximum $WL/4$ at the centre.

Suggested profile: a **harped (bent / triangular) cable** – the cable is at (or near) the centroid at the supports and is deflected downward to the maximum eccentricity exactly under the load point, the two legs being straight.

1. The prestress moment $P \cdot e$ then varies linearly, just like the B.M.D., so it balances the load moment at every section.
2. No tension at the top near the supports, as $e \approx 0$ there.
3. The inclined legs give an upward component that resists part of the shear.
4. In pre-tensioned members harping is done by hold-down devices; in post-tensioned members by duct profile.

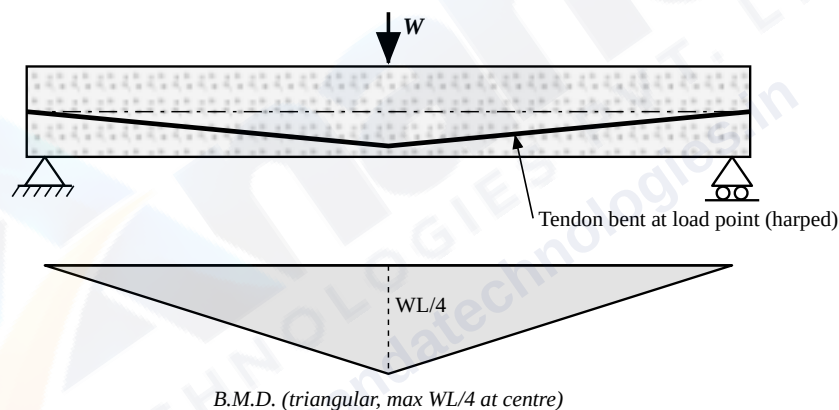


Fig.: Beam with central point load – B.M.D. and suggested harped profile

(Correct profile with sketch 2 M, justification 2 M)

e) Hoyer (long-line) system of pre-tensioning

4 M

The **Hoyer system** (long-line method) is the most common method of **pre-tensioning**, used for mass production in a factory.

Procedure:

1. Two strong **abutments** (end bulkheads) are built at the ends of a long casting bed, 50 m to 200 m apart.
2. High-tensile wires/strands are threaded through the end plates of a series of moulds placed in one line, anchored at the fixed end and stretched by a hydraulic jack at the other end; then anchored by wedge grips.

3. **Shutters (end plates) are placed between the individual members**, so that several members are cast in one line in one operation.
4. Concrete is placed, compacted and cured (often steam cured).
5. When the concrete reaches the transfer strength, the wires are released gradually from the abutments and **cut between the units**; the prestress is transferred to each member **by bond**. The members shorten and camber slightly.

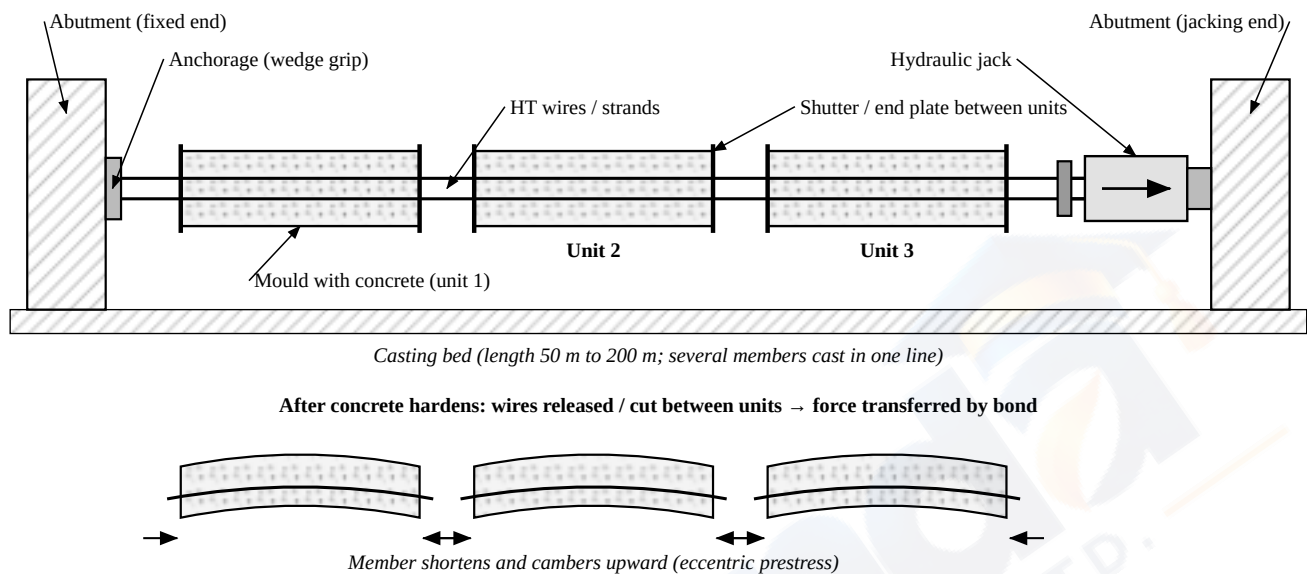


Fig.: Hoyer's long line system of pre-tensioning

(Explanation 2 M, labelled sketch 2 M)

Q.5 Attempt any TWO of the following: (12 M)

a) Storage, transportation and erection of precast panels

6 M

Storage:

- Store on firm, level, well-drained ground close to the crane reach, in the order of erection.
- Slabs/beams are stacked flat on timber battens placed at the lifting points (about 0.2 L from ends), all battens in one vertical line.
- Wall panels are stored vertically in A-frame racks; limit stack height; protect edges and inserts.
- Continue curing; mark every unit (type, date of casting, weight) on the face.

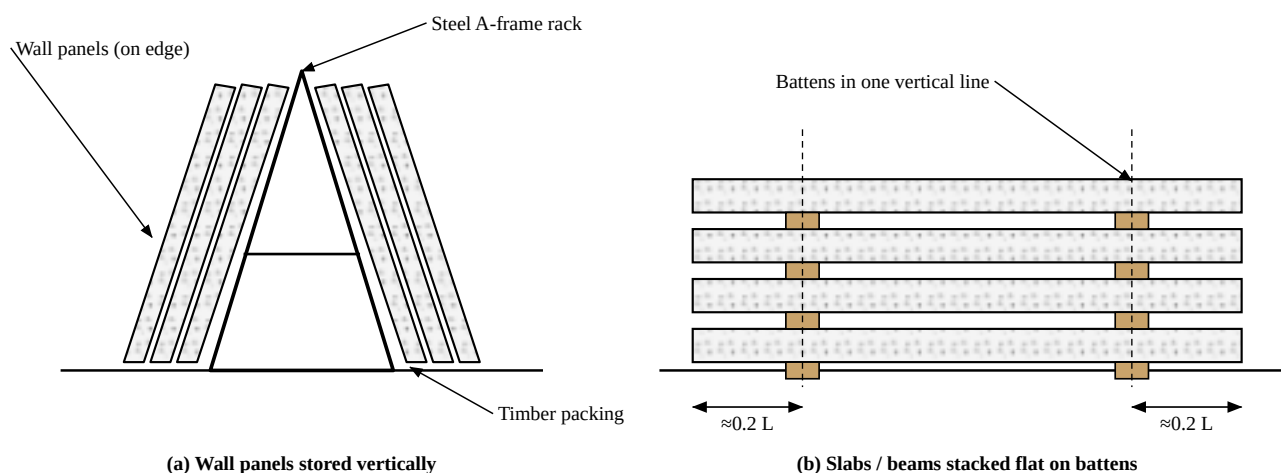


Fig.: Storage of precast elements at site / yard

Transportation:

- Transport only after the unit attains the required strength (shown by cube tests).
- Use flat-bed trailers / low-bed trucks; panels on A-frames, beams supported at the same points as in storage.
- Tie down with chains over rubber/timber padding; avoid impact and cantilever overhang.
- Plan route (turning radius, bridges, height) and keep the travel sequence matched with erection.

Erection:

- Check foundations, bearing levels and markings before lifting.
- Lift by mobile/tower crane using slings and spreader beam at the cast-in lifting hooks only; lift smoothly without jerks.
- Place the unit on bedding mortar / bearing pads, align and level it; give temporary props or bracing.
- Make the permanent joints (grouting, in-situ concrete, welding of inserts) and remove props after the joint gains strength.

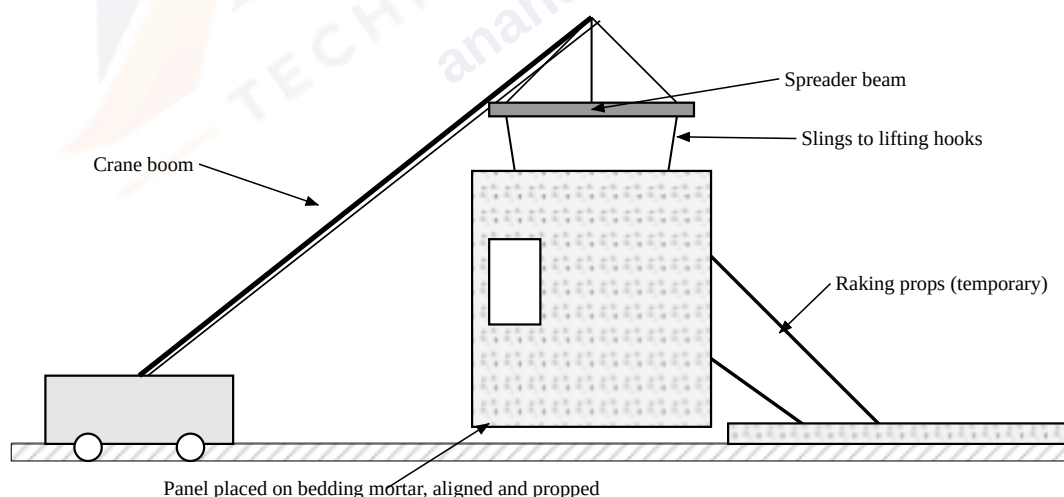


Fig.: Erection of a precast wall panel by crane with spreader beam

(Storage 2 M, transportation 2 M, erection 2 M)

b) Magnel-Blaton system

The **Magnel-Blaton system** (Belgium) is a post-tensioning system using **sandwich plates and flat wedges**.

1. The cable consists of many wires (5 or 7 mm) arranged in layers in a rectangular grid and kept apart by spacers along the duct.
2. At the end of the member a thick steel **distribution plate** bears on the concrete.
3. Steel **sandwich plates**, each having wedge-shaped grooves on both faces, rest on the distribution plate.
4. Wires are tensioned **two at a time** by a jack and anchored in pairs by **flat steel wedges** driven into the grooves of the sandwich plate.
5. After all wires are anchored, the duct is grouted.

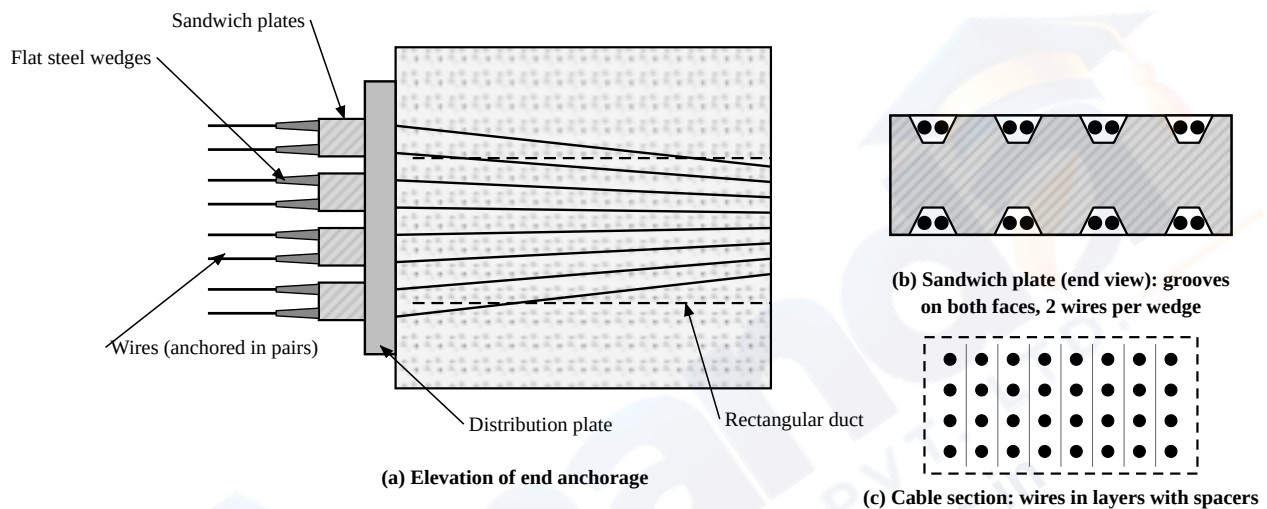


Fig.: Magnel-Blaton system – sandwich plates with flat wedges

Applications: large bridge girders and heavy members needing large cables (many wires); the force can be built up in stages.

(Explanation 3 M, sketch 2 M, application 1 M)

c) Types of prestressing steel

Prestressing steel must have high tensile strength, low relaxation, good ductility and bond. Types used:

1. **High-tensile wires:** Cold-drawn, stress-relieved wires of 2.5–8 mm Ø (IS 1785, plain; IS 6003, indented). Ultimate strength about 1500–2000 N/mm². Indented/crimped surface improves bond; used in pre-tensioned sleepers, poles, slabs and in Freyssinet / Gifford-Udall cables.
2. **Strands:** Two, three or seven wires twisted together (7-ply strand = 6 wires helically around a straight central wire; IS 6006, low-relaxation IS 14268). Flexible, supplied in long coils, better bond; used in long-line pre-tensioning and in post-tensioned multi-strand cables.
3. **High-tensile bars:** Alloy steel bars 10–40 mm Ø, threaded at the ends (IS 2090); anchored by nuts; used in short members, vertical/transverse prestressing, ties and rock anchors.
4. **Cables:** Group of parallel wires or strands placed in a duct and anchored together; used for heavy prestressing in large post-tensioned girders.

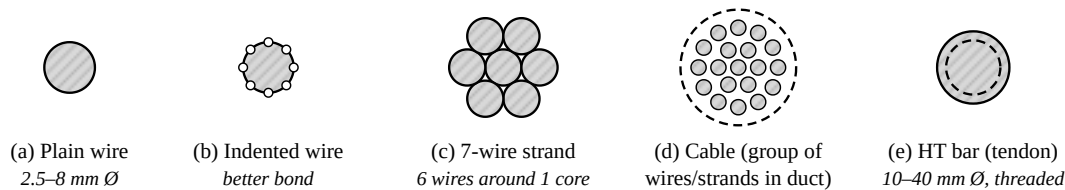


Fig.: Types of prestressing steel (cross-sections)

(Types 2 M, two types in detail 4 M)

Q.6 Attempt any TWO of the following: (12 M)

a) Eccentric cable – stresses at transfer and service

6 M

Given: $b = 300$ mm, $D = 600$ mm, $L = 9$ m (simply supported), straight tendon at $e = 120$ mm below centroid, $P_i = 900$ kN at transfer, loss = 15 %, live load = 12 kN/m, unit weight of concrete = 25 kN/m³.

Step 1 – Section properties

$$A = b \times D = 300 \times 600 = 180,000 \text{ mm}^2$$

$$I = bD^3/12 = 300 \times 600^3 / 12 = 5.4000\text{e}+09 \text{ mm}^4$$

$$Z = bD^2/6 = 300 \times 600^2 / 6 = 1.8000\text{e}+07 \text{ mm}^3$$

Step 2 – Moments at mid-span

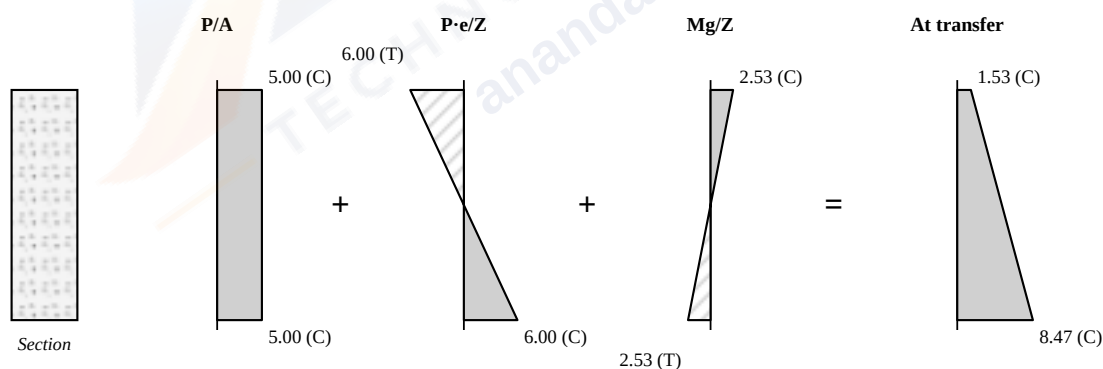
$$g = 0.3 \times 0.6 \times 25 = 4.50 \text{ kN/m} \rightarrow M_g = gL^2/8 = 4.50 \times 9^2/8 = 45.56 \text{ kN}\cdot\text{m}$$

$$M_q = qL^2/8 = 12 \times 9^2/8 = 121.50 \text{ kN}\cdot\text{m} \rightarrow M_{\text{total}} = 167.06 \text{ kN}\cdot\text{m}$$

Step 3 – At transfer (P_i + self weight)

$$P_i/A = 900 \times 10^3 / 180,000 = 5.00 \text{ N/mm}^2; P_i \cdot e/Z = 900 \times 10^3 \times 120 / 1.8000\text{e}+07 = 6.00 \text{ N/mm}^2; M_g/Z = 2.53 \text{ N/mm}^2$$

$$\text{Top} = 5.00 - 6.00 + 2.53 = \mathbf{1.53 \text{ N/mm}^2 \text{ (C)}} \quad \text{Bottom} = 5.00 + 6.00 - 2.53 = \mathbf{8.47 \text{ N/mm}^2 \text{ (C)}}$$



Stresses in N/mm²; C = compression (shaded), T = tension (hatched)

Fig.: Stress distribution at transfer (mid-span)

Step 4 – At service (P_e + self weight + live load)

$$P_e = (1 - 0.15) \times 900 = 765.0 \text{ kN}; P_e/A = 4.25; P_e \cdot e/Z = 5.10; M_{\text{total}}/Z = 9.28 \text{ N/mm}^2$$

$$\text{Top} = 4.25 - 5.10 + 9.28 = \mathbf{8.43 \text{ N/mm}^2 \text{ (C)}} \quad \text{Bottom} = 4.25 + 5.10 - 9.28 = \mathbf{0.07 \text{ N/mm}^2 \text{ (C)}}$$

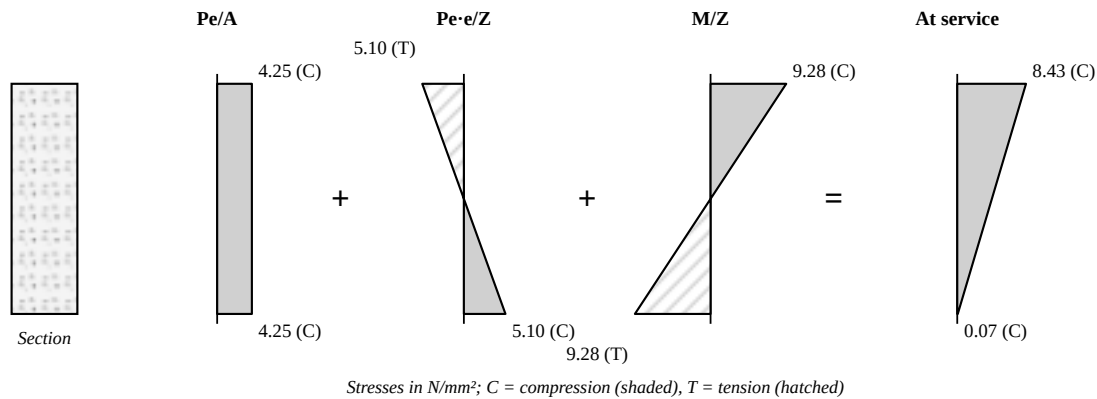


Fig.: Stress distribution at service (mid-span)

(Section & moments 1 M, transfer stresses 2 M, service stresses 2 M, diagrams 1 M)

b) Losses due to creep, shrinkage and relaxation

6 M

i) Loss due to creep of concrete: Creep is the slow, continuous increase of strain in concrete under a sustained stress. The prestress keeps the concrete under permanent compression, so the member shortens with time and the bonded tendon loses part of its stretch.

Loss = $\epsilon_{cc} \cdot E_s = \theta \cdot (f_c/E_c) \cdot E_s = \theta \cdot m \cdot f_c$, where θ = creep coefficient (IS 1343: 2.2 at 7 days, 1.6 at 28 days, 1.1 at 1 year age of loading), f_c = stress in concrete at tendon level. Reduced by high-grade concrete, later loading, low w/c ratio.

Loss due to shrinkage of concrete: Concrete shrinks as it dries; the tendon shortens with it. Loss = $\epsilon_{sh} \cdot E_s$. IS 1343: $\epsilon_{sh} = 300 \times 10^{-6}$ (pre-tensioning); $200 \times 10^{-6} / \log_{10}(t + 2)$ (post-tensioning, t = age at transfer in days). Post-tensioned members lose less because part of the shrinkage is over before stressing.

Loss due to relaxation of steel: When high-tensile steel is held at a constant length under high stress, its stress gradually reduces. IS 1343 values: 0 at $0.5 f_{pu}$, 35 N/mm² at $0.6 f_{pu}$, 70 N/mm² at $0.7 f_{pu}$, 90 N/mm² at $0.8 f_{pu}$. Low-relaxation strands reduce this loss.

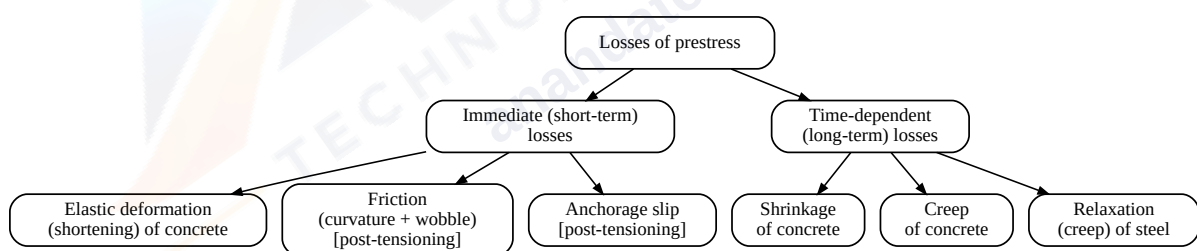


Fig.: Classification of losses of prestress

(Each loss with IS value 2 M)

c) Straight and parabolic tendon profiles

6 M

The cable (tendon) profile is the line followed by the tendon along the span. In a simply supported rectangular beam the following profiles are used:

Concentric tendon: tendon along the centroidal axis ($e = 0$). Produces uniform compression P/A over the section; it does not counteract bending, so it is used for axially loaded members, piles, poles and short beams.

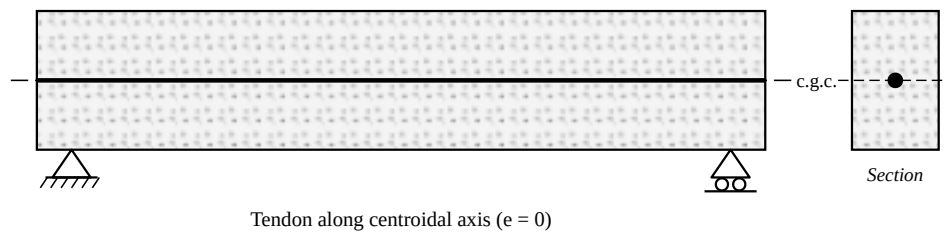


Fig.: (a) Concentric tendon

Eccentric straight tendon: tendon placed below the centroid at a constant eccentricity e along the whole span. It gives $P/A \pm Pe/Z$ – useful moment Pe at mid-span, but at the supports (where load moment is zero) the same Pe may cause tension at the top. Easy to provide in pre-tensioned members.

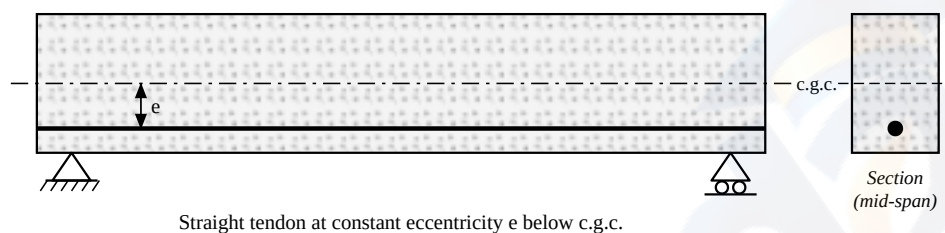


Fig.: (b) Eccentric straight tendon

Parabolic tendon: tendon follows a parabola with $e = 0$ (at the centroid) at the supports and maximum e at mid-span, matching the parabolic B.M.D. of a UDL. Moment due to prestress varies like the load moment, so stresses are favourable at every section; tendon slope also gives a vertical component that reduces shear. Common in post-tensioned members.

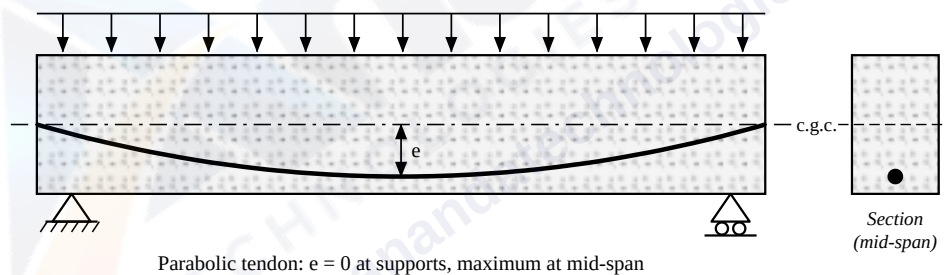


Fig.: (c) Parabolic tendon

(Each profile: sketch 1 M + explanation 1 M)

Comparison: straight tendons are simple and used in pre-tensioned members; parabolic tendons need ducts (post-tensioning) but give the best stress distribution along the span.

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