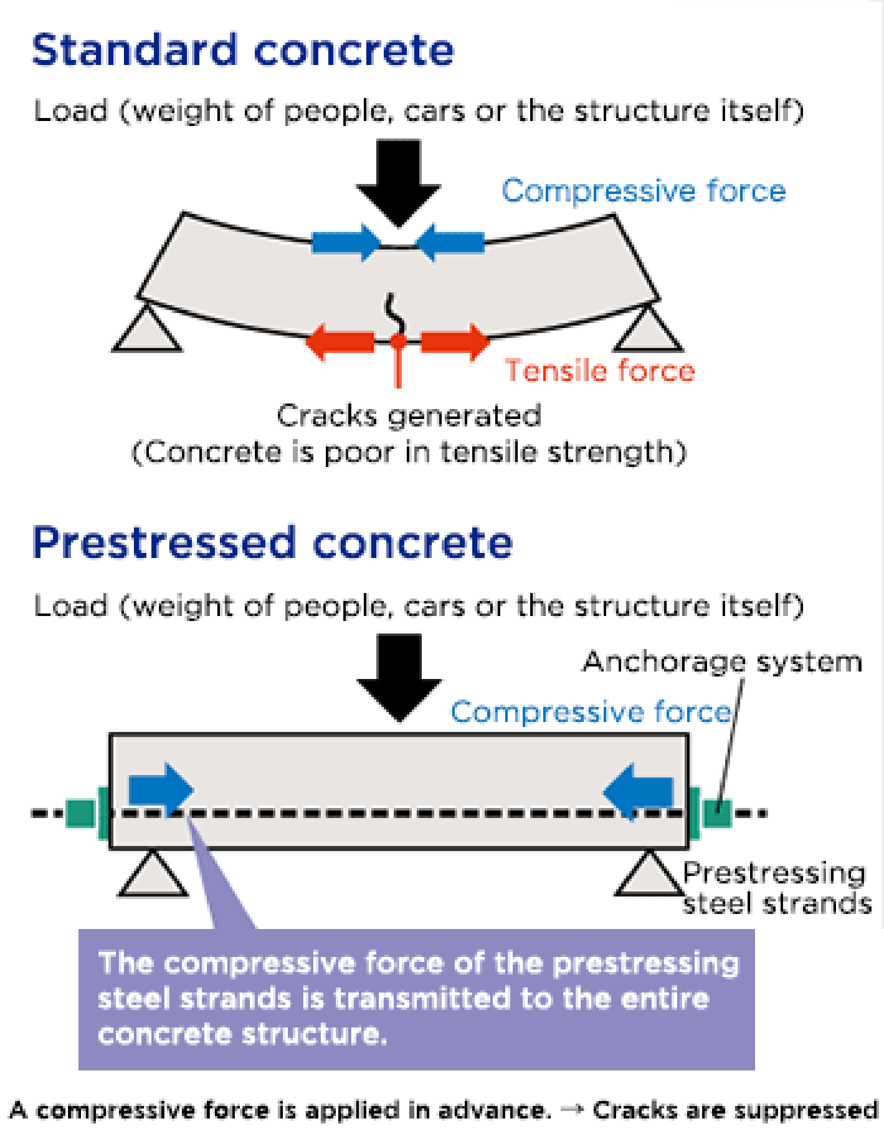
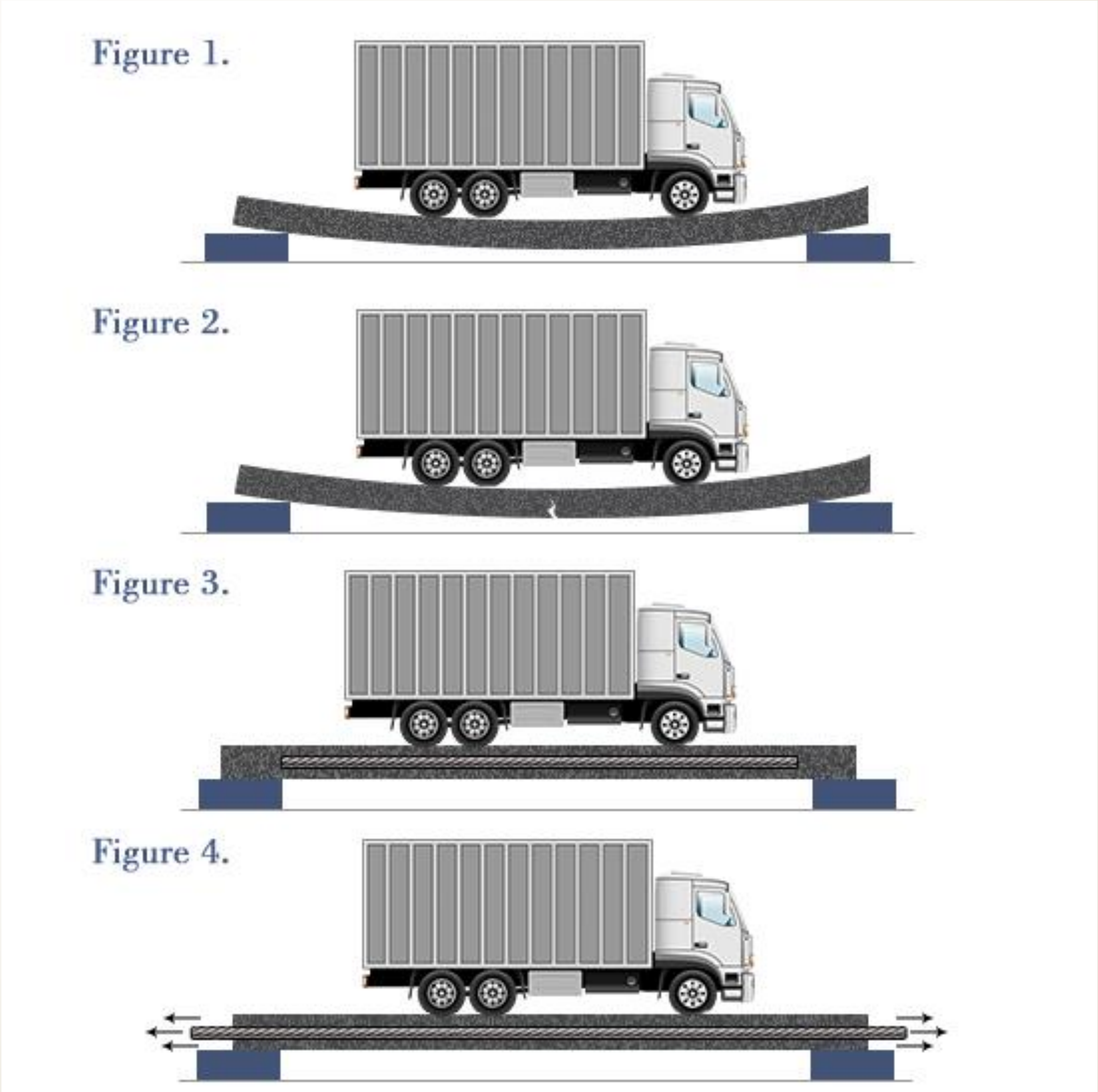
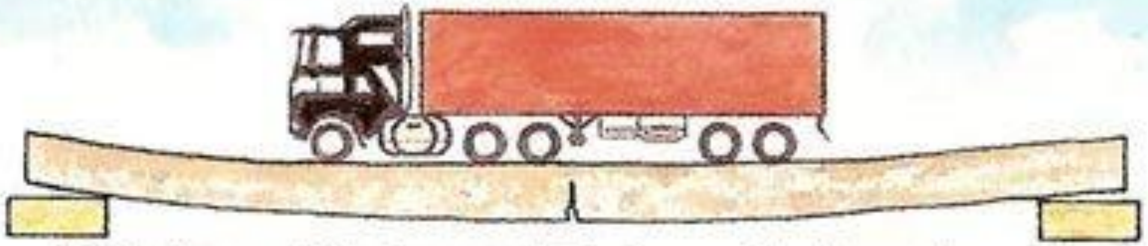
PRESTRESSED CONCRETE

INTRODUCTION





▲ A concrete beam will begin to bend when heavily loaded.



▲ The base of the beam starts to crack where the concrete is pulled apart.

▲ Placing a steel rod inside the beam holds the concrete together and stops the beam from cracking.

▲ Stretching the rod and then releasing it to squeeze the concrete makes the beam very strong.

INTRODUCTION

- Process of induction of compressive stresses in the structure before it is put to its actual use is known as **Prestressing.**

OR

- **Prestressing** is the intentional creation of permanent stress in a structure or assembly, for improving its behavior and strength under various service conditions.
- **Prestressed Concrete** is basically concrete in which internal stresses of a suitable magnitude and distribution are introduced so that the stresses resulting from external loads are counteracted to a desired degree.
- **Prestressed Concrete Member** is a member of concrete in which internal stresses are introduced in a planned manner, so that the stresses resulting from the superimposed loads are counteracted to a desired degree.
- In ordinary reinforced concrete, consisting of concrete and mild steel as basic components, the **compressive stresses are born by concrete** while **tensile stresses are born entirely by steel**.

INTRODUCTION

- In prestressed concrete, compression is induced prior to loading in the zones **where external loads would normally cause tensile stresses**.
- In the case of long beams, where large shear forces exist, the beam sizes have to be large to limit the diagonal tensile stresses under certain limits.
- Prestress decrease diagonal tensile stresses. This has led to adopt modified I-section and T-section in which there is substantial reduction in web area.
- In order to get the maximum advantage of a prestressed concrete member, **it is necessary to use not only high strength concrete but also high tensile steel wires**.
- **In the design of a prestressed concrete member, the estimated loss of prestress due to shrinkage of concrete and creep of concrete and steel is at the order of nearly 200 N/mm^2.**

NEED OF PRESTRESSING

- To offset the deficiency of tensile strength in concrete, steel reinforcement is provided near the bottom of simple beams to carry the tensile stresses.

ADVANTAGES OF PRESTRESSED CONCRETE

1.Durability

- As this technique eliminates weakness of concrete in tension, such members remain free from cracks; hence **can resist the effects of impact, shock, and reversal of stresses more efficiently than R.C.C. structure.**
- They **provide reliable long-term performance in extremely harsh conditions** that could destroy lesser materials.
- They are **resistant to deterioration from weather extremes, chemical attack, fire, accidental damage and the determined efforts of vandals.**

ADVANTAGES OF PRESTRESSED CONCRETE

2. Adaptability

- Precast prestressed concrete products **can be designed and manufactured for any application, ranging in size from short span bridges to some of the largest projects in the world.**
- **Permits precast manufacturers to vastly expand the design variety possible using precast components.**
- **The inherent plasticity of concrete permits to create precast components in shapes and sizes,** which would be prohibitively expensive using other materials.

ADVANTAGES OF PRESTRESSED CONCRETE

3. Fire resistance

- Prestressed concrete bridges are **not easily damaged by fire.**
- Have **excellent fire resistance, low maintenance costs, elegance, high corrosion resistance, etc.**

4. Impacts local economy directly

- Prestressed concrete is produced by local small business – employing local labour.
- Most of its raw materials are also **locally purchased** and the health of the local prestressed concrete industry directly impacts further on the local economy.
- Due to smaller loads, due to smaller dimensions being used, there **is a considerable saving in cost of supporting members and foundations.**
- Standard structural shapes such as hollow core, double tees, beams, columns and panels **can be mass-produced at low cost.**

ADVANTAGES OF PRESTRESSED CONCRETE

5. Fast and Easy Construction

- Precast concrete components lend themselves to **fast construction schedules.**
- Precast **manufacturing can proceed while site preparation is underway.**
- Precast units can be delivered to the jobsite and **installed the moment they are needed in any weather.**
- Fast construction means **earlier completion and the resulting cost savings.**
- **Saves the cost of shuttering and centring for large structures.**

ADVANTAGES OF PRESTRESSED CONCRETE

6. Aesthetics

- Precast components can be delivered with a wide range of shapes and **finishes ranging from smooth dense structural units to any number of architectural treatments.**
- **Strikingly rich and varied surface textures and treatments can be achieved** by exposing colure sands, aggregates, cements and colouring agents using sandblasting and chemical retarders.
- Stone, tile brick and other materials can be cast into precast panels at the factory, **enabling designers to achieve the expensive look of masonry.**

DISADVANTAGES OF PRESTRESSED CONCRETE

Although prestressing has many advantages, there are still some drawbacks of this process.

- The **unit cost of high strength materials being used is higher as mostly high tensile steel is used.**
- **Extra initial cost is incurred** due to use of prestressing equipment and its installation.
- **Extra labour and transportation cost** is involved.
- Prestressing is **uneconomical for short spans and light loads.**

CURRICULUM

UNIT-I

Basic Concept of Prestressing

Need for High Strength Steel and Concrete, Advantages of Prestressed Concrete, Applications of Prestressed Concrete, Materials for Prestressed Concrete: High-Strength Concrete, High-Tensile Steel.

Introduction to Prestressing Systems

Tensioning Devices, Pretensioning Systems, Post-Tensioning Systems, Thermo-Electric Prestressing, Chemical Prestressing.

Analysis of Prestress and Bending Stresses

Basic Assumptions, Analysis of Prestress, Resultant Stresses at a Section, Pressure Line or Thrust Line and Internal Resisting Couple, Concept of Load Balancing, Stresses in Tendons, Cracking Moment.

Losses of Prestress

Loss Due to Elastic Deformation of Concrete, Loss Due to Shrinkage of Concrete, Loss Due to Creep of Concrete, Loss Due to Relaxation of Stress in Steel, Loss Due to Anchorage Sleep, Loss of Stress Due to Friction, Total Losses Allowed for Design.

CURRICULUM

UNIT-II
Deflection of Prestress Concrete Members Factors Influencing Deflections, Short Term Deflections of Uncracked Members, Effect of Tendon Profile on Deflections, Deflections Due to Self-Weight and Imposed Loads, Prediction of Long Time Deflections, Deflection of Cracked Members, Requirements of various codes of practice. **Flexural Strength of Prestressed Concrete Sections** Simplified Code Procedures (IS: 1343-1980), Shear and Principle Stresses, Ultimate Shear Resistance of Prestress Concrete Members, Design of Shear Reinforcement as per IS: 1343 - 1980.

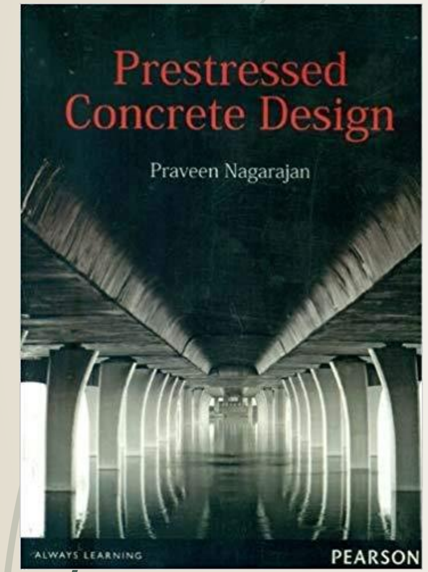
CURRICULUM

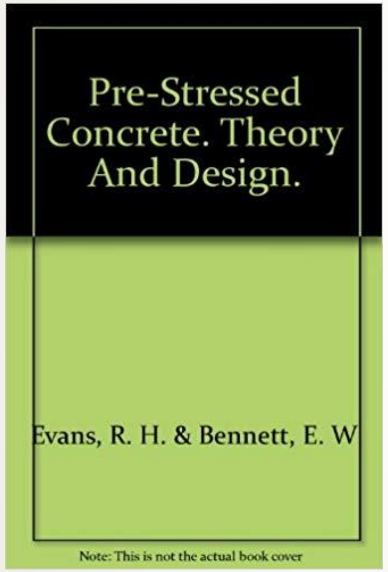
UNIT-III
Philosophy of Limit-State Design Limit State Design Criteria for Prestressed Concrete Members, Design Loads and Strengths, Partial Factors for Loads. **Design of Prestressed Concrete Sections** Design of Section for Flexure, Design of Section for Axial Tension, Design of Section for Compression and Bending, Design of Section for Shear and Torsion, Estimation of Self-Weight of Beams, Design of Pretensioned Beams, Design of Post-Tensioned Beams, Design Examples.

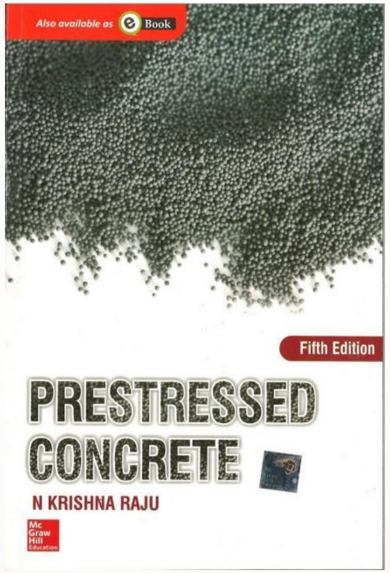
CURRICULUM

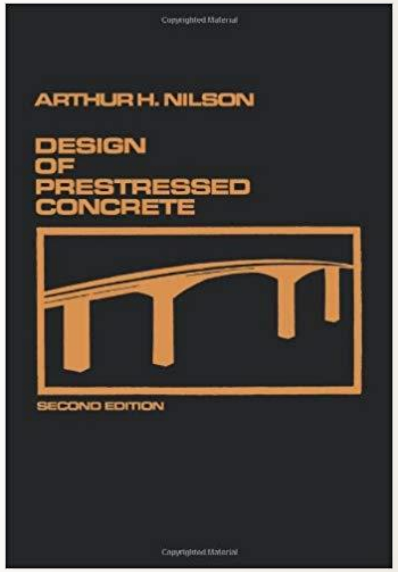
UNIT-IV
Prestressed Concrete Bridges Advantages of Prestressed Concrete Bridges, Pretensioned Prestressed Concrete Bridge Decks, Post-tensioned Prestressed Concrete Bridge Decks, Design of Post-tensioned Prestressed Concrete Slab Bridge Deck.

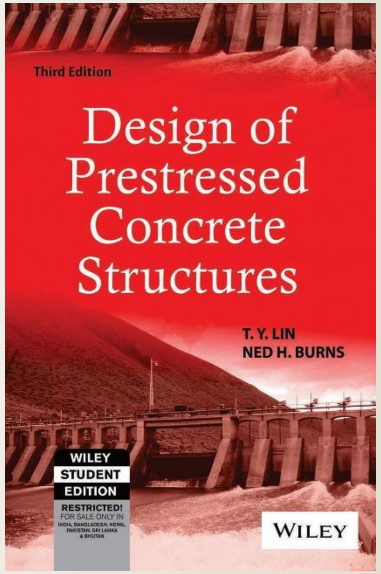
REFERENCE BOOKS





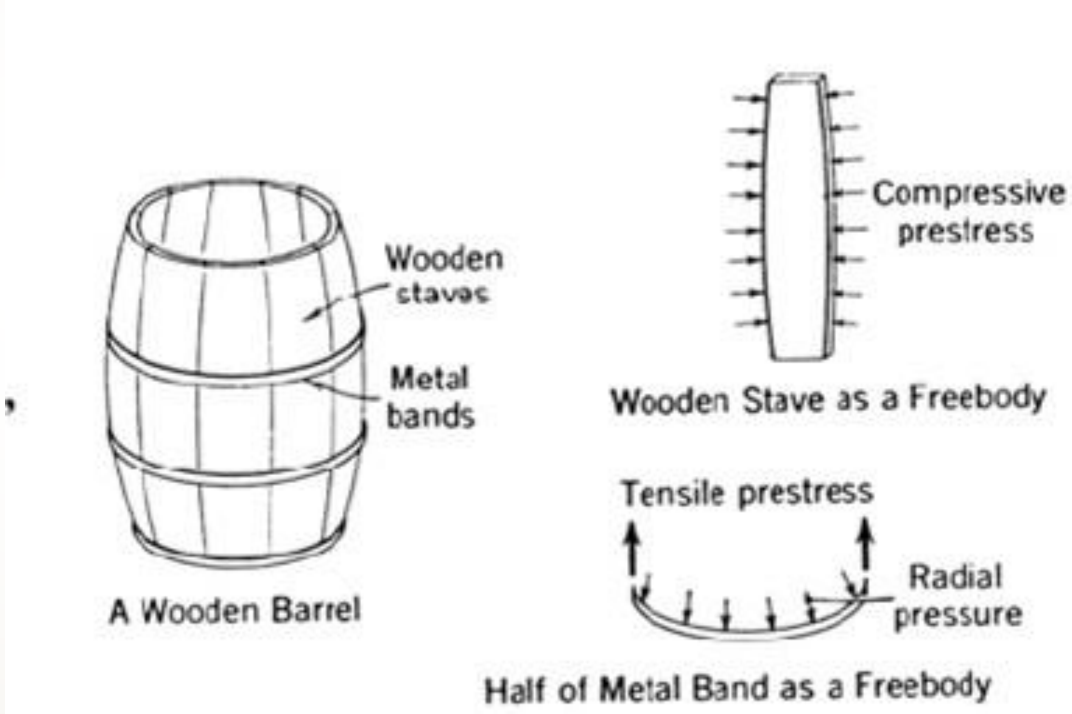






BASIC CONCEPT OF PRESTRESSED CONCRETE

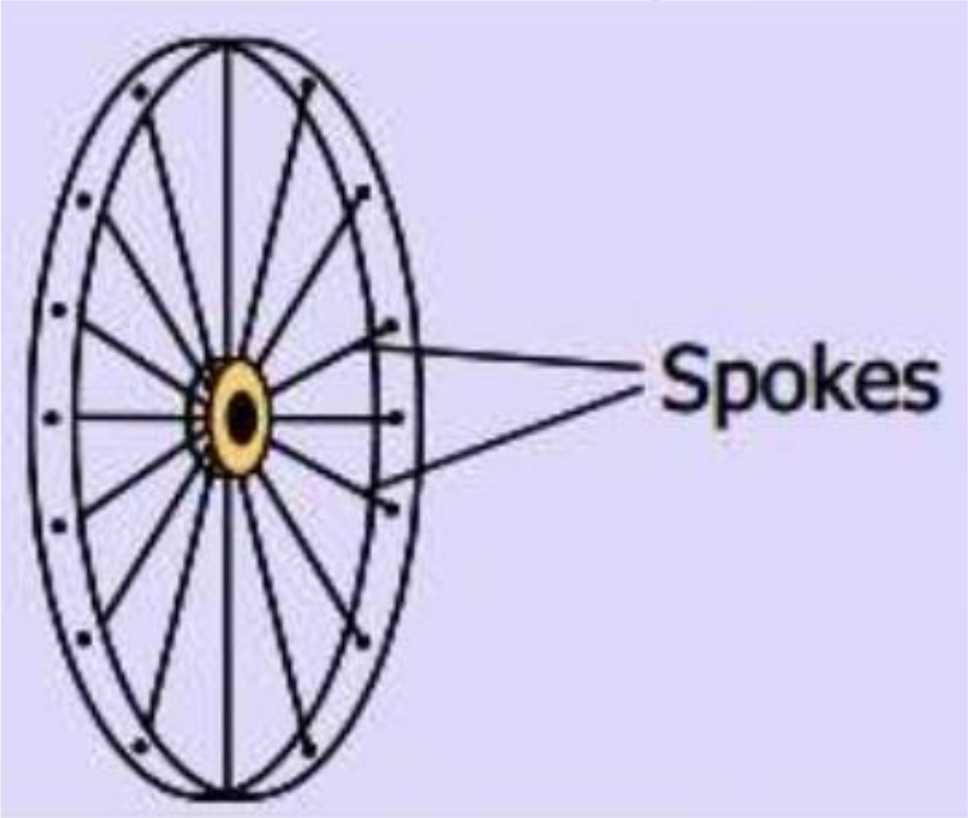
- ✓ Concept of prestressing existed before its application in the concrete



Force fitting of metal bands on wooden barrels

BASIC CONCEPT OF PRESTRESSED CONCRETE

Pre-tension is to such an extent that there will always be a residual tension in the spoke.



Pre-tensioning of spokes in bicycle wheel

NEED FOR HIGH STRENGTH STEEL AND CONCRETE

The significant observations which resulted from the pioneering research on prestressed concrete were:

1) **Necessity of using high-strength steel and concrete.**
2) **Recognition of losses of prestress due to various causes.**

- The early attempts to use mild steel in prestressed concrete were not successful **(Working stress of 120 N/mm^2 in mild steel is completely lost)**.
- The normal loss of stress in steel is generally about **100 to 240 N/mm^2** and it I apparent that if this stress is to be small portion of the initial stress, **the stress in steel in the initial stage must be very high, about 1200 to 2000 N/mm^2.**
- **These high stress ranges are possible only with the use of high-strength steel.**

NEED FOR HIGH STRENGTH STEEL AND CONCRETE

- High-strength concrete is necessary in prestressed concrete, as the material offers high resistance in tension, shear, bond and bearing.
- In the zone of anchorages, **the bearing stress being higher**, high-strength concrete is invariably preferred to minimise costs.
- High strength concrete is **less liable to shrinkage cracks, and** has a **higher modulus of elasticity** and **smaller ultimate creep strain, resulting in smaller loss of prestress in steel.**
- The use of high-strength concrete results in a **reduction in the cross-sectional dimensions of prestressed concrete structural elements.**
- With a reduced dead-weight of material, **longer spans become technically and economically practicable.**

ADVANTAGES OF PRESTRESSED CONCRETE

- Cross-section is more effectively utilised (In use of materials)
- Improved resistance to shearing forces (Reduction in principal tensile stress, Use of curved cables)
- Flexural member is stiffer under working loads compared to RC member of same size
- Improved durability (Due to freedom from cracks)
- Improved ability of material for energy absorption (Resistance to impact and repeated working loads)
- Well established economy of prestressed concrete for long spans
- Considerable resilience due to capacity of completely recovering from substantial effects of overloading

ADVANTAGES OF PRESTRESSED CONCRETE

- Utilisation of concrete in tension zone leads to saving upto 15 to 30% compared to RC members
- Saving in steel of range 60 to 80% (Due to high permissible stresses allowed in high-tensile wires)
- Reduces cost of foundation (Due to reduction in dead weight of prestressed members)

APPLICATIONS OF PRESTRESSED CONCRETE

- Bridges
- Slabs in buildings
- Water tank
- Concrete pile
- Thin shell structures
- Offshore platforms
- Nuclear power plants

APPLICATIONS OF PRESTRESSED CONCRETE

- In India, the applications of pre-stressed concrete diversified over the years. The first pre-stressed concrete bridge was built in 1948 under the Assam Rail Link Project. Among bridges, the Pamban Road Bridge at Rameshwaram, Tamilnadu, remains a classic example of the use of pre-stressed concrete girders.

APPLICATIONS OF PRESTRESSED CONCRETE

Ganga Sethu, Patna

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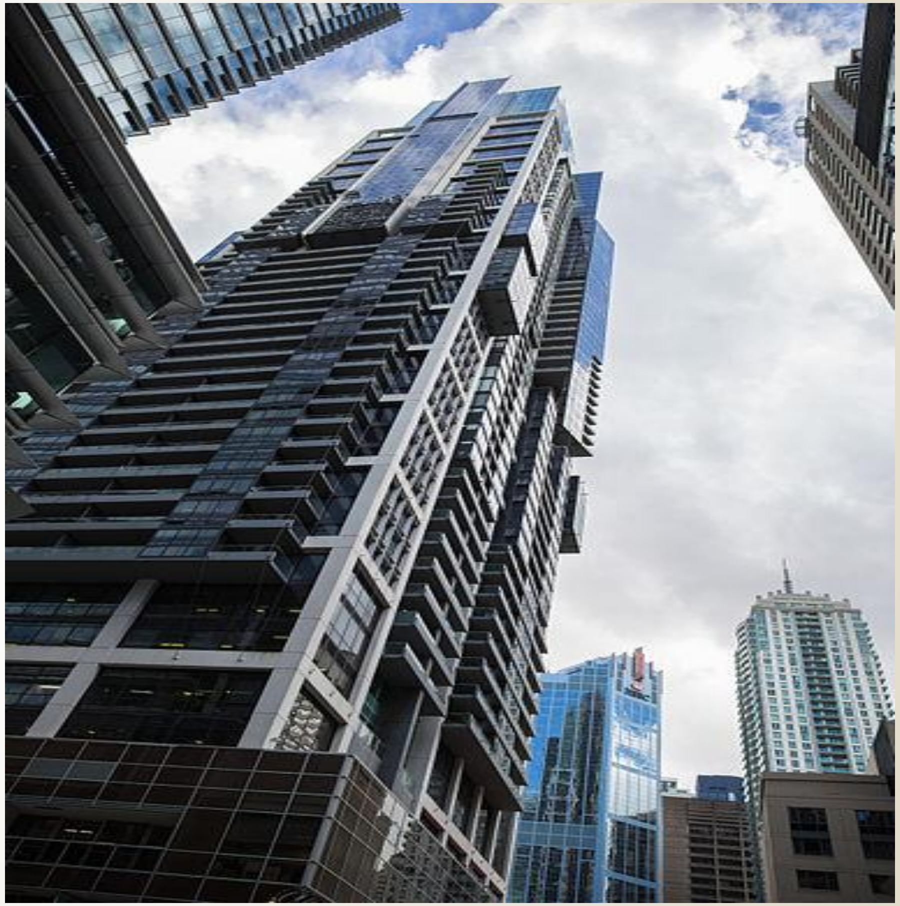
APPLICATIONS OF PRESTRESSED CONCRETE

ICC Tower, Hong Kong

Guoco Tower, Singapore (Under construction)

APPLICATIONS OF PRESTRESSED CONCRETE

Kai Tak Cruise Terminal, Hong Kong



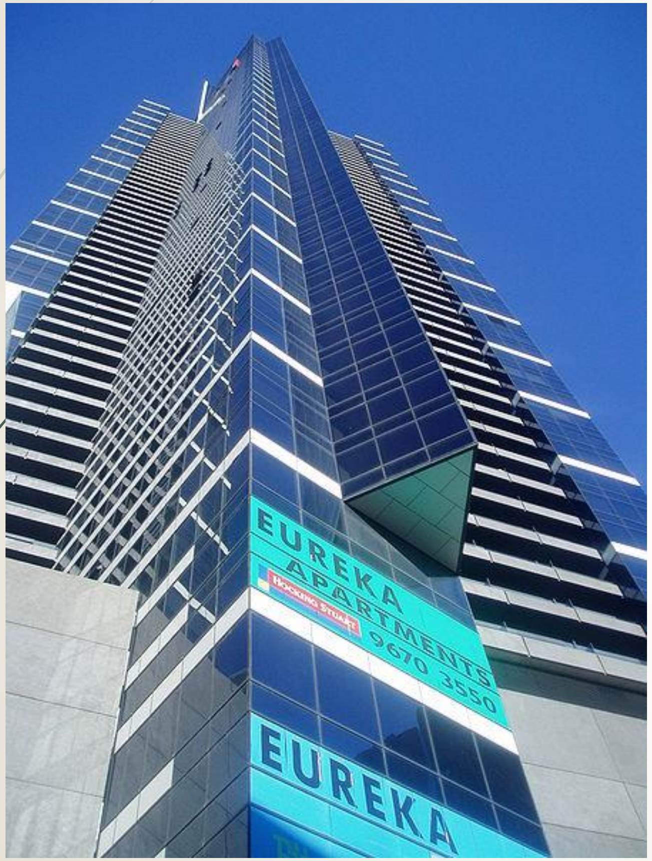
World Tower, Sydney

APPLICATIONS OF PRESTRESSED CONCRETE

Capital Gate, Abu dhabi

Torre Espacio (Madrid)

APPLICATIONS OF PRESTRESSED CONCRETE

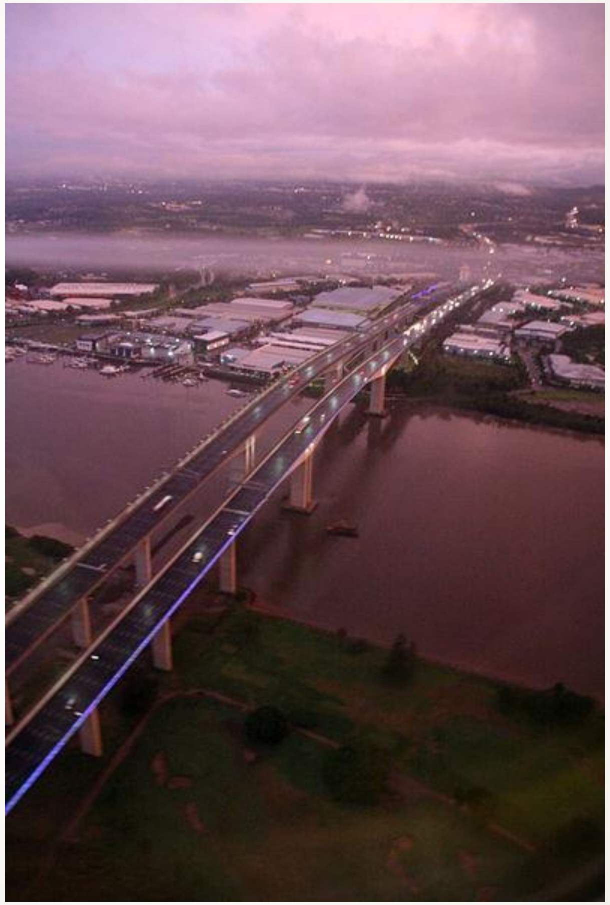


Eureka Tower LC, Melbourne

Torre Espacio (Madrid)

APPLICATIONS OF PRESTRESSED CONCRETE

Ocean Heights, Dubai



Gate Way Bridge, Brisbane

C N Tower, Canada

APPLICATIONS OF PRESTRESSED CONCRETE

Incheon Grand Bridge, South Korea

MATERIALS FOR PRESTRESSED CONCRETE

1) High Strength Concrete

i) High-strength concrete mixes

- Concrete with **high compressive strength at early stage is required.**
- **Low shrinkage, minimum creep characteristics** and **a high value of Modulus of Elasticity** are generally deemed necessary for concrete used for prestressed members.
- Desirable properties such as **durability, impermeability and abrasion resistance** are highly influenced by the strength of concrete.
- With development of vibration technique in 1930, it became easy to produce high strength concrete having 28 day cube compressive strength in the range of 30 N/mm^2 to 70 N/mm^2. (Without taking any recourse to unusual materials or processing)

MATERIALS FOR PRESTRESSED CONCRETE

i) High-strength concrete mixes

- Experimental investigations by Erntory and Shacklock have indicated that in high-strength concrete mixes, workability, type & maximum size of aggregate and the strength requirement influence the selection of water cement ratio.
- High strength concrete can be designed by using any of the following established methods:

1. Erntory and Shacklock's empirical method
2. ACI's mix design procedure for no slump concrete
3. British D.O.E. Method
4. Indian Standard code method

MATERIALS FOR PRESTRESSED CONCRETE

i) High-strength concrete mixes

- IS:1343-1980 stipulates that only **controlled concrete** should be used for prestressed concrete construction.
- The exact specifications with regard to the acceptance criteria for concrete generally vary from one code to another.
- The British code BS EN:1992 stipulates that not more than 5% of the test results should fall below the 28-day characteristic compressive strength.
- **While Indian standard code IS:456-2000 and IS:1343 prescribe a similar stipulation of five percent.**

MATERIALS FOR PRESTRESSED CONCRETE

ii) Strength requirements

- The minimum 28-day cube compressive strength prescribed in IS:1343-1980 is **40 N/mm^2 for pre-tensioned members** and **30 N/mm^2 for post-tensioned members.**
- The ratio of standard cylinder to cube strength may be assumed to be **0.8** in absence of any relevant test data.
- **Minimum cement content of 300 to 360 kg/m^3** is prescribed mainly to cater the durability requirement.
- In high strength concrete mixes, the **water content should be as low as possible** with due regard to **adequate workability and concrete** should be suitable for compaction by the means available at site.
- To safeguard against excessive shrinkage, the code prescribes that the **cement content should preferably not exceed 560 kg/m^3.**

MATERIALS FOR PRESTRESSED CONCRETE

iii) Permissible stresses in concrete

- The permissible compressive and tensile stress in concrete at the stage of transfer and service loads are defined in terms of corresponding compressive strength of concrete at each stage.

Maximum permissible stress in concrete in concrete in flexure (N/mm^2)

Stage	Type of stress	Permissible stresses in concrete in flexure
At transfer	Compressive stress	Varies linearly from 0.54 to 0.37f_{ci} for post-tensioned work and from 0.51 to 0.44f_{ci} for pre-tensioned work depending on the strength of concrete
	Tensile stress	-

MATERIALS FOR PRESTRESSED CONCRETE

iii) Permissible stresses in concrete

Maximum permissible stress in concrete in concrete in flexure (N/mm^2)

Stage	Type of stress	Permissible stresses in concrete in flexure
At Service Load	Compressive stress	Varies linearly from 0.41 to $0.35f_{ck}$ depending on the strength of concrete
	Tensile stress	Type 1 members: None
		Type 2 members: Tensile stresses not to exceed 3 N/mm^2
		Type 3 members: Hypothetical tensile stresses vary from 3.2 N/mm^2 for M30 to a maximum of 7.3 N/mm^2 for M 50 grade concrete depending upon limiting crack width.

MATERIALS FOR PRESTRESSED CONCRETE

2) High Tensile Steel

i) Types of High Tensile Steel

- For prestressed concrete members, the high-tensile steel used generally consists of **wires, bars or strands.**
- High tensile strength is generally achieved by marginally increasing the carbon content in steel in comparison with mild steel.
- **High-tensile steel usually contains 0.6-0.85% carbon, 0.7-1% manganese, 0.05% of sulphur and phosphorus with traces of silicon.**
- The high carbon ingots are hot-rolled into rods and cold-drawn through a series of dies to decrease the diameter and increase the tensile strength.
- Specifications for hard drawn steel wire for presterssed concrete are covered in IS:1785 (Part-II)-1983.

MATERIALS FOR PRESTRESSED CONCRETE

i) Types of High Tensile Steel

- The process of cold-drawing through dies decreases the durability of the wires.
- The cold-drawn wires are subsequently tempered to improve their properties.
- **Tempering or ageing or stress relieving by heat treatment of the wires at 150-420°C enhances the tensile strength.**
- The cold-drawn stress relieved wires are generally available in nominal sizes of 2.5, 3, 4, 5, 7 and 8 mm diameter they should confirm to the IS:1785 (Part-I)-1983.
- The hard-drawn steel wires which are indented or crimped are preferred fro pre-tensioned elements because of their superior bond characteristics. (Specifications for indented wires ➔ IS:6003-1983)

MATERIALS FOR PRESTRESSED CONCRETE

i) Types of High Tensile Steel

Wires

- Prestressing wire is a single unit made of steel.

MATERIALS FOR PRESTRESSED CONCRETE

i) Types of High Tensile Steel

- The small diameter wires of 2-5mm are mostly used in the form of strands comprising two, three or seven wires.
- The helical form of twisted wires in the strand substantially improves the bond strength.
- 2 and 3 ply strands are made up of 2 mm and 3 mm diameter individual wires, while the 7 ply strands are twisted using the wires of 2 to 5 mm diameter.
- The nominal diameter of strands vary from 6.3 mm to 15.2 mm.
- Properties of strands are covered in IS:6006-1983.

MATERIALS FOR PRESTRESSED CONCRETE

i) Types of High Tensile Steel

- High tensile steel bars commonly employed in prestressing are manufactured in nominal sizes of 10, 12, 16, 20, 22, 25, 28 and 32 mm diameter and are covered in IS:2090-1983.
- The ultimate tensile strength of the bars does not vary appreciably with the diameter, since the high strength of bars is due to alloying rather than to cold working in case of wires.

MATERIALS FOR PRESTRESSED CONCRETE

i) Types of High Tensile Steel

Strands

- Two, three or seven wires are wound to form a prestressing strand.

MATERIALS FOR PRESTRESSED CONCRETE

i) Types of High Tensile Steel

Tendon

- A group of strands or wires are wound to form a prestressing tendon.

MATERIALS FOR PRESTRESSED CONCRETE

i) Types of High Tensile Steel

Cable

- A group of tendons form a prestressing cable.

MATERIALS FOR PRESTRESSED CONCRETE

ii) Strength Requirements

- The ultimate tensile strength of a plain hard-drawn steel wire varies with its diameter.

Tensile strength and elongation characteristics of cold-drawn stress relieved wires (IS:1785-Part-I-1983)

Nominal Diameter (mm)	Tensile strength (Minimum) (N/mm^2)	Elongation (%)
2.50	2010	2.5
3.00	1865	2.5
4.00	1715	3.0
5.00	1570	4.0
7.00	1470	4.0
8.00	1375	4.0

MATERIALS FOR PRESTRESSED CONCRETE

ii) Strength Requirements

Mechanical properties of high-tensile steel bars (IS:2090-1983)

a) Characteristic tensile strength (minimum)	980 N/mm^2
b) Proof stress	Not less than 80% of the minimum specified tensile strength
c) Elongation at rupture on a gauge length of 5.65A (minimum) Where, A = area of cross-section	10%

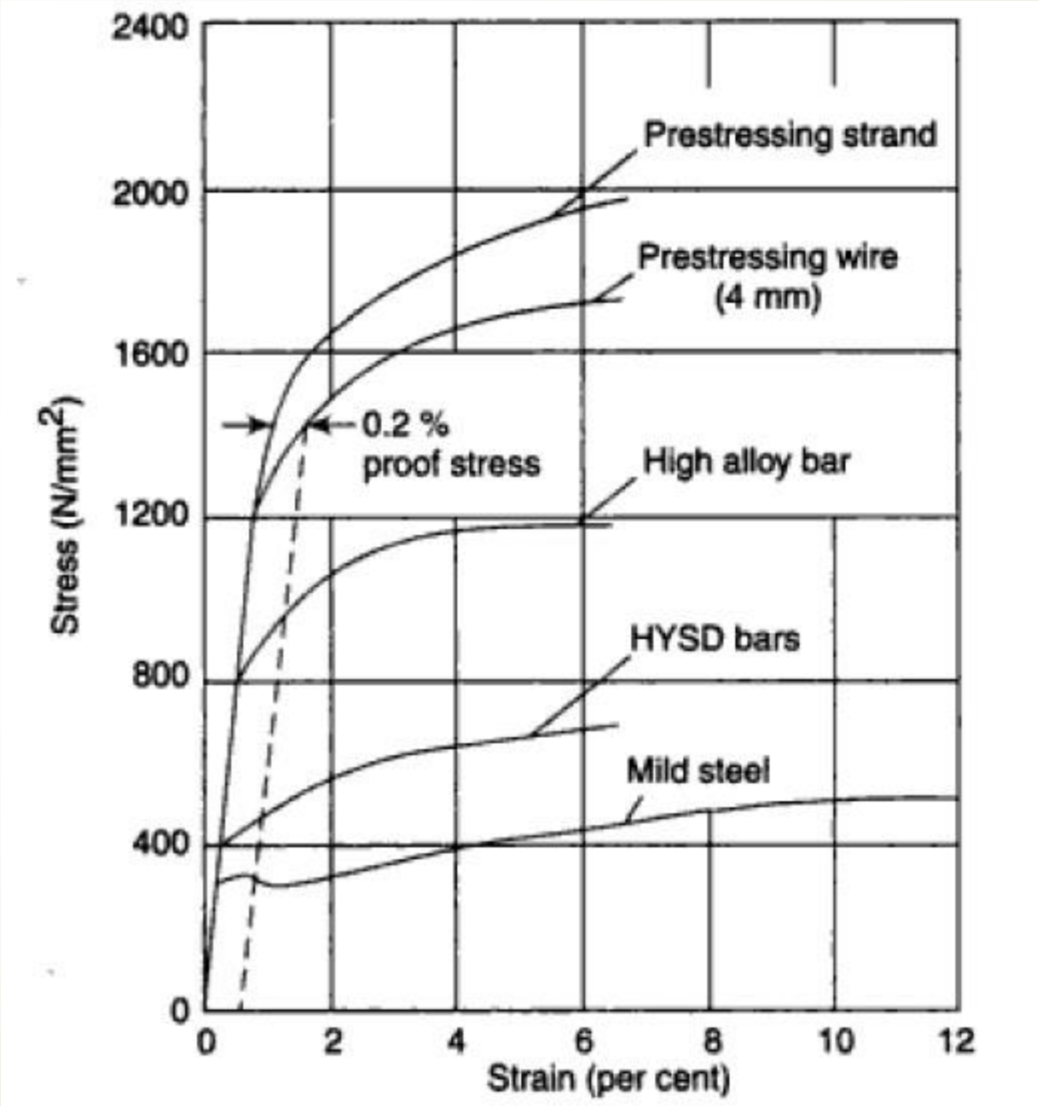
Mechanical properties of high-tensile indented wires (IS:6003-1983)

Nominal Diameter (mm)	Tensile strength (Minimum) (N/mm^2)	Elongation (%)
5.00	1570	4.0
4.00	1715	3.0
3.00	1865	2.50

MATERIALS FOR PRESTRESSED CONCRETE

ii) Strength Requirements

- Typical stress-strain characteristics of high tensile steel wires is shown in figure.
- Unlike ordinary mild steel, high-tensile wires have no well defined yield point and it is necessary to refer to the proof stress, which correspond to specified permanent strains.
- The 0.2% proof stress for high-tensile steel wires and bars should not be less than 85 and 80% respectively, of the minimum specified tensile strength.



MATERIALS FOR PRESTRESSED CONCRETE

ii) Strength Requirements

- An important requirement of steel used in a prestressed member is plasticity of the steel at stresses near ultimate stress.
- It is essential to achieve progressive failure of prestressed concrete members with sufficient warning before final failure.
- To avoid the possibility of brittle failure fracture, normal practice is to specify that the high-tensile steel will have a minimum elongation at rupture.
- IS code prescribes a minimum percentage of elongation varying from 2.5% for wires to 10% for bars as specified in the tables.
- However, for strands the % elongation measured on a gauge length not less than 600 mm should not be less than 3.5% immediately prior to the fracture of any component of wire.

MATERIALS FOR PRESTRESSED CONCRETE

iii) Permissible streses in steel

- Tensile stresses in steel at the time of tensioning behind the anchorages and after allowing for all possible losses are generally expressed as a fraction of the ultimate tensile strength or proof stress.
- The recommendations of the various national codes vary marginally with regard to the allowable stresses in prestressed members at various stages.

MATERIALS FOR PRESTRESSED CONCRETE

iii) Permissible streses in steel

Permissible stresses in high-tensile steel (IS:1343-1980)

At the time of initial tensioning	Initial prestress no tot exceed 80% of the characteristic tensile strength of tendons
Immediately after prestress transfer	-
Final stress after allowing for all losses of prestress	Not less than 45% of the characteristic tensile strength of tendons

METHODS FOR IMPARTING PRECOMPRESSION TO CONCRETE

- Generation of compressive force between the structural element and its abutments using flat jacks.
- Development of hoop compression in cylindrically shaped structures by circumferential wire binding.
- Use of longitudinally tensioned steel embedded in concrete or housed in ducts.
- Use of principle of distortion of a statically determinate structure either by displacement or by rotation of one part relative to other remainder.
- Use of deflected structural steel sections embedded in concrete until the hardening of the later.
- Development of limited tension in steel and compression in concrete by using expanding cements.