: Pre-stressed Concrete:

Pre-stressed concrete:

↳ A concrete in which certain magnitude of pre-stress (pre-compression) is introduced and distributed in such a manner that it counteract the working load is pre-stressed concrete.

↳ It overcomes the natural weakness of concrete i.e. whole concrete section is in compression.

↳ It eliminates the tensile crack.

- The process of inducing compressive stress in a structure before it is part of its use is known as pre-stressing.

Materials used in prestressed concrete:

a. High grade concrete.
b. High strength tendon.

a. High grade concrete:

↳ Minimum grade of concrete required is;

→ Pre-tensioning pre-stressed concrete: M_{40}.

→ Post tensioning pre-stressed concrete: M_{35}.

↳ Maximum cement content should not be greater than 530 kg/m^3.

b. High strength tendon:

↳ steel grade of (1250 - 2700) MPa.

↳ Tendon consists of straight core with seven wires wound around.

↳ Similar to wire tendons, strands can be used individually or in groups to form cables.

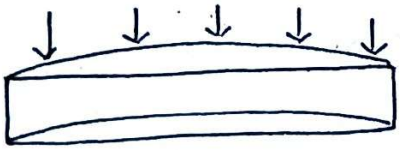
Working mechanism of pre-stressed concrete:

↳ Steel tendon is introduced in tensile zone of beam which is subjected to tensile force by tensioning the tendon.

↳ After tensioning, tendon is released. and tensile force gets converted to compressive force.

↳ Due to compressive stress in concrete, the beam deflect upwards as shown in fig. below.

↳ When external load is applied on the structure, it is counteracted by upward deflection of beam. Finally the beam deflection is reduced within the allowable limits. Hence the structure become safe.



Advantages of Pre-stressed concrete over reinforced concrete:

1. Serviceability and strength:
   a. Reduces occurrence of crack i.e. tension crack doesnot develop.
   b. Smaller x-section of concrete resists large load.
   c. concrete can be used efficiently.
   d. Reduction in steel corrosion.
   e. Increase in durability
   f. Reduced self weight and section depth.
   g. High stiffness and shear capacity.

2. Application:
   a. Important for long cantilever structure.
   b. Can be used for long span bridge, building with large column free-space.
   c. complex geometry structures including complex curves uses prestressed concrete.
   d. More aesthetic appeal due to slender section.

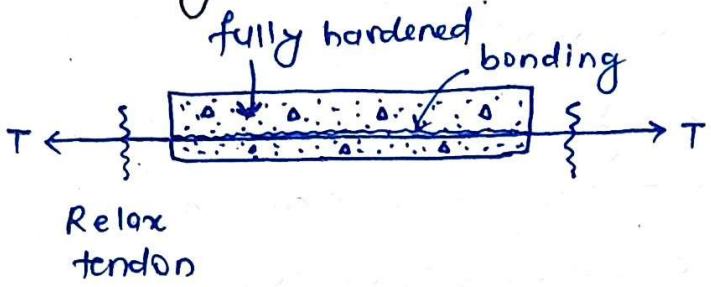
3. Economy:
   a. Rapid construction
   b. Better quality control
   c. Reduced maintenance
   d. suitable for repitidive construction
   e. Multiple use of formwork.

*: Types of Pre-stressed concrete:

a. Pre-tensioning pre-stressed concrete.
b. Post tensioning pre-stressed concrete.

a. Pre-tensioning pre-stressed concrete:

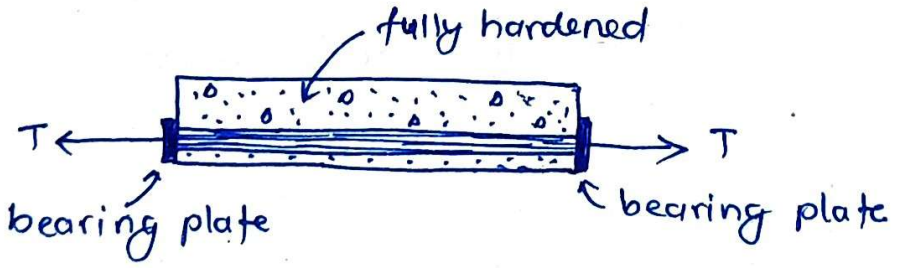
↳ First tensioning of tendon is done then concreting is carried out.



↳ Pre-stress is transfer to concrete through bonding mechanism.
↳ used for small span and lighter weight structure
eg: electric pole.
↳ Pre-cast or factory made method.

b. Post-tensioning pre-stressed concrete:

↳ First concreting is carried out then tensioning of tendon is done.



↳ Compressive stress is transferred through bearing mechanism.
↳ This method of pre-stressing is cast insitu method.
↳ use for large span and heavy structure
eg: bridge

*: Profile of the tendon:

↳ A tendon is a group of steel wires bundled together as a unit. This wire develops stress in concrete before the concrete is subjected to service loads.

According to ISO-6707:

A tendon is a group of steel bars given a tensile stress that produced a compressive stress in prestressed concrete.

↳ Placement of tendon is eccentric, this is due to load balancing concept.

↳ shape of BMD due to external loads = profile of tendon.

*: What are the requirements of earthquake resistant building construction? [10 marks] [PSC - 2078, 2079]

Ans: IS 1893 : 2016 has the provision for earthquake resistant building construction:

a. Shape:

↳ Building with simple geometry and symmetric in plan are good from earthquake resistant point of view.

↳ Building with restraint corners like U, L, V, H etc shape in plan suffer more damage during earthquake.

↳ While selecting shape of building, following points should be considered:

(i) Torsion irregularity
(ii) Reentrant corners
(iii) Diaphragm
(iv) Out-of plane offsets
(v) Non-parallel system
(vi) Stiffness irregularity
(vii) Mass irregularity
(viii) Vertical geometric irregularity
(ix) Discontinuity in capacity.

b. Proportion:

↳ length to breadth ratio for building ≤ 3:1

↳ length to breadth ratio for room ≤ 3:1

↳ height to width ratio for building ≤ 3:1

c. Foundation:

↳ should be designed considering geotechnical data such as
- nature of soil deposits.
- bearing capacity of soil.
- position of ground water table.
- prospects of liquefaction etc.

↳ should have strong foundation on hard and uniform ground.

d. Ductility:

↳ Frame of building should have adequate ductility to undergo large deformation without collapse.

↳ attempt should be made to improve ductility by proper detailing strategies following available codes of practice such as IS 13920.

e. Redundancy:

↳ Redundancy means holding different elements in reserve which came into action when distortion increase.

↳ ensures safety when an element in lateral force resisting system fails for any reason.

↳ provides multiple locations for yielding, distributes inelastic activity throughout the structure and improves ductility and energy dissipation.

↳ Redundancy can be improved by

- providing solid infill wall.
- use of braces in frames.
- shear wall fixed to frame.
- providing multiple bays in each direction.

f. Minimum torsion:

↳ Member resisting horizontal force should be arranged such that centre of rigidity and centre of mass in each floor lie close to each other in both major axes.

↳ Special calculation for additional shear force should be done in case twist cannot be avoided.

→ IS 1893: 2002 has provision for such calculation.

*: General requirements of earthquake resistant construction:

Ans: NBC 204: 2015 provides provision for earthquake resistant construction: (Earthen buildings)

Some basic factors leading to enhanced seismic resistant

a. Proper site selection:

↳ stable and safe to withstand total building load.

↳ site should be selected according to section 4 of guidelines.

b. Appropriate planning:

↳ symmetric in plan and elevation along with simple in geometry ensures more seismic safety.

↳ recommended span and proportion should be in accordance to section 5 of guidelines.

c. Good foundation resting on firm base:

↳ Foundation should be durable and strong having high bearing capacity.

↳ site investigation shall be carried out in accordance with section 4 of guidelines.

↳ Dimension and quality of masonary for foundations should be in accordance with section 6 of guidelines.

d. creating a box-effect:

↳ attempt to make construction act as a single unit during earthquake.

↳ Following elements need to be introduced as stated in section-10 of guideline.

- vertical reinforcement
- Horizontal bands.
- diagonal bracing
- lateral restraints.

e. Better bonding between the masonary units:

↳ bond should be of good quality between the masonary units.

↳ all masonary units should be properly laid to provide integrity.

f. controlled size and location of opening:

↳ large unstiffened opening should be avoided.

↳ opening size and location should be controlled.

↳ Recommended size and location of opening should be in accordance with section-8 of guidelines.

g. Light construction:

↳ lighter structure less attracts the earthquake.

↳ lighter materials like timber, bamboo etc are preferred, provided they are available and suitable.

↳ thickness of the wall should be as low as possible but in no case;

- less than 230 mm for brick masonary.
- less than 350 mm for stone masonary.

Q: What are the rule of thumb in RCC building without masonary infill? [10 marks]

Ans: NBC code: 1994 has provision for the rule of thumb in design of RCC structure without masonary infill, thy are:

1. The span of the beam shall not exceed 4.5 m.
2. There should not be more than 6 bays in each direction.
3. Each slab pannel shall be lesser than 18.5 sq.m.
4. The maximum height of structure is 11m or 3 storeyed. whichever is less.
    - however an additional storey of smaller plan area (not exceeding 25% of floor area) shall be permitted.
5. The length of the wing of the structure (lc_1 and lc_2) shall be restricted such that they are lesser than 15% of length of rectangular part in either direction.

6. No wall except the paraphet wall should be built in a cantilever slab.
    - such wall shall be constructed only if cantilevered slab is framed with beam.

7. The foundation shall be at a uniform level.
8. Building shall not have soft-storey.
9. The size of cantilever projection should not exceed 1m.
10. The length to width ratio or height to width ratio must not exceed 3.

↳ Building complying all these provision shall be designed using these guidelines:

a. Building occupancy: Residential building
b. Bay dimension: 3m x 3m to 4.5m x 4.5m.
c. No. of bay: 2x2 to 6x6.
d. No. of storey: upto 3 and stair cover.
e. story height:
   - Terai = 3.35m
   - For other regions = 2.75m
f. Wall thickness:
   - Interior = 115mm
   - Exterior = 230mm
g. Cantilever projection = 1m (from centreline of beam)
h. Concrete grade: M_{20}
i. Reinforcement = Fe415 or Fe500.
j. Mortar:
   - For half brick wall 1:4 (min^m)
   - For full brick wall 1:6 (min^m)
k. Reinforcement detailing in slab
   ↳ 8ϕ @ 150mm in all critical section with appropriate cranking.

l. Slab thickness : 125mm

m. Beam dimension :

- width = 230 to 250 mm.
- depth = 855 mm including slab for floor beam.
  = 230 mm for tie beam.

n. staircase dimension

- thickness of slab = 125mm
- width = 1050 mm
- rise or tread : as per building plan.

o. column dimension: 300mm x 300mm

p. Reinforcement detailing :

- column : detail drawing provided in code.
- foundation: 12mm ϕ bar provided in both direction.

*: What are the rule of thumb in RCC building with masonary infill ? [10 Marks]

Ans: NBC 201:1994 has provision for rule of thumb in design of RCC structure without masonary infill:

Note: All points are same as above for without masonary infill except,

① length of wing of the structure (k_1 and k_2) shall be restricted such that they are lesser than 30% of length of rectangular part in either direction.

$$k_1, k_2 < 0.3A \text{ or } 0.3B$$

② infill wall should be provided in such a way that it should resist lateral forces

- $x_m - x_r \leq 0.1A$
- $y_m - y_r \leq 0.1B$

; where x_m, y_m = centre of ma
x_r, y_r =

Q: What are the rule of thumb for design of load bearing building? [10 marks]

Ans: NBC-202: ~~2015~~ has provision for load bearing building.

↳ Any one wishing to build following types of building don't need to employ qualified personnel for appropriate design.

- upto 3-storeyed load bearing brick masonary building (cement-sand mortar)
- upto 2-storeyed load bearing stone masonary building (cement-sand mortar)
- upto one-storeyed load bearing brick masonary building (mud-mortar)

Provision made in codes are:

a. Thickness of wall:

1. Brick masonary (cement mortar)
   - ↳ for single storey: at least 230 mm
   - ↳ for multi storey:
     - ground floor wall: 350 mm (min^{m})
     - upper floor wall: 230 mm (min^{m})

2. Stone masonary (cement mortar)
   - ↳ for single storey: at least 350 mm
   - ↳ for multi storey: same as brick masonary (cement mortar)

3. Brick masonary (mud mortar)
   - ↳ for single storey: at least 350 mm.
   - ↳ for multi storey: same as above...

b. Footing:

1. Brick masonary (cement mortar)
   - single storey
     - ↳ 230 mm x 540 mm x 900 mm
     - ↳ stepped over pcc and brick soling.
     - ↳ depth 800 mm.
   - multi storey
     - ↳ 350 mm x 450 mm x 600 mm.
     - ↳ stepped over pcc & brick soling.
     - ↳ depth 900 mm.

2. stone masonary
   - single storey
     - ↳ 350 mm x 900 mm
     - ↳ depth 800 mm
   - multi storey
     - ↳ 350 mm x 600 mm x 900 mm
     - ↳ depth 900 mm

3. Brick masonary (mud-mortar)
   - single storey
     - ↳ 350 mm x 600 mm x 900 mm
     - ↳ stepped over brick soling
     - ↳ depth 500 mm
   - multi storey
     - ↳ 350 mm x 600 mm x 720 mm
     - ↳ stepped over brick soling
     - ↳ depth 900 mm

c. Types of band at plinth level:

1. Brick or stone masonary (cement mortar)
   - ↳ RCC band of 150 mm thick
   - ↳ height : 300 to 750 mm from GL.

2. Brick masonary (mud mortar)
   - ↳ wooden collar band
   - ↳ height: 300 to 750 mm from GL.

Note:
- ↳ Band is mandatory when the soil is soft or uneven.
- ↳ Band also serve as damp proof course.

d. Openings in wall:
- ↳ small in size and centrally located.
- ↳ top of opening shall be at same level.

e. Lintel band:
- ↳ should be provided in all opening
- ↳ width: same as wall
- ↳ thickness: 75 mm with 2-10ϕ longitudional bar.
- ↳ 2-10ϕ bars are held in position by stirrup 6mm in diameter spaced 150mm apart.

f. Other bands:
- ↳ Band at eaves level in the form of roof band.
- ↳ Triangular portion of masonary: gable band.

g. Roofing material:
- ↳ must be light, well connected and adequately tied to walls.

h. Stone masonary wall:
- ↳ full wall thickness stones should be used in every 600 mm lift not exceeding 1.2 m apart horizontally.

Date:-

Q. What are the requirements of earthquake resistant building construction? [10 marks]

Ans: NBC-202: 2015 and NBC-204: 2015 has provision for earthquake resistant building construction.

NBC-203: 2015 → low strength masonary building.

NBC-204: 2015 → Earthen building.

General requirements of earthquake resistant building are:

a. Proper site selection:
- ↳ stable and safe to withstand total building load.
- ↳ site should be selected according to section-4 of guidelines.

b. Appropriate planning:
- ↳ plan and elevation along with simple in geometry.
- ↳ recommended span and proportion should be accordance with section-4 guidelines.

c. Good foundation resting on firm base.
- ↳ foundation should be durable and strong having high bearing capacity

Date:-

↳ Dimension and quality of masonary for foundation should be in accordance with section-6 of guidelines.

d. Creating a box-effect:

↳ Attempt to make construction act as a single unit during earthquake

↳ Following elements need to be introduced as stated in section-10 of guidelines:

- vertical reinforcements.
- diagonal bracing.
- lateral restraints.
- Horizontal bands.

e. Better bonding between masonary units

↳ Bond should be of good quality between masonary units.

f. Controlled size and location of opening:

↳ large unstiffened opening should be avoided.

↳ Recommended size and location of opening should be as per section-8 of guidelines.

g. light construction.

Date:-

some other requirements are:

i. Roof:

↳ for sloping roof of span > 6m, use truss instead of rafters.

↳ prefer 4 side sloping roof instead of 2-side sloping.

ii. Chajja:

↳ Restrict projection to 0.9m

↳ for larger projection, use edge beam or column.

iii. Parapet:

↳ Build parapets with brick upto 300m followed by iron railings.

iv. Concrete & mortar:

↳ Use river sand for making mortar and concrete.

↳ Coarse agg. of size > 20mm should be avoided.

v. Bands:

↳ Following RC band should be provided.

- plinth band
- lintel and sill band
- Roof band
- Gable band.

vi. Retrofitting:

↳ preparing a building in a scientific manner so that all elements act one uni

Nepal National Building

1. NBC-205 : 1994
   Mandatory Rule of thumb for Reinforced concrete building without masonary infill wall.

2. NBC-201 : 1994
   Mandatory Rule of thumb for Reinforced building with masonary infill wall.

3. NBC-202 : 2015
   Guideline on load bearing masonary units.

4. NBC-208 : 2015
   Guideline for Earthquake resistant building construction. (low strength masonary building)

5. NBC-204 : 2015
   Guideline for Earthquake resistant building construction.
   (Earthen building).

6. IS-1893 : 2016 Requirements of Earthquake resistant building construction.

: Structural Engineering:

Date:-

7. NBC-105: 2020 Seismic Design of Building.