(more than two wires)

Tendon :- A group of strands or wires are wound to form a pre-stressing tendon.

Cable : A group of tendons.

Sec-C

Pre-stressed Concrete Structures

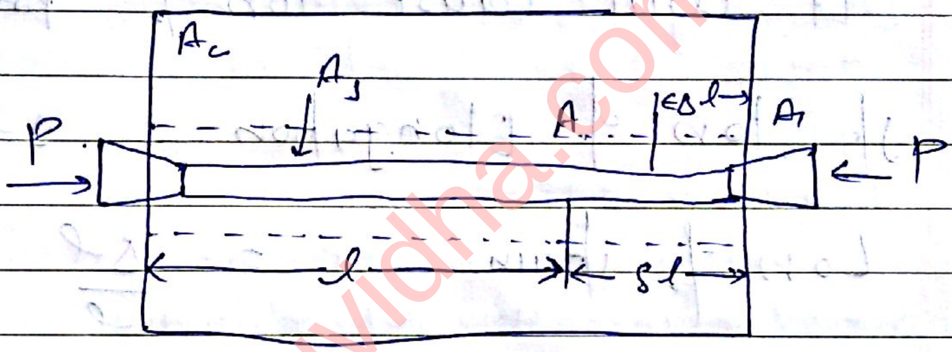
Concept :-

If a steel reinforcement provided in a concrete is applied a force and is anchored after getting an elongation of δl. Now force is removed.

Stress in steel

$$e = \frac{\delta l}{l}$$

$$\left[\frac{f}{e} = E \quad f = eE \right]$$



Stress developed in steel

$$f_s = e \cdot E_s$$

or

$$f_s = \frac{\delta l}{l} E_s$$

If cross-sectional area of steel is A_s.
force developed due to δl deformation

$$F_s = f_s \times A_s = \frac{\delta l}{l} E_s \times A_s$$

This force $F_s = F$ - force applied on concrete

P T O

It is called pre-stressing force.

P_s = tensile in steel.

P_c = compressive in concrete.

$$f_c = \frac{P}{A_c}$$

If due to any reason a elongation provided is reduced, say by Δl. It will cause loss of pre-stress.

If loss of elongation = Δl

Loss of strain = $\frac{\Delta l}{l}$

Loss of stress or pre-stress =

$$\frac{\Delta l}{l} E_s$$

Net (Final) pre-stress available =

$$\frac{\delta l}{l} E_s$$

Definition :-

A Pre-stress concrete is one in which there have been introduced internal stresses of such magnitude and distribution, that stresses caused due to external loading are counter balance upto a desired degree.

Assumptions :-

1) Concrete is a homogeneous material.
2) plane section before bending remains plane after bending.
3) strain diagram is uniform.
4) with in the limit of deformation, hook's law is valid (applicable) to concrete and steel.
5) The stresses in reinforcement ~~do~~ does not changes along the length of reinforcement. stress changes takes place only for concrete.
6) variation of stress in reinforcement due to change in external loading is ~~ign~~ ignored.

Advantages of Pre-stress concrete -

* Need less materials.
* Smaller and lighter structure
* No cracks. (means reduce cracks)
* Better corrosion resistance.
* Good for water tanks and nuclear plant.
* Allow to carry a greater load or span of greater distance
* Improving the performance of the building under various service conditions.

Disadvantages:-

* Need higher quality material.
* more complex technically
* more expensive
* Harder to recycle.

Applications:

widely used in —

* Bridges
* slabs in buildings
* water tanks
* Concrete piles
* Nuclear Power plants
* Columns and Beams.

Principle of Pre-stressing :-

Pre-stressed concrete is a method for over coming concrete's natural weakness in tension.
It can be used to produce beams, floors or bridges with a longer span than is practical with ordinary reinforced concrete.

Classification of Pre-stressed members :

(A) Externally OR Internally Pre-stressed :-

This classification is based on the location of the pre-stressing tendon with respect to the concrete section.
In such type of ~~pre-stressing~~ pre-stressed concrete structures, pre-stressing may be done inside or outside of the section.

(B) Linear OR circular Pre-stressing :-

This classification is based on the shape of the member pre-stressed.

a) Linear Prestressing :- Pre-stressing can be done in straight structures such as beams.

b) Circular Pre-stressing :- Pre-stressing around a circular structure such as tank is known as circular pre-stressing.

Page

(C) Bounded OR unbounded tendon.

* The tendon may be bounded to concrete (pre-tensioning or post-tensioning with grouting)
* The tendon may be unbounded to concrete (post-tensioning without grouting)

(D) Pre-tensioning And post tensioning :-

a) Pre-tensioning pre-stress :-

* In pre-tension, the tendons are tensioned against some abutments before the concrete is placed.
* After the concrete hardened, the tension force is released.

b) post-tensioning pre-stress :-

* In post-tension, the tendons are tensioned after the concrete has hardened.

* After the concrete hardened and had enough ~~resist~~ strength, the tendon was placed inside the duct stressed and anchored against concrete.

~~Difference~~ B/w

V. V. Imp

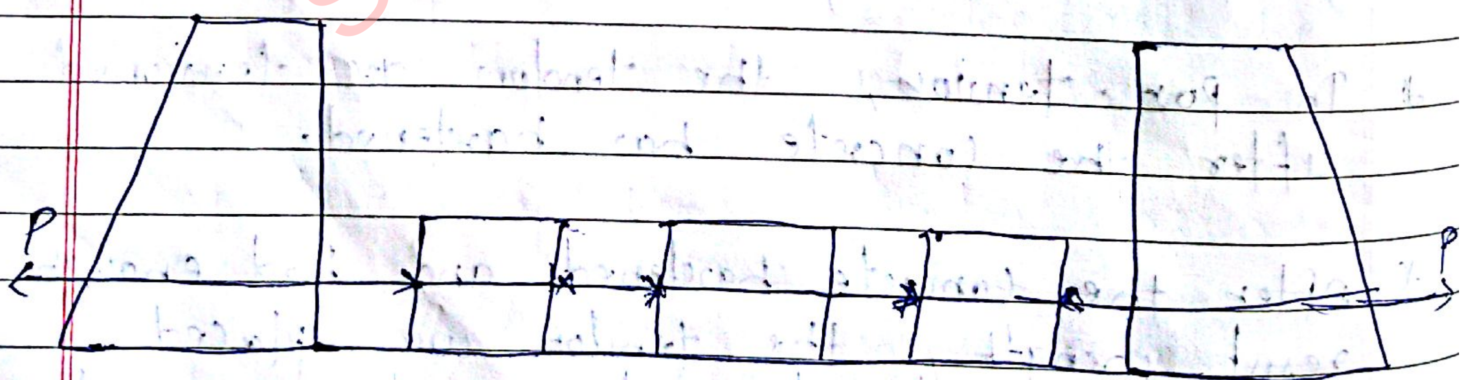
Various Pre-stressing Systems :-

(A) Pre-tensioning

(B) Post-tensioning

Pre-tensioning :-

The tendons are tensioned before casting of ~~iron~~ concrete.
The Pre-compression is transmitted from steel to concrete through bond over the transmission length near the ends.

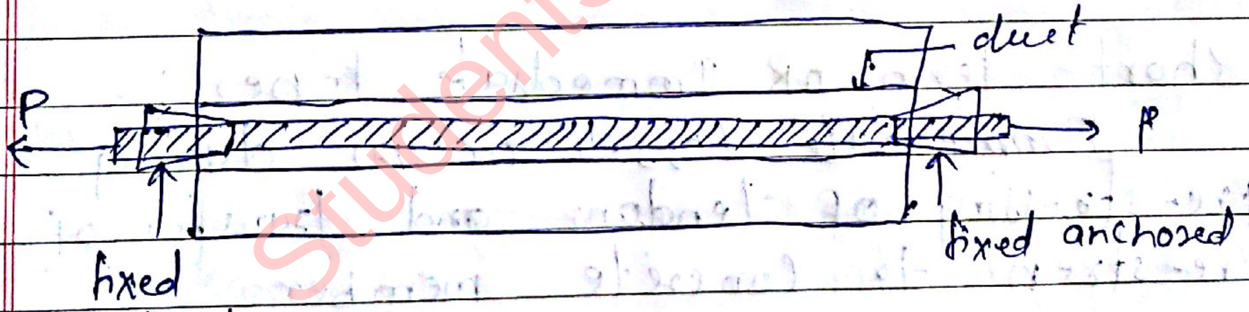


Properties :-

i) steel is in direct contact with concrete.
ii) steel is tensioned before casting of concrete.
iii) After setting of concrete, steel reinforcement are cut.
iv) pre-stressing force is applied due to bond action

Post Tensioning :-

The tendons are tensioned after the concrete has hardened.
The pre-compression is transmitted from steel to concrete by the anchorage device



Properties :-

i) steel and concrete are not in direct contact.
ii) concrete is casted before pre-stressing of steel.
iii) A duct is left in concrete during casting.
iv) After settling of concrete, steel reinforcement (tendons) are inserted in duct and tensioned either from one end or both end and anchored.

V.V.Pml

Losses in Pre-stress :-

Loss of Pre-stress is a great concern since it affects the strength of member and also significantly affects the member's serviceability including stresses in concrete, cracking, camber and deflection.

Loss of Pre-stress is classified into two types

A) Short-term or Immediate losses.

B) Long-term OR Dependent Losses.

Short-term OR Immediate loses :-
Immediate losses occurs during Pre-stressing of tendons and transfer of Pre-stress to concrete member.

Long term OR Time Dependent losses -

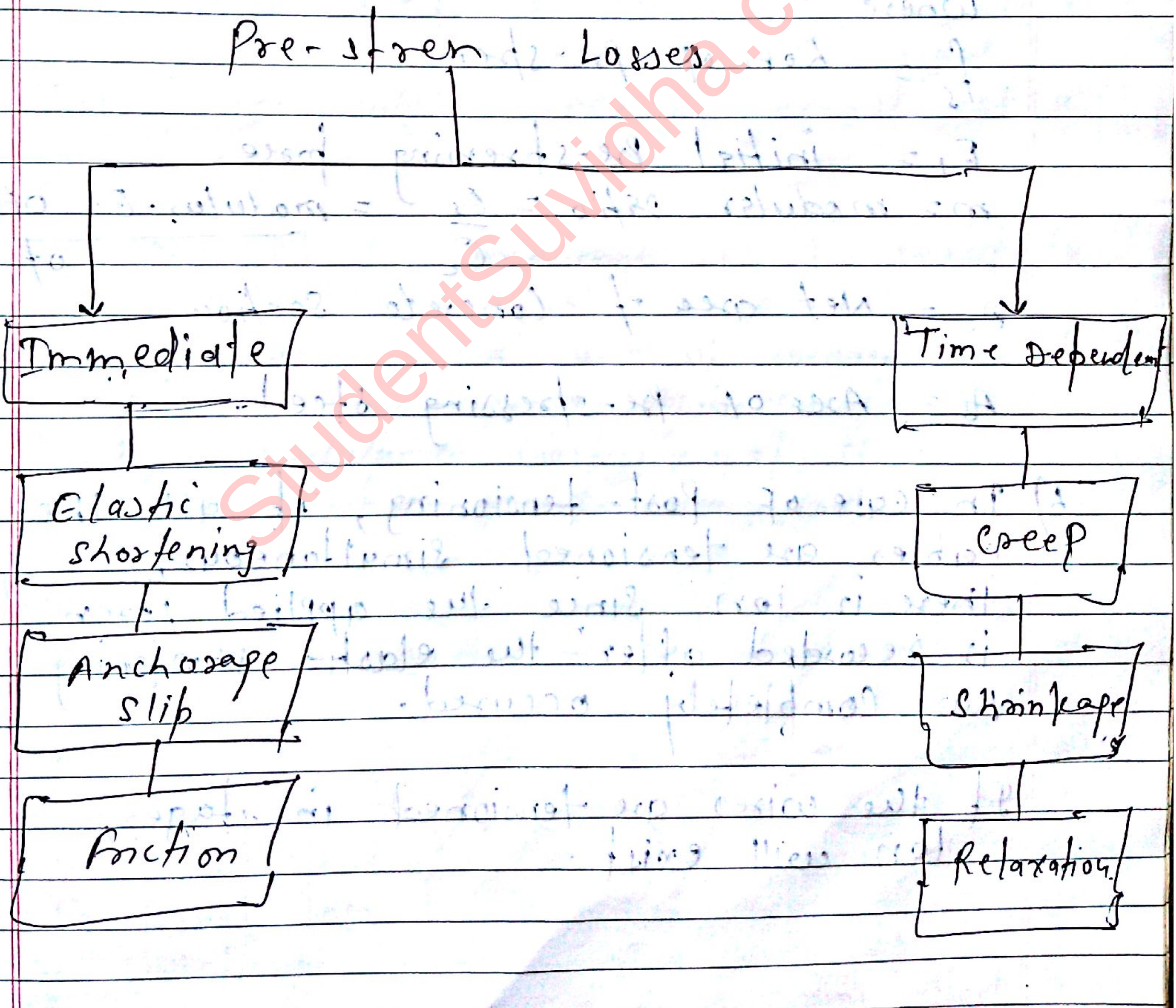
Time dependent losses occurs during service life of structure.

Immediate Losses include –

i) Elastic shortening of Concrete.
ii) Slip at anchorages.
iii) Friction.

Time Dependent losses –

i) Creep and shrinkage of Concrete.
ii) Relaxation of prestressing steel.



1) Elastic shortening of concrete :-

a) In pretensioned concrete, when the pre-stress is transferred to concrete, the member shortens and the pre-stressing steel also shortens in it. Hence there is a loss of prestress.

$$f_s = \frac{m F_1}{A_c + m \cdot A_s}$$

where

f_s = loss of pre-stress.

F_1 = initial pre-stressing force.

m = modular ratio = $\frac{E_s}{E_c}$ = modulus E. of steel / of concrete

A_c = Net area of concrete section

A_s = Area of pre-stressing steel.

b) In case of post-tensioning, if all the cables are tensioned simultaneous, there is loss since the applied stress is recorded after the elastic shortening has completely occured.

If the wires are tensioned in stages, loss will exist.

2) Anchorage Slip :-

This type of loss may occur in both pre-tensioned and post-tensioned members.

The amount of loss due to slip vary with the type of anchorage provided and the nature of construction method.

Mathematically,

Loss of pre-stress due to slip at anchorage can be calculated as -

$$\Delta f_s = P/A$$

$$= \frac{\Delta \cdot E_s}{L}.$$

where

Δ = slip of anchorage.

L = length of cable.

A = Cross-sectional area of tendon.

Δf_s = total loss in pre-stress.

E_s = modulus of elasticity of steel.

P = pre-stressing force in cable.

3) Friction :-

~~loss due to friction does not occur in p~~

The friction generated at the interface of concrete and steel during the stretching of a curved tendon in a post-tensioned member.

Frictional loss is the summation of

a) Frictional loss due to length effect

b) " " " to curvature effect.

The loss due to friction does not occur in pre-tensioned members because there is no concrete during the stretching of the tendons.

Methods available to reduce the frictional losses —

1) Cables should pass through metal tubes
2) The bends should be through as small an angle as possible.
3) Radius of curvature for bends should be large.
4) Pre-stressing the wire from both ends.

4) Creep of concrete :-
This type of loss occurs due to continuous deformation of concrete with time under sustained load.

Factors affecting creep of concrete -

* Age
* Applied stress level
* Density of concrete
* Cement content in concrete
* water - cement ratio
* temperature

5) Shrinkage of Concrete :-

Shrinkage of concrete is defined as the contraction due to loss of moisture.
Due to the shrinkage of concrete, the pre-stress in the tendon is reduced with time.

a) For pre-tensioned members, transfer commonly takes place after 24 hours after casting of concrete

b) For post-tensioned members, stressing may takes place after one day or much later, thus a large percentage of shrinkage may already taken place by them.

6) Relaxation

Relaxation is the redn in stress with time at constant strain.

* decrease in the stress is due to the fact that some of the initial elastic strain is ~~transfered~~ transformed in to inelastic strain under constant strain.

* Percentage of relaxation varies from 1 to 5%.

J.V. [illegible]

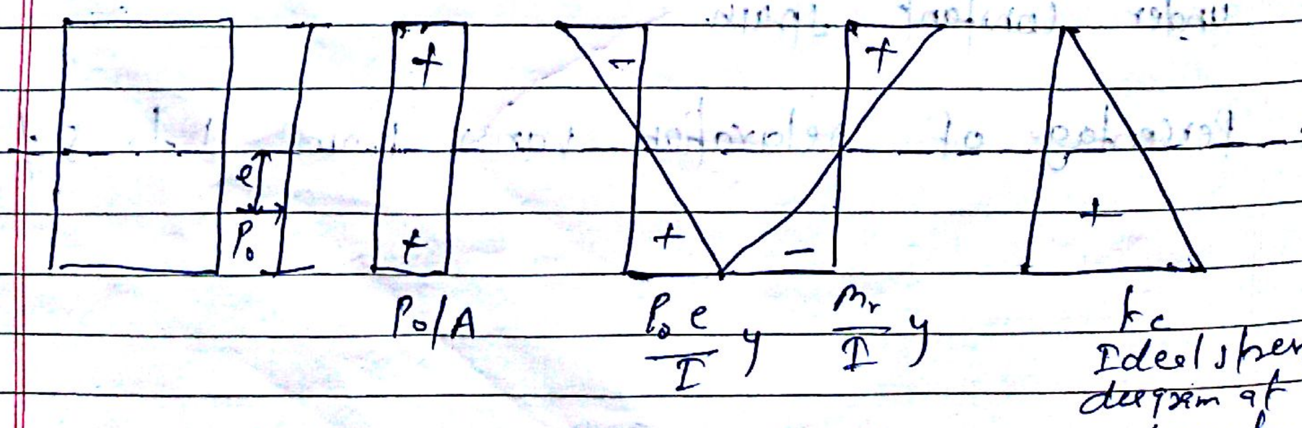
Stages of loading OR, stages to be considered in the design of Pre-stressed concrete members :-

The Pre-stressed concrete has to be designed at different stages of loading which are given below.

1) At transfer
2) At final stage of loading

At transfer stage, or initial stage of loading :-
just after transfer of pre-stressing force in the members,

1) Losses of pre-stress are not considered
2) Live load is not considered.
3) Dead load may be considered (if not supported)
4) Dead load not to be consider if beam is still on its prestressing bed.

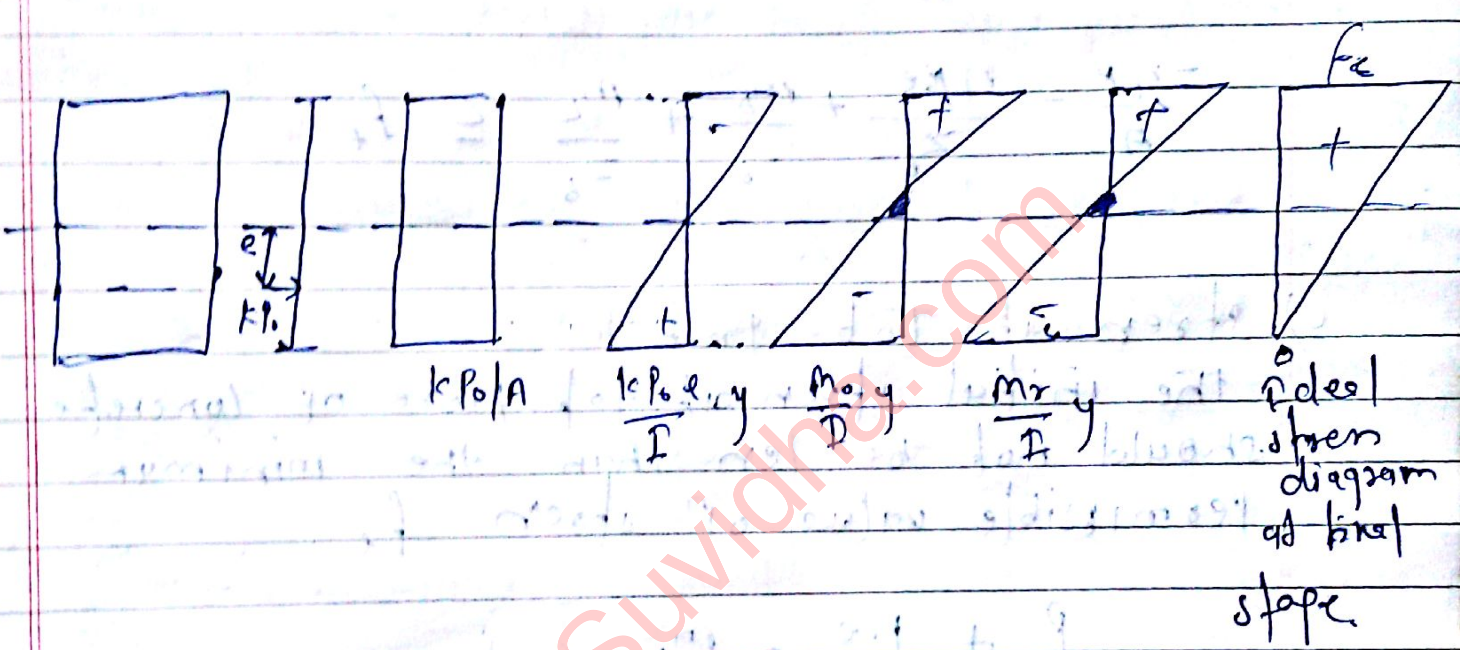


Ideal stress diagram at transfer

At final stage :-

1) Losses are to be considered. | i.e. loss = 20%
final $P = kP_0$; | $k = 0.80$
where k = loss factor (1 - loss %) ;

2) All loads are to be considered.



Initial and final stress conditions :-

The Pre-stressed beams should satisfy the following stress conditions.

A) stress at Bottom Initially :-
The stress at bottom should not exceed permissible compressive stress. f_c.

$$\frac{P}{A} + \frac{P.e}{Z_b} - \frac{M_D}{Z_b} \leq f_c . \quad -(1)$$

(B) stress at Bottom Finally :-

After looses, the effective pre-stressing forces may be taken as $\eta . P$.
The final stress at bottom should be less than the minimum allowable stress. f_t.

$$\frac{-\eta . P}{A} - \frac{\eta P . e}{Z_b} + \frac{M_D}{Z_b} + \frac{M_L}{Z_b} \leq f_t .$$

C). stress at Top Initially :-
The initial stress at top fibre of concrete should not be less than the minimum permissible value of stress f_t.

$$\frac{P}{A} + \frac{P . e}{Z_t} - \frac{M_D}{Z_t} \leq f_t .$$

D) stress at top Finally :-
The stress in the top fibre of concrete at final stage should be less than the maximum permissible stress

$$\frac{\eta P}{A} - \frac{\eta . P . e}{Z_t} + \frac{M_D}{Z_t} + \frac{M_L}{Z_t} \leq f_c$$

where $P.e = M$ = moment due to pre-stressing
Z_b and Z_t = section modulus for bottom and top fibres.
M_L and M_D = Live load and Dead load moments.

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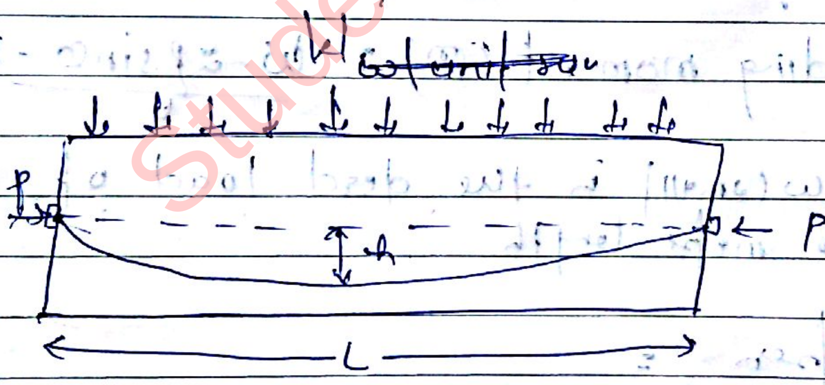
Analysis of Pre-stressed Members
OR
Load Balancing Concept :-

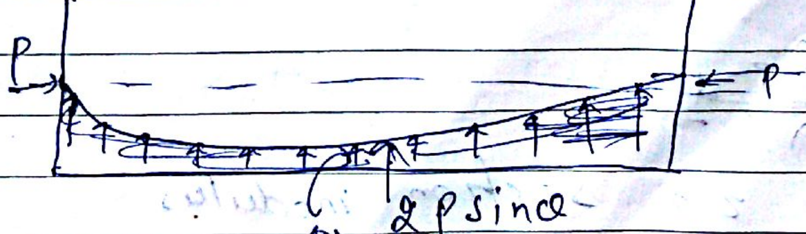
There are three approaches to analyse a pre-stressed member at transfer and under service loads.
These approaches are based on the following concepts.

a) Based on stress concept
b) Based on force concept
c) Based on load balancing concept.

Load Balancing Concept :-



a) Beam member



b) Free body of concrete +

P

In the concept of load balancing,

* make the profile of cable straight from the point where it is at end.

* The upward balancing load due to profile of cable (point load = $2P\sin\theta$)

downward load = W

* Net point load = $W - 2P\sin\theta$

The axial longitudinal force provided by the tendon

$= P\cos\theta$

or

P (as θ is very small angle)

Net Bending moment (M) = $\frac{(W - 2P\sin\theta) \cdot L}{4} + \frac{wL^2}{8}$

where w (small) is the dead load of the beam per metre length

Final stress =

$$\frac{P}{A} \pm \frac{M}{Z}$$

Where Z = Section modulus