LOSSES OF PRESTRESS

Nature of Losses of Prestress

- **Initial prestress in concrete undergoes a gradual reduction with time from the stage of transfer due to various causes and is referred as "Loss of Prestress".**
- **From design point of view, a reasonable good estimate of such is required.**

No	Pretensioning
1.	Elastic deformation of concrete
2.	Relaxation of stress in steel
3.	Shrinkage of concrete
4.	Creep of concrete

No	Post-tensioning
1.	•No loss due to elastic deformation if all wires are tensioned simultaneously •If wires are tensioned successively then there will be loss due to elastic deformation of concrete
2.	Relaxation of stress in steel
3.	Shrinkage of concrete
4.	Creep of concrete
5.	Friction
6.	Anchorage sleep

- In addition to above, there may be losses of prestress due to sudden changes in temperature, especially in steam curing of pretensioned units.
- The rise in temperature causes a partial transfer of prestress (due to elongation of the tendons between adjacent units in long-line process) which may cause a large amount of creep if the concrete is not properly cured.
- If there is possibility of a change of temperature between the times of tensioning and transfer, the corresponding loss should be allowed for in the design.

Loss due to Elastic Deformation of Concrete

- The loss of pre-stress due to elastic deformation of concrete depends on the modular ratio and the average stress in concrete at the level of steel.
- If f_c = Prestress in concrete at the level of steel

  E_s = Modulus of elasticity of steel

  E_c = Modulus of elasticity of concrete

Modular ratio, $\alpha_e = E_s / E_c$

Stain in concrete at the level of steel = f_c / E_c

Stress in steel corresponding to this strain = $(f_c / E_c) \times E_s$

Loss of stress in steel = $\alpha_e f_c$

If the initial stress in steel is known, % loss of stress in steel due to the elastic deformation of concrete can be computed.

EX: A pretensioned concrete beam, 100 mm wide by 300 mm deep, is prestressed by straight wires carrying an initial force of 150 kN at an eccentricity of 50 mm. Es = 210 kN/mm², Ec = 35 kN/mm². Estimate the percentage loss of stress in steel due to elastic deformation of concrete if the area of steel wires is 188 mm².

- P = 150 kN
- e = 50 mm
- A = 3E4 mm^2
- I = 225E6 mm^4
- $\alpha_e = E_s / E_c = 6$
- Initial stress in steel = (150E3 / 188) = 800 N/mm^2
- Stress in concrete, f_c = (150E3 / 3E4) + (150E3 x 50 x 150 / 225E6) = 6.66 N/mm^2
- Loss of stress due to elastic deformation of concrete = α_e x f_c = (6 x 6.66) = 40 N/mm^2
- Percentage loss of stress in steel = 40 x 100 / 800 = 5%

EX: A post-tensioned concrete beam, 100 mm wide by 300 mm deep, is prestressed by three cables, each with a cross-sectional area of 50 mm^2 and with an initial stress of 1200 N/mm^2. All 3 cables are straight and located 100 mm from the soffit of the beam. If $\alpha_e = 6$, calculate loss of stress in 3 cables due to elastic deformation of concrete for following cases:
a) Simultaneous tensioning and anchoring of all the cables
b) Successive tensioning of 3 cables, one at a time.

- Force in each cable, P = (50 x 1200) = 60E3 N
- A = 3E4 mm^2 | I = 225E6 mm^4
- e = 50 mm | y = 50 mm
- Stress in concrete at level of steel, $f_c = (P/A) + (Pe/Z) = 2.7\ N/mm^2$

a) <u>When the cables are tensioned simultaneously</u>

Loss of stress = 0

b) <u>When the cables are tensioned successively</u>

Cable 1 is tensioned and anchored – no loss due to elastic deformation

Cable 2 is tensioned and anchored – loss of stress in cable 1 is given by

$$\alpha_e\ f_c = (6 \times 2.7) = 16.2\ N/mm^2$$

Cable 3 is tensioned and anchored – loss of stress in cable 1 & 2 is given by,

Loss of stress in cable 1 = (6 x 2.7) = 16.2 N/mm^2

Loss of stress in cable 2 = (6 x 2.7) = 16.2 N/mm^2

- Total loss in stress due to elastic deformation of concrete is

Cable 1 = (16.2 + 16.2) = 32.4 N/mm^2

Cable 2 = 16.2 N/mm^2

Cable 3 = 0

Average loss of stress considering all cables = 16.2 N/mm^2

Note: It can be shown that if the number of wires, bars or strands are large, the loss due to elastic shortening approaches (but does not exceed) one-half of the corresponding load with pretensioning, i.e. loss of stress = (1/2) x α_e x fc

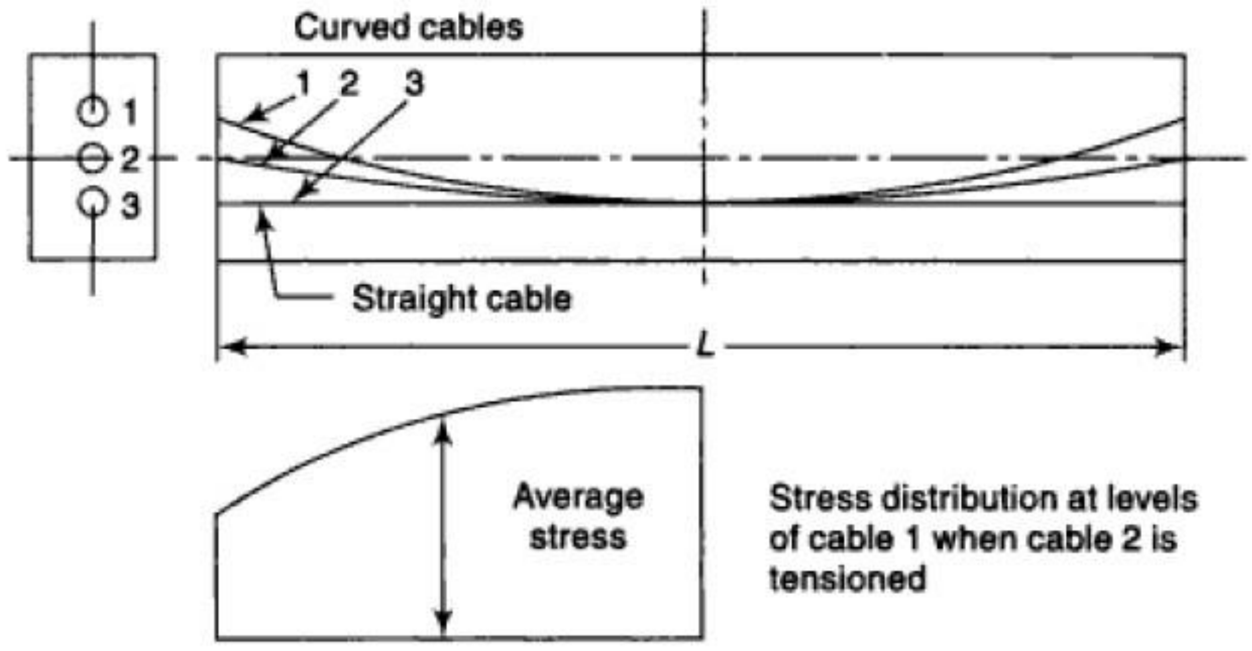
Where, fc = stress in concrete at the level of steel due to the effect of all the cables simultaneously tensioned.

Applying this to above problem,

Loss of stress = (1/2) x 6 x (3 x 2.7) = 24.3 N/mm^2

Loss of Stress due to Successive Tensioning of Curved Cables

- In most bridge girders cables are curved with maximum eccentricity at the centre of the span.
- In such cases the loss of stress due to the elastic deformation of concrete is estimated by considering the average stress in concrete at the level of steel.
- Consider a beam shown in figure, which is post-tensioned by 3 parabolic cables.
- The stress distribution in concrete at the level of cable 1 is also shown in figure, when cable 2 is tensioned.
- For computing the loss of stress, the average stress (shown in figure) is considered. When cable 3 is tensioned, there will be losses of stress in both cables 1 & 2.



Successive Tensioning of Curved Cables

EX: A post-tensioned concrete beam, 100 mm wide by 300 mm deep, spanning over 10 m is stressed by successive tensioning and anchoring of 3 cables 1, 2 and 3 respectively. The c/s area of each cable is 200 mm^2 and the initial stress in the cable is 1200 N/mm^2. $\alpha_e = 6$. The first cable is parabolic with an eccentricity of 50 mm below the centroidal axis at the centre span and 50 mm above the centroidal axis at the support sections. The second cable is parabolic with zero eccentricity at the supports and an eccentricity of 50 mm at the centre span. The 3rd cable is straight with a uniform eccentricity of 50 mm below the centroidal axis. Estimate the % loss of stress in each of the cables, if they are successively tensioned and anchored.

- Force in each cable, P = 240 kN
- A = 3E4 mm^2
- I = 225E6 mm^4
- $\alpha_e = E_s / E_c = 6$
- When cable 1 is tensioned and anchored – no loss of stress due to elastic deformation of concrete.
- When cable 2 is tensioned and anchored – stress at the level of cable 1 is given by,

Stress at support section = (240E3 / 3E4) = 8 N/mm^2

- Stress at the centre of span = (240E3 / 3E4) + (240E3 x 50 x 50 / 225E6) = 10.7 N/mm^2
- Average stress in concrete = 8 + (2 x 2.7 / 3) = 9.8 N/mm^2
- Loss of stress in cable 1 = (6 x 9.8) = 58.8 N/mm^2

- **When cable 3 is tensioned and anchored, stress distribution at the levels of cable 1, cable 2 and the average stress and loss of stress is obtained as follows:**

	Cable 1	Cable 2
Stress at support	(240E3 / 3E4) – (240E3 x 50 x 50 / 225E6) **= 5.3 N/mm²**	(240E3/ 3E4) **= 8 N/mm²**
Stress at the center of span	(240E3 / 3E4) + (240E3 x 50 x 50 / 225E6) **= 10.7 N/mm²**	(240E3 / 3E4) + (240E3 x 50 x 50 / 225E6) **= 10.7 N/mm²**
Average stress in concrete	[5.3 + (2 x 5.4 /3)] **= 8.9 N/mm²**	[8 + (2 x 2.7 /3)] **= 9.8 N/mm²**
Loss of stress in cable	(6 x 8.9) **= 53.4 N/mm²**	(6 x 9.8) **= 58.8 N/mm²**

Total losses		
Cable No.	**Loss of stress**	**Percentage Loss**
Cable 1	58.8 + 53.4 **= 112.2 N/mm²**	**9.8%**
Cable 2	**58.8 N/mm²**	**4.9%**
Cable 3	**No loss of stress**	**0%**

EX: A simply supported concrete beam of uniform section is post-tensioned by means of two cables, both of which have an eccentricity of 100 mm below centroid of the section at mid-span. The first cable is parabolic and is anchored at an eccentricity of 100 mm above the centroid at each end. The second cable is straight and parallel to the line joining the supports. If the c/s area of each cable is 100 mm^2, the concrete beam has a sectional area of 2E4 mm^2 and i = 120 mm, calculate the loss of stress in the first cable when the second is tensioned to a stress of 1200 N/mm^2. take the α_e = 6 and neglect friction.

- A = 2E4 mm^2
- i = 120 mm
- I = (2E4 x 1202) = 288E6 mm^4
- Prestressing force, P = (1200 x 100) = 12E4 N
- When cable 2 is tensioned and anchored, stress at the level of cable 1 is given by,
- Stress in concrete = (12E4 / 2E4) ± (12E4 x 100 x 100 / 288E6) = (6 ± 4.2)

= 10.2 N/mm^2 at central section and 1.8 N/mm^2 at end section

Average stress in concrete = [1.8 + (2/3) 8.4] = 7.4 N/mm^2

Loss of stress in cable 1 = (6 x 7.4) = 44.4 N/mm^2

Loss due to Shrinkage of Concrete

- Shrinkage of concrete in pre-stressed members results in a shortening of tensioned wires and hence contributes to the loss of stress.
- Shrinkage of concrete is affected by the type of cement, aggregates and method of curing used.
- Use of high strength concrete with low water cement ratios results in a reduction in shrinkage and consequent loss of pre-stress.
- Primary cause of drying shrinkage ➔ loss of water
- For pre-tensioned members, generally moist curing is done until time of transfer.
- So, total residual shrinkage strain will be larger.

IS : 1343

Loss of Stress = ε_{cs} x E_s

ε_{cs} = total residual shrinkage strain = 300E-6 for prestressing

$\left[\frac{200\ x\ 10^{-6}}{log_{10}\,(t+2)}\right]$ for post-tensioning

Where, t = age of concrete at transfer in days

EX: A concrete beam is pre-stressed by a cable carrying an initial pre-stressing force of 300 kN. The c/s area of wires in cable is 300 mm^2. Calculate % loss of stress in the cable only due to shrinkage of concrete using IS:1343 assuming beam to be a) Pre-tensioned & b) post-tensioned. E_s = 210 kN/mm^2, age of concrete at transfer = 8 days.

- $P_i = \left(\frac{300E3}{300}\right)$ = 1000 N/mm^2

a) If the beam is pre-tensioned and residual shrinkage is strain = 300E-6

Loss of pre-stress = (300E-6 x 210E3) = 63 N/mm^2

% loss of stress = $\left(\frac{63\ X\ 100}{1000}\right)$ = 6.3%

b) If the beam is post-tensioned and residual shrinkage is strain = $\left[\frac{200\ x\ 10^{-6}}{log_{10}\ (t+2)}\right]$ = 200E-6

Loss of prestress = (200E-6 x 210E3) = 42 N/mm^2

% loss of stress = $\left(\frac{42\ X\ 100}{1000}\right)$ = 4.2%

Loss due to Creep of Concrete

- Sustained pre-stress in he concrete of a prestressed member results in creep of concrete which effectively reduces the stress in high-strength tensile steel.
- Factors influencing creep
- Loss of stress in steel due to creep of concrete can be estimated if the magnitude of ultimate creep strain or creep co-efficient is known.

Methods:

1. Ultimate creep strain method

If ε_{cc} = ultimate creep strain for a sustained unit stress

f_c = pre-stress in concrete at the level of steel

E_s = Modulus of elasticity of steel

The loss of stress in steel due to creep of concrete = $\varepsilon_{cc} f_c E_s$

2. Creep Co-efficient Method

If ε_c = Creep strain

ε_e = Elastic strain

Φ = Creep co-efficient

f_c = Stress in concrete

E_s = Modulus of elasticity of steel

E_c = Modulus of elasticity of concrete

α_e = Modular ratio

The loss of stress in steel due to creep of concrete = $\varepsilon_{cc}\, f_c\, E_s$

- Creep co-efficient = $\left(\frac{Creep\ Strain}{Elastic\ Strain}\right) = \left(\frac{\varepsilon_c}{\varepsilon_e}\right)$
- $\varepsilon_c = \Phi \times \varepsilon_e = \Phi \times (f_c / E_c)$
- Loss of stress in steel = $\varepsilon_c\, E_c\, \Phi\, E_s = \Phi \times (f_c/E_c)\, E_s = \Phi \times f_c \times \alpha_e$
- The magnitude of Φ varies depending on humidity, concrete quality, duration of applied loading and the age of concrete when loaded.

EX: A concrete beam of rectangular section 100 mm x 300 mm is prestressed by 5 wires of 7 mm diameter located at an eccentricity of 50 mm, the initial stress in wire is 1200 N/mm^2. Estimate the loss of stress in steel due to creep of concrete using ultimate creep strain method and creep co-efficient method (IS : 1343) for following data: Es = 210 kN/mm^2, Ec = 35 kN/mm^2, A = 3E4 mm^2, I = 225E6 mm^4, Ultimate creep strain, $\mathcal{E}cc$ = 41E-6 mm/mm per N/mm^2, Creep co-efficient = Φ = 1.6

- P = (5 x 38.5 x 1200) = 23E4 N
- $\alpha_e = \left(\frac{E_s}{E_c}\right)$ = 6
- Stress in concrete at level of steel is given by, fc = $\left[\frac{23E4}{3E4} + \frac{23E4\ X\ 50\ X\ 50}{225E6}\right]$ = 10.2 N/mm^2

a) Ultimate Creep Strain Method

Loss of stress in steel = $\mathcal{E}cc$ fc Es

= 41E-6 x 10.2 x 210E6

= 88 N/mm^2

b) Creep co-efficient Method

Loss of stress in steel = Φ x f_c x α_e

= 1.6 X 10.2 X 6

= 97.92 N/mm^2

Loss due to Relaxation of Stress in Steel

- IS:1343 provides gives guidelines for calculating this loss as a % of initial stress in steel.
- IS code recommends a value varying from 0 to 90 N/mm^2 for stress in wires varying from 0.5fpu to 0.8fpu.
- Temporary overstressing by 5-10% for period of 2 min is sometimes used to reduce this loss for drawn wires.
- Over-stressing does not appear to be beneficial for stabilized wires which has 0.1% proof stress in excess of 85% of the tensile strength.

<u>Relaxation losses for pre-stressing steel at 1000 h at 27 ± 2ºC (IS:1343)</u>

Sr. No.	Initial Stress	Relaxation Loss (%)	
		Normal	Low
1	$0.5f_{pu}$	0	0
2	$0.6f_{pu}$	0.3	1.0
3	$0.7f_{pu}$	5.0	2.5
4	$0.8f_{pu}$	8.0	4.5

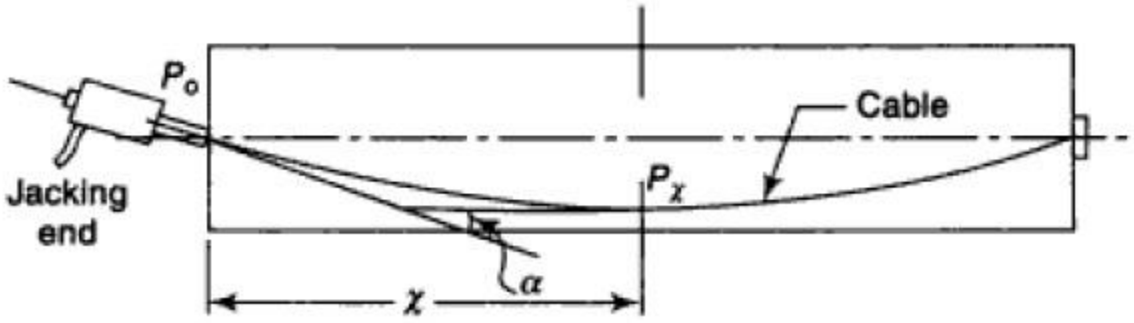
Loss due to Friction

- For post-tensioned members, the tendons are housed in ducts preformed in concrete.
- Ducts may be either straight or follow curved profile.
- Consequently, on tensioning curved tendons, loss of stress occurs in post-tensioned members due to friction.

The magnitude of loss may be of two types:

1. Loss of pre-stress due to curvature effect
2. Loss of stress due to the wobble / wave effect

   Takes place due to accidental or unavoidable misalignment.



Loss of Stress due to Friction

For the beam shown in figure,

If magnitude of pre-stressing force is P_x at a distance x from the tensioning end then it follows an exponential function of the type,

$$P_x = P_o e^{-(\mu\alpha + Kx)}$$

- ➔ P_o = Pre-stressing force at jacking end
- ➔ μ = Co-efficient of friction between duct and cable
- ➔ α = Cumulative angle in radians through which the tangent to the cable profile has turned between any two points under consideration
- ➔ K = Friction co-efficient for wave effect
- ➔ e = 2.7183

Values of Co-efficient of friction μ

Condition	Value
Steel moving on smooth concrete	0.55
Steel moving on steel fixed to duct	0.35
Steel moving on steel fixed to concrete	0.25
Steel moving on lead	0.25
Multi layer wire rope cables in rigid rectangular steel sheaths	0.18-0.30
Multi layer wire rope cables with spacer plates providing lateral separation	0.15-0.25

Values of friction co-efficient for wave effect k

Condition	Value
Normal Conditions	0.15 per 100 m
For Thin walled ducts and where heavy vibrations are encountered, other adverse conditions	1.5 per 100 m

k may be reduced to 0 where

- ➔ The clearance between the duct and cable is sufficiently large to eliminate the 'wave effect'.
- ➔ Sheath is made of heavy gauge steel tube with water tight joints. (Deformation of the duct profile is prevented during vibration of concrete)

How to Reduce Frictional Losses?

- By using various lubricants
- Over tensioning the tendons by an amount equal to maximum frictional loss
- Jacking the tendons from both the ends of the beam (generally adopted when the tendons are too long or angles of bending are large).

EX: A concrete beam of 10 m span, 100mm wide and 300 mm deep is prestressed by 3 cables. Area of each cable is 200 mm^2 and initial stress in the cable is 1200 N/mm^2. Cable 1 is parabolic with an eccentricity of 50 mm above the centroid at supports and 50 mm below at the centre of span. Cable 2 is also parabolic with 0 eccentricity at supports and 50 mm below centroid at the centre span. Cable 3 is straight with uniform eccentricity of 50 mm below the centroid. If the cables ate tensioned from one end only, estimate the % loss of stress in each cable due to friction. Assume μ = 0.35 and K = 0.0015 per m.

- Slope = ???
- Equation of parabola, $y = (4e/L^2) * x * (L - x)$
- Slope at the ends (X = 0) $\frac{dy}{dx} = \left(\frac{4e}{L^2}\right)(L - 2x) = \left(\frac{4e}{L}\right)$
- For cable 1 Slope at End = $\frac{4 \times 100}{10 \times 1000} = 0.04$
- Cumulative angle between tangents, α = (2 x 0.04) = 0.08 radians
- For cable 2 Slope at End = $\frac{4 \times 50}{10 \times 1000} = 0.02$
- Cumulative angle between tangents, α = (2 x 0.02) = 0.04 radians
- Initial prestressing force in each cable, P_o = (200 x 1200) = 24000 N

- If P_x = Prestressing force (stress) in cable at the farther end,

$$P_x = P_o e^{-(\mu\alpha + Kx)}$$

For, small values of ($\mu\alpha$ + Kx), we can take

$$P_x = P_o [1 - (\mu\alpha + Kx)]$$

$$\text{Loss of stress} = P_o(\mu\alpha + Kx)$$

$$\text{Cable 1} = P_o(0.35 \times 0.08 + 0.0015 \times 10) = 0.043\ P_o$$

$$\text{Cable 2} = P_o(0.35 \times 0.04 + 0.0015 \times 10) = 0.029\ P_o$$

$$\text{Cable 3} = P_o(0 + 0.0015 \times 10) = 0.015\ P_o$$

Cable No	Loss of Stress, N/mm²	Percentage loss
1	51.6	4.3
2	34.8	2.9
3	18.0	1.5

EX: A post-tensioned concrete beam, 200 mm wide and 450 mm deep is prestressed by a circular cable (total area = 800 mm^2) with zero eccentricity at the ends and 150 mm at the centre. The span of the beam is 10 m. The cable is to be stressed from one end such that an initial stress of 840 N/mm^2 is available in the unjacked and immediately after anchoring. Determine the stress in the wires at the jacking end and % loss of stress due to friction. Take co-efficient of friction for curvature effect = 0.6, Friction co-efficient for wave effect = 0.003/m.

- Slope = ???
- If R is the radius of the circular cable, then $(R - 0.15)^2 + 5^2 = R^2$

$$\rightarrow R = 84 \text{ m}$$

- If α is the angle between the horizontal and the tangent drawn to the cable at support, then

$$\sin \alpha = 5 / 84 = 0.06 \text{ radians}$$

$$P_x = P_o [1 - (\mu\alpha + Kx)]$$

$$P_x = P_o [1 - (0.6 \times 0.12 + 0.03 \times 10)] = 0.898 P_o$$

- $P_o = \frac{P_x}{0.898} = \frac{840}{0.898} = 940 \text{ N/mm}^2$
- Loss of stress in cable = 940 – 840 = 100 N/mm^2
- % Loss of stress = 10.6%

Loss due to Anchorage Sleep

- In most post-tensioning systems, when the cable is tensioned and jack is released to transfer prestress to concrete, the friction wedges, employed to grip the wires, slip over a small distance before the wires are firmly housed between the wedges.
- The magnitude of sleep depends upon the type of wedge and stress in the wires.
- When anchor plates are employed, it may be necessary to allow for the small settlement of the plate into the end of the concrete member.
- Loss during anchoring, which occurs with wedge type grips, is normally allowed for on the site by over-extending the tendon in the prestressing operation by the amount of the draw in before anchoring.
- This method is satisfactory provided the momentary over-stress does not exceed the prescribed limits of 80-85 5 of ultimate strength of the wire.

- Magnitude of the loss of stress due to slip in anchorage is computed as follows:

Δ = slip of anchorage, mm

L = length of the cable, mm

A = Cross-sectional area of the cable, mm^2

E_s = Modulus of elasticity of steel, N/ mm^2

P = pre-stressing force in the cable, N

$$\Delta = PL / A\,E_s$$

$$\text{Loss of stress due to anchorage sleep} = \left(\frac{P}{A}\right) = \frac{E_s\,\Delta}{L}$$

- Loss of stress is caused by definite total amount of shortening.
- For shorter members the loss is higher compared to long ones.
- For long line pre-tensioning system, the slip at the anchorage is normally very small in comparison with the length of the tensioned wire and hence is generally ignored.
- For shorter member due care should be taken to allow for the loss of stress due to anchorage slip.

EX: A concrete beam is post-tensioned by a cable carrying an initial stress of 1000 N/mm2. the slip at the jacking end was observed to be 5 mm. E_s = 210 kN/mm^2. Estimate the % loss of stress due to anchorage slip if the length of the beam is (a) 30 m and (b) 3 m.

(a) For a 30 m long beam,

Loss of stress = $\left[\frac{210E3 \; X \; 5}{30 \; X \; 1000}\right]$ = 35 N/mm^2

% loss of stress = $\frac{35}{1000}$ x 100 = 3.5%

(b) For a 3 m long beam,

Loss of stress = $\left[\frac{210E3 \; X \; 5}{3 \; X \; 1000}\right]$ = 350 N/mm^2

% loss of stress = $\frac{35}{100}$ x 100 = 35%

TOTAL LOSSES ALLOWED IN DESIGN

- It is normal practice in design of pre-stressed concrete members to assume the total loss of stress as a % of the initial stress and provide for this in the design computations.
- Since the loss of pre-stress depends on several factors, such as properties of concrete and steel, method of curing, degrees of pre-stress and method of pre-stressing, so it is difficult to generalize exact amount of total loss of pre-stress.

TYPE OF LOSS	% LOSS OF STRESS	
	PRE-TENSIONING	*POST-TENSIONING*
Elastic shortening & Bending of concrete	4	1
Creep of concrete	6	5
Shrinkage of concrete	7	6
Creep in steel	8	8
TOTAL	*25*	*20*

- If, f_{pe} = Effective stress in tendons after losses
- f_{pi} = Stress in tendons at transfer
- η = Reduction factor for loss of prestress
- $\eta = \left(\frac{f_{pe}}{f_{pi}}\right)$
- Value of η is generally taken as 0.75 for pretensioned and 0.80 for post-tensioned members.

EX: A concrete 200 mm wide and 300 mm deep, is prestressed with wires (area 320 mm^2) located at a constant eccentricity of 50 mm and carrying an initial stress of 1000 N/mm^2. The span of the beam is 10 m. Calculate the percentage loss of stress in wires if (a) the beam is pre-tensioned, and (b) the beam is post-tensioned, using the following data: Es = 210 kN/mm^2 and Ec = 35 kN/mm^2. Relaxation of steel stress = 5 percent of the initial stress. Shrinkage of concrete for pretensioning = 300 x 10^{-6} and 200 x 10^{-6} for post-tensioning. Creep co-efficient = 1.6, Slip of anchorage 1 mm Frictional coefficient for wave effect = 0.0015/m

Solution:

- **Prestressing force** $= \dfrac{(320 \text{ x } 1000)}{1000} = 320 \text{ kN}$
- **Cross-sectional area, A = 60000 mm^2**
- $\alpha_e = \left(\dfrac{E_s}{E_c}\right)$ **= 6**
- **Moment of Inertia, I** $= \dfrac{(200 \text{ x } 300^3)}{12} = 45 \text{ x } 10^7 \text{ mm}^4$

- Stress in concrete at the level of steel, $f_c = \frac{(320 \text{ x } 10^3)}{6 \text{ x } 10^4} + \frac{(320 \text{ x } 10^3 \text{ x } 50 \text{ x } 50)}{45 \text{ x } 10^7} = 7 \text{ N/mm}^2$

Losses of Stress

TYPE OF LOSS	*PRETENSIONED BEAM (N/mm^2)*	*POST-TENSIONED BEAM (N/mm^2)*
Elastic deformation of concrete	6 x 7 = 42	--
Relaxation of stress in steel	5 % of 1000 = 50	5 % of 1000 = 50
Creep of concrete	(1.6 x 7 x 6) = 67.20	(1.6 x 7 x 6) = 67.20
Shrinkage of concrete	$(300 \times 10^{-6} \times 210 \times 10^3) = 63$	$(200 \times 10^{-6} \times 210 \times 10^3) = 42$
Friction effect	--	(10 x 0.0015 x 1000) = 15
Slip of anchorage	--	$(1 \times 210 \times 10^3)$ (10 x 1000) = 21
TOTAL loss of stress	*222.20*	*195.20*
% loss of stress	*22.2%*	*19.52%*

EX: A prestressed concrete pile, 250 mm square, contains 60 pre-tensioned wires, each of 2 mm diameter, uniformly distributed over the section. The wires are initially tensioned on the prestressing bed with a total force of 300 kN. Calculate the final stress in concrete and the percentage loss of stress is steel after all losses, given the following data: Es = 210 kN/mm^2, Ec = 32 kN/mm^2, Shortening due to creep = 30 x 10^{-6} mm/mm per N/mm^2 of stress. Total shrinkage strain = 200 x 10^{-6} per unit length. Relaxation of steel stress = 5 percent of the initial stress.

Solution:

- Prestressing force, P = 300 kN
- Average initial stress in concrete $= \dfrac{(300 \text{ x } 1000)}{250 \text{ x } 250} = 4.8 \text{ N/mm}^2$
- $\alpha_e = \left(\frac{E_s}{E_c}\right)$ = 6.56
- Initial stress in wires $= \dfrac{(300 \text{ x } 10^3)}{188.4} = 1590 \text{ N/mm}^2$

Losses of stress:

1. Elastic deformation of concrete = (6.58 x 4.8) = 31.5 N/mm^2
2. Creep of concrete = $(30 \times 10^{-6}) \times 4.8 \times 210 \times 10^3$ = 30 N/mm^2
3. Shrinkage of concrete = $(200 \times 10^{-6}) \times 210 \times 10^3$ = 42 N/mm^2
4. Relaxation of steel stress = (0.05 x 1590) = 79.5 N/mm^2

Total loss = 183 N/mm^2

Effective prestress = (1590 – 183) = 1407 N/mm^2

Final stress in concrete $= \dfrac{(1407 \text{ x } 188.4)}{250 \text{ x } 250} = 4.26 \text{ N/mm}^2$

Percentage loss of stress in steel $= \dfrac{183}{1590} \text{ x } 100 = 11.6\%$