CHAPTER 14

Prestress Losses

CONTENTS.

14. Prestress Losses

14.1 Types of Losses:

1. Loss due to elastic shortening of concrete.
2. Loss due to creep of concrete.
3. loss due to shrinkage of concrete.
4. Loss due to relaxation/ creep of steel.
5. Loss due to anchorage slip
6. Loss due to friction.

Short Term	Long Term
1. Elastic Shortening	1. Creep of Concrete
2. Anchorage Slip	2. Shrinkage of Concrete
3. Friction	3. Relaxation

PreTensioning	Post Tensioning.
1. Elastic Shortening.	1. No loss due to Elastic Shortening in case of simultaneous tensioning but it is present in the case of successive tensioning.
2. Creep of Concrete	
3. Shrinkgge	
4. Relaxation	

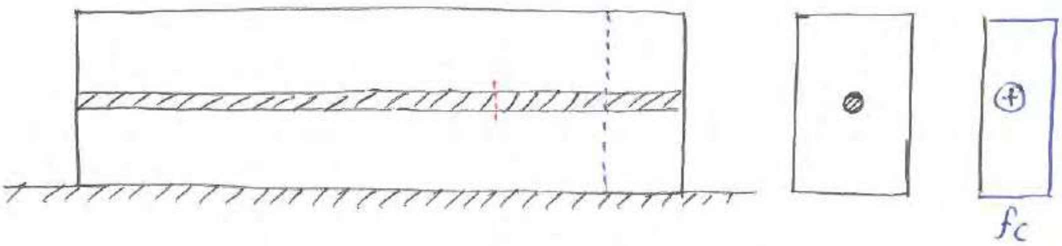
*Note:

- Total loss of pre-stressing of pre-tensioned member is invariably higher than as of post-tensioned member.
- for design purpose, 20% and 25% of initial pre-stress is considered as total loss for post-tensioned and pre-tensioned member respectively.

14.2 Loss due to Elastic Shortening of Concrete:

14.2.1 Pre-Tensioned Member:

Case I: Concentrically Placed Cable:



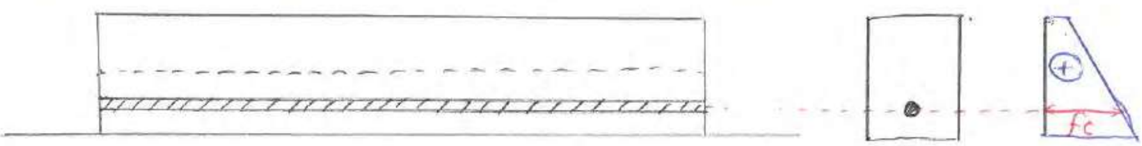
$$\text{Loss of strain of cable} = \text{compressive strain of concrete} = \frac{f_c}{E_c}$$

Now,

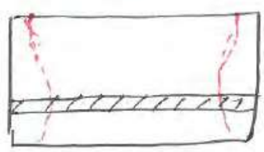
$$\text{Loss of stress of cable} = \text{Loss of strain of cable} \times E_s = \frac{f_c}{E_c} \times E_s$$

$$\text{Loss of stress of cable} = m f_c$$

Case II: Cable placed at constant eccentricity:



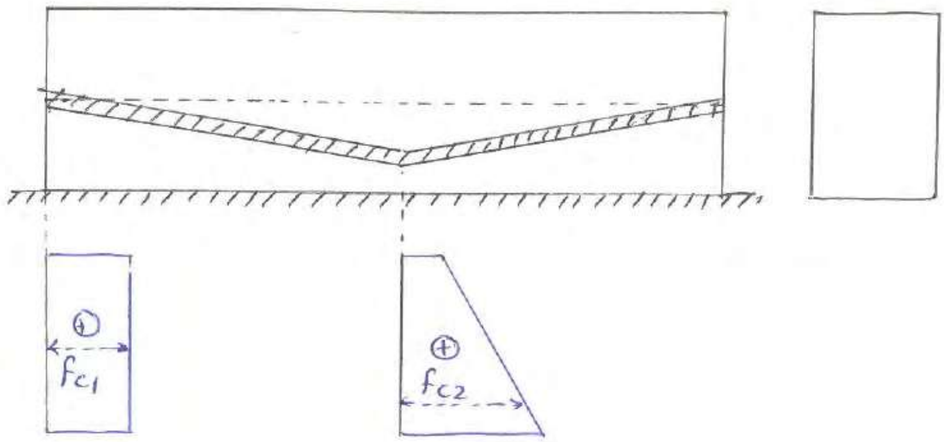
$$\text{Loss of stress of cable} = m f_c$$

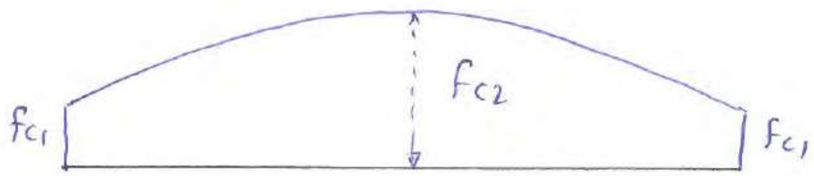


where,

f_c = stress in concrete at the level of cable.

Case III : Cable placed at Varying Eccentricity:





Loss of stress of cable = mf_c

where,

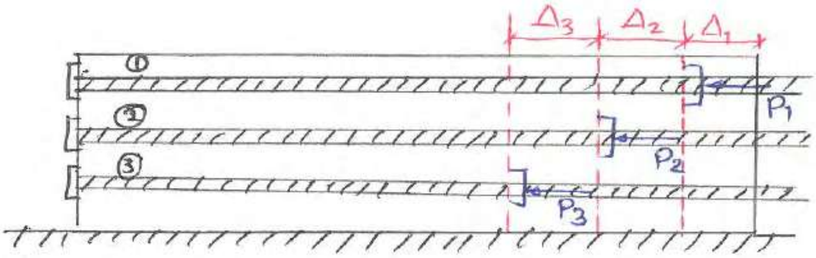
$$f_c = f_{c1} + \frac{2}{3}(f_{c_2} - f_{c_1})$$

14.2.2 Post-Tensioned Member

Case I: Simultaneous Tensioning:

Loss = 0

Case II : Successive Tensionsioning



Tensioning of Cable ①

Loss of cable ① = 0

Tensioning of cable ②:

Loss of cable ① = Due to Δ_2

Loss of cable ② = 0

Tensioning of Cable ③:

Total loss of cable ① = Due to $\Delta_2 + \Delta_3$

Total loss of cable ② = Due to Δ_3

Total loss of Cable ③ = 0

14.3 Loss due to Creep of Concrete:

$$\text{creep coefficient}(\theta) = \frac{\text{Ultimate creep strain of concrete}}{\text{Instantaneous elastic strain of concrete}}$$

$$\text{Ultimate creep strain of concrete} = \theta \frac{f_c}{E_c}$$

Now,

$$\text{Loss of stress of cable} = \text{Loss of strain of cable} \times E_s$$

$$= \text{Ultimate creep strain of concrete} \times E_s$$

$$= \theta \cdot \frac{f_c}{E_c} \times E_s$$

$$\text{Loss of stress of cable} = \theta m f_c$$

14.4 Loss due to Shrinkage of Concrete:

- Pre-Tensioned Member:

$$\epsilon_{st} = 3 \times 10^{-4}$$

$$Loss = 3 \times 10^{-4} \times E_s$$

- Post-Tensioned Member.

$$\epsilon_{st} = \frac{2 \times 10^{-4}}{\log(T+2)}$$

$$Loss = \frac{2 \times 10^{-4}}{\log(T+2)} \times E_s$$

where, T = Age of concrete in days at the time of transfer of prestressing force

14.5 Loss due to Relaxation of Steel:

Some part of elastic strain provided for prestressing is converted into permanent/plastic strain. This permanent strain does not provide any stress so there is loss of stress of cable. Loss due to relaxation of steel depends on following.

1. Chemical composition of material.
2. Temperature of cable. Relaxation is more at higher temp.
3. Stress level of cable. Relaxation is more at higher stress level.

In general, 1 to 8% of initial prestress is considered as loss due to relaxation.

14.6 Loss due to Anchorage Slip:

Total anchorage slip $= \Delta$

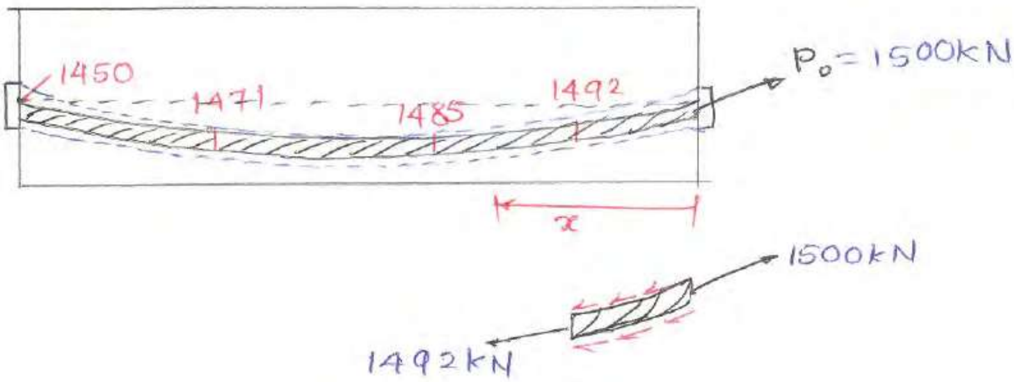
Loss of strain $= \frac{\Delta}{L}$

Loss of stress $= \frac{\Delta}{L} \times E_s$

where,

L = Length of cable ≈ Length of Member.

14.7 Loss due to Friction:



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

$$\text{Loss} = P_o - P_x$$

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

$$= P_o(1 - e^{-(kx+\mu\alpha)})$$

After expanding and neglecting higher order terms

$$\text{Loss} = P_o(kx + \mu\alpha)$$

where

x → Distance between point of application of prestressing force and point under consideration, along length of member (in m)

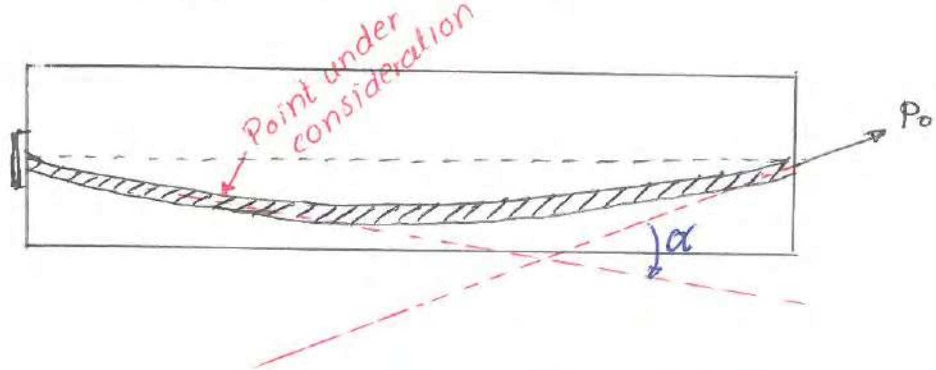
k = A constant that depends on wave effect/ vobble effect (0.002/m)

wave effect/ wobble effect

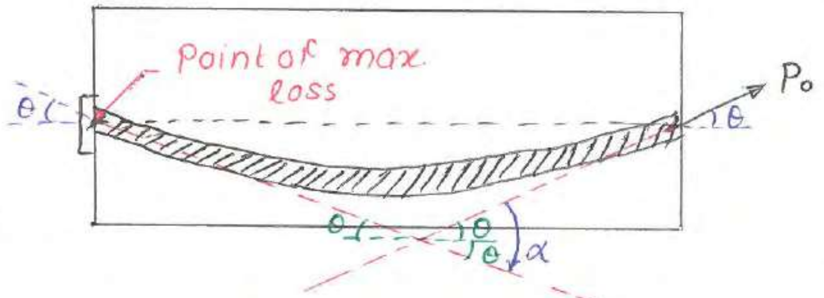
μ = Coefficient of friction (0.17 to 0.25)

α

α = Cummulative angle in radian through which tangent on cable profile turns between point of application of prestressing force and point under consideration.

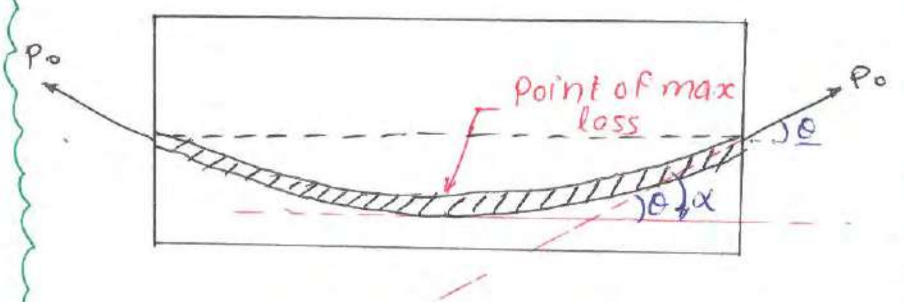


One End Jacking:



For maximum loss, $\alpha = 2\theta$

Both ends Jacking:

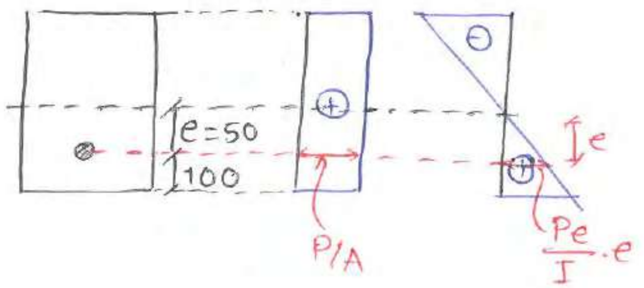


For maximum loss, $\alpha = \theta$

Ex. A pre-tensioned PSC beam of section size 225 x 300 mm is pre-stressed by 250 mm² cable area. Initial stress 1100 N/mm², wire located at 100 mm from soffit, M40, relaxation of steel 5%, $E_s = 2 \times 10^5$ N/mm², $\theta = 1.6$. Calculate total loss.

⇒

1) Elastic Shortening:



$$f_c = \frac{P}{A} + \frac{Pe}{I} \cdot e$$

$$= \frac{250 \times 1100}{225 \times 300} + \frac{250 \times 1100 \times 50}{\frac{225 \times 300^3}{12}} \times 50$$

$f_c = 5.43$ N/mm²

Loss = $m f_c$

$$= \frac{E_s}{E_c} \cdot f_c$$

$$= \frac{2 \times 10^5}{5000\sqrt{40}} \times 5.43$$

Loss = 34.34 N/mm².

Note:

Effect of DL is not considered while calculating this loss because span is required to calculate BM.

2) Creep:

$Loss = \theta \cdot m f_c$

$= 1.6 \times 34.34$

$= 54.94\ N/mm^2$

3) Shrinkage Loss $= 3\times10^{-4}\times E_s$

$= 3\times10^{-4}\times 2\times10^{5}$

$= 60\ N/mm^2$

4) Relaxation

Loss = 5% of initial stress

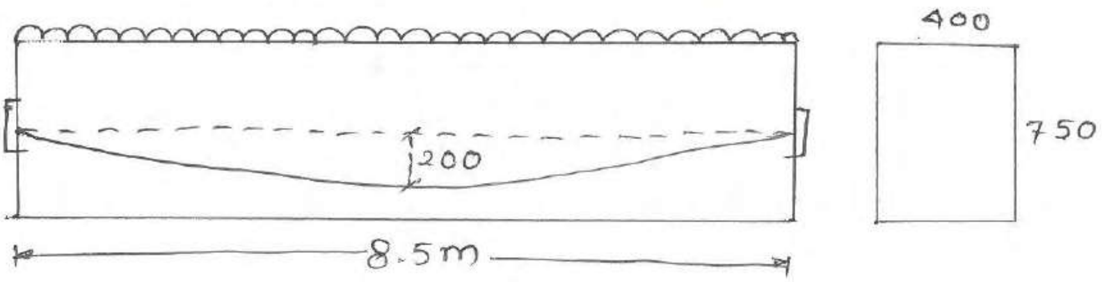
$= 5 \times \frac{1}{100} \times 1100$

$= 55\ N/mm^2$

⇒ Total loss = $204.28\ N/mm^2$

$\%\ Loss = \frac{204.28}{1100} \times 100 = 18.57\%$

Ex. A post tensioned PSC member is as given below. Prestressing force 1600 kN initial stress $1580\ N/mm^2$. $E_s = 2\times10^5\ N/mm^2$, $E_c = 30\times10^3\ N/mm^2$, total anchorage slip 3mm, relaxation of steel 3%, $\mu = 0.25$, $k = 0.002/m$, $\theta = 1.6$, jacking is from both ends, prestressing force is transfered after 28 days of casting. Calculate total loss.

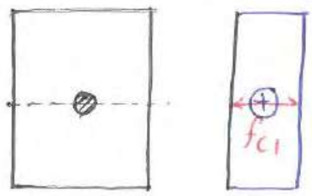


⇒ 1) Elastic Shortening

Loss = 0

2) Creep:

At ends:



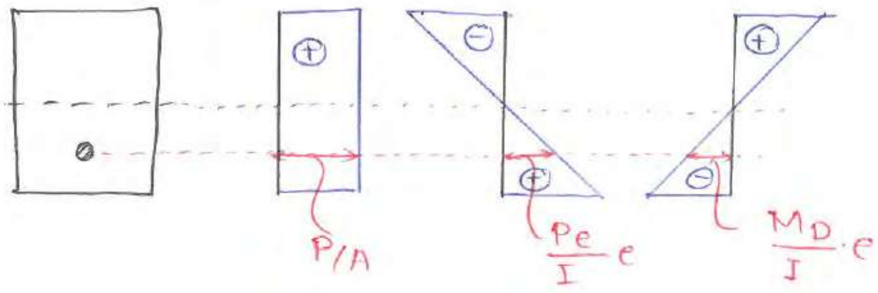
$f_{c1} = \frac{P}{A} = \frac{1600 \times 10^3}{400 \times 750}$

$f_{c1} = 5.33\ N/mm^2$

At mid span:

$DL = 0.4 \times 0.75 \times 1 \times 25 = 7.5\ kN/m$

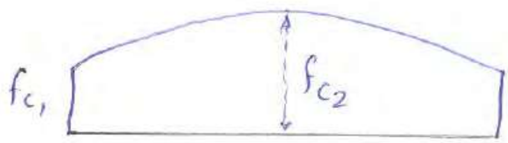
$M_D = \frac{W_D L^2}{8} = \frac{7.5 \times 8.5^2}{8} = 67.73\ kNm$



$f_{c2} = \frac{P}{A} + \frac{Pe}{I} \cdot e - \frac{M_D}{I} e$

$= \frac{1600 \times 10^3}{400 \times 750} + \frac{1600 \times 10^3 \times 200}{\frac{400 \times 750^3}{12}} \times 200 - \frac{67.73 \times 10^6}{\frac{400 \times 750^3}{12}} \times 200$

$f_{c2} = 8.91\ N/mm^2$



$f_c = f_{c1} + \frac{2}{3} (f_{c2} - f_{c1})$

$= 5.33 + \frac{2}{3} (8.91 - 5.33)$

$f_c = 7.72\ N/mm^2$

$Loss = \theta . m f_c$

$= \theta \times \frac{E_s}{E_c} \times f_c$

$= 1.6 \times \frac{2 \times 10^5}{30 \times 10^3} \times 7.72$

$Loss = 82.35 \ N/mm^2$

3) Shrinkage.

$Loss = \frac{2 \times 10^{-4}}{\log(T+2)} \times E_s$

$= \frac{2 \times 10^{-4}}{\log(28+2)} \times 2 \times 10^5 = 1.35 \times 10^{-4} \times 2 \times 10^5$

$Loss = 27. \ N/mm^2$

4) Relaxation

Loss = 3% of initial stress

$= 3 \times \frac{1}{100} \times 1580$

$= 47.4 \ N/mm^2$

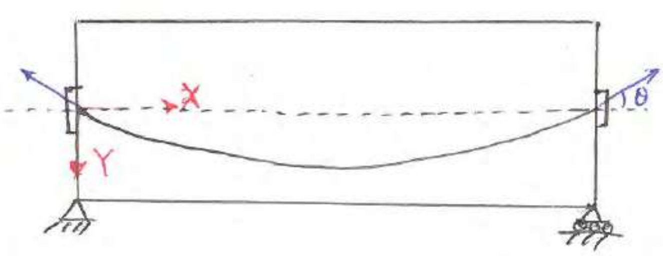
5) Anchorage slip:

$Loss = \frac{\Delta}{L} \times E_s$

$= \frac{3}{8.5 \times 10^3} \times 2 \times 10^5$

$= 70.55 \ N/mm^2$

6) Friction:



$y = \frac{4h}{L^2} x (L-x)$

$\frac{dy}{dx} = \frac{4(e+0)}{L^2} (L-2x)$

at $x=0$ $\tan\theta = \frac{4e}{L^2} (L-2\times 0)$

$$\theta = \frac{4e}{L}$$ ***

$$\theta = \frac{4 \times 200}{8 \times 10^3} = 0.094 \text{ rad}$$

so, $\alpha = \theta = 0.094$ rad.

Loss $= P_o (kx + \mu\alpha)$

$= 1580 \times (0.002 \times \frac{8.5}{2} + 0.25 \times 0.094)$

$= 1580 \times 0.032$

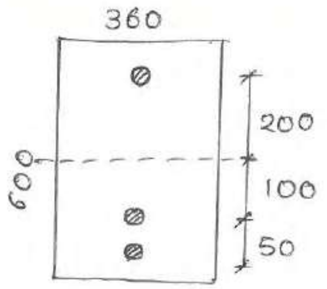
Loss $= 50.56 \text{ N/mm}^2$

Total Loss $= 277.86 \text{ N/mm}^2$

$\% \text{ Loss} = \frac{277.86}{1580} \times 100$

$\% \text{ Loss} = 17.58\%$

Ex. Calculate loss due to elastic shortening only for the pretensioned section given below. Initial stress 1000 N/mm^2, $m = 6$



$A_1 = 300 \text{ mm}^2$

$A_2 = 500 \text{ mm}^2$

$A_3 = 700 \text{ mm}^2$

→ $P_1 = A_1 \times \sigma = 300 \times 1000$

$P_1 = 300 \text{ kN}$

$P_2 = 500 \text{ kN}$

$P_3 = 700 \text{ kN}$

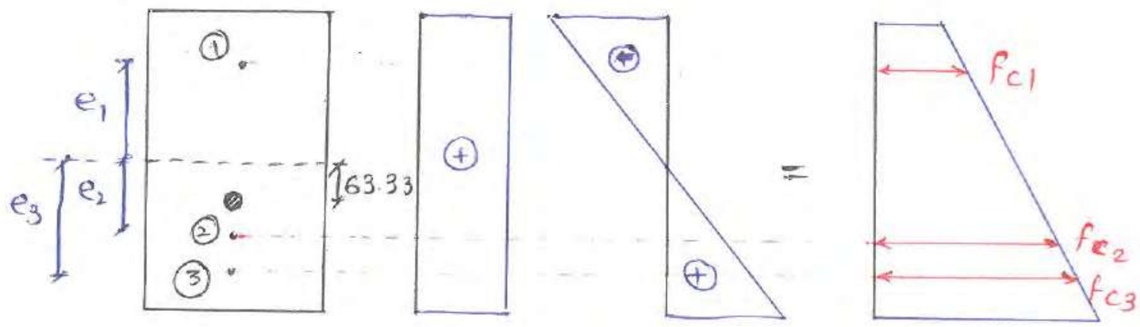
Position of resultant prestressing force from top fibre $= \frac{P_1 y_1 + P_2 y_2 + P_3 y_3}{P_1 + P_2 + P_3}$

$$= \frac{300 \times (100) + 500 \times (400) + 700 \times (450)}{1500}$$

$= 363.33$ mm

Now, $e = 363.33 - 300$

$e = 63.33$ mm.



$$f_{c1} = \frac{P}{A} - \frac{Pe}{I} \cdot e_1$$

$$= \frac{1500 \times 10^3}{360 \times 600} - \frac{1500 \times 10^3 \times 63.33}{\frac{300 \times 600^3}{12}} \times 200$$

$f_{c1} = 4.01$ N/mm²

$$f_{c2} = \frac{P}{A} + \frac{Pe}{I} \cdot e_2$$

$$= \frac{1500 \times 10^3}{360 \times 600} + \frac{1500 \times 10^3 \times 63.33}{\frac{360 \times 600^3}{12}} \times 100$$

$f_{c2} = 8.41$ N/mm²

$$f_{c3} = \frac{P}{A} + \frac{Pe}{I} \cdot e_3$$

$$= \frac{1500 \times 10^3}{360 \times 600} + \frac{1500 \times 10^3 \times 63.33}{\frac{360 \times 600^3}{12}} \times 150$$

$f_{c3} = 9.14$ N/mm²

Loss in cable ① $= m f_{c1} = 24.06$ N/mm²

Loss in cable ② $= m f_{c2} = 50.46$ N/mm²

Loss in cable ③ $= m f_{c3} = 54.84$ N/mm²