Post-Tension Slabs: Analysis, Design & Construction

Course No: S02-035
Credit: 2 PDH

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Table of Contents

List of Figures

List of Tables

1. Introduction

As civil engineers, we are increasingly tasked with finding efficient solutions to our construction projects. Post tension slabs offer an ideal solution for a variety of applications, offering enhanced durability, strength and flexibility. In this article, we will discuss the major benefits of post tension slabs, including their increased safety, design versatility and cost-effectiveness. We will also explore some of the considerations that should be taken into account before selecting post tension slabs as the suitable option for a construction project.

Post tension concrete slabs are a type of prestressed concrete, wherein high-strength steel cables or wires are used to apply tension to the concrete slab. This prestressing force helps to counteract the forces of compression that would otherwise act on the concrete. Post tension slabs are typically used in the construction of bridges, parking structures, high-rise buildings and other structures where enhanced durability and strength are required.

2. How does Post Tension Slab Work?

Post tension is special type of slab that is due to the many benefits of it. Further, it works very well with many structural applications. Depending on the application of the post tension, the method of having development is varying.

Arrangement of the tendons in the concrete simply supported beam, continues beam, slab, box girder, etc. are different to each other. The design concept also very with the type of the structure.

Figure 1. Post tension cables

Post tension cable are providing in the similar manner as we provide the reinforcement to carry the tensile stresses in the section. Though the design concepts of post tension elements and reinforced concrete elements, they used for the same purpose.

As you can see in the above figure, cables are place close to the bottom of the slab and top of the slab based on the sagging and hogging bending moment developments.

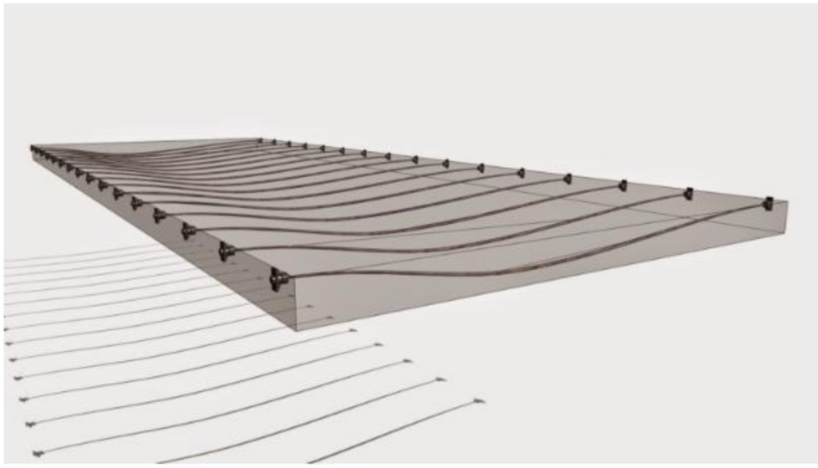


Figure 2. Placement of Cables

3. Main Component of Post Tensioning

3.1 Anchors

Anchor is the main component that hold the tensioned cable. There are different types of anchors, and the type of anchor is varying at two ends.

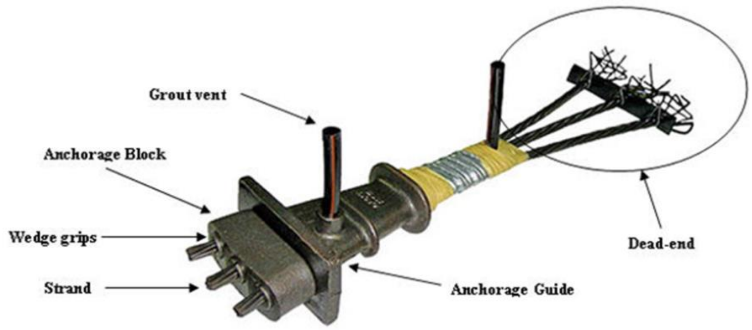


Figure 3. Anchor Components

3.2 Ducts

There are different types of ducts. They can be categorized based on the type of material used for construction. Steel or corrugated pipes are used for this purpose. The tendons are runs in these ducts and they should be placed as specified in the tendon layout.

Figure 4. Ducts

3.3 Tendons

The major component of the pre-stressing and post tension is the tendon. Depending on the loads to be applied on the tendons in post tension slabs, the area of the tendons are determined.

Figure 5. Tendons

4. PT slab Construction Steps

The basic steps of the construction of the PT slab is as follows:

- Complete the formwork of the slab
- Lay the bottom reinforcement of the slab which would be specified by the design
- Lay the post tension concrete slab ducts
- Fix the top reinforcement net
- Installation of reinforcement net would be done together with the post tension ducts.
- Install all other MEP amendments.
- Proceed with concreting the after confirmation of the formwork, setting out, reinforcement, ducting arrangement etc.
- After concrete gain the adequate strength, proceed with stressing of the post tension cables.
- Proceed with grouting

5. Advantages of Post Tension Slabs

The major benefits of post tension concrete slabs include their increased safety, design versatility and cost effectiveness.

With regards to safety, post tension slabs offer a number of advantages. The prestressing force applied to the concrete helps to increase its resistance to both tensile and compressive forces. This results in a more stable structure that is less likely to experience cracking or failure. In the event of an earthquake or other catastrophic event, post tension concrete slabs are less likely to collapse, making them a safer option for construction projects.

Post tension slabs also offer increased design versatility. Due to the pre-stressing force, PT slabs can span greater distances than conventional concrete slabs. This makes them an ideal solution for a variety of construction projects. In addition, post tension slabs can be designed to accommodate a variety of loads.

- Since we can omit the beams, floor to floor height can be reduce. As a result of that cost would reduce.
- It reduces or eliminates shrinkage cracking-therefore no joints, or fewer joints, are needed
- Cracks that do form are held tightly together
- Weight of the structure would reduce.
- It allows us to build slabs on expansive or soft soils
- Less columns allow more spaces without disturbances.
- It allows slabs and other structural members to be thinner
- Low serviceability issues
- Low maintenance
- Sustainable construction

6. Disadvantages of Post Tension Slabs

- Since this is a specialized work, skill labor and technical staff is required.
- Poor workmanship could lead to failure of construction
- Quality of construction is very important, failure of any construction could lead serious issues.
- Laying of tendons shall be done as specified in the drawings and there is no room for errors.

7. Post-Tension Type

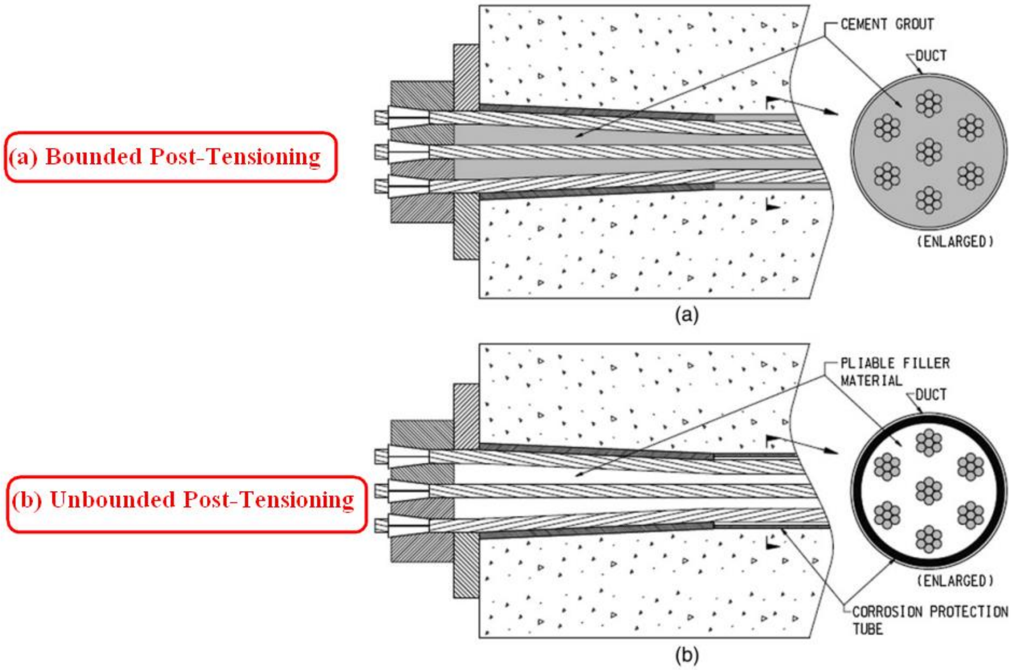


Figure 6. Bounded Post-Tensioning vs Unbounded Post-Tensioning

(a) Bonded Post-Tensioning

It is used for large structural elements such as beams and transfer girders, design advantages include increased span lengths and load carrying capacity and reduced deflection.

(b) Un-bonded Post-Tensioning

It is typically used in new construction for elevated slabs, slabs-on-grade, beams, and transfer girders, joists, shear walls, and mat foundations. Light and flexible, the un-bonded mono strand can be easily and rapidly installed – providing an economical solution.

8. Strength of Pre-stressing Steel

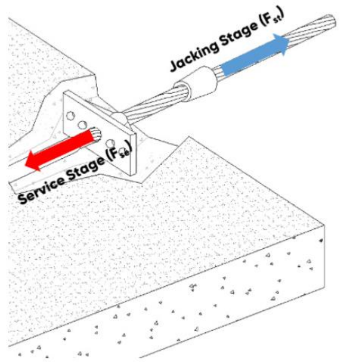


Figure 7. Jacking Stage and Service Stage

Table 1. Tension Stress after prestressing and after anchoring

Step	**Immediately after prestressing**	**After anchoring**
Tension Stress	Min[0.94 f_{py}, 0.80 f_{pu}]	0.70 f_{pu}

Table 2. Diameter for each component

Diameter	**A_{ps} (mm^2)**	**f_{pu} (M_{pa})**	**f_{py} (M_{pa})**	**f_{pe} (M_{pa})**	**F_{st} (kN)**	**F_{se} (kN)**
12.7mm	98.71	1,860	1,674	1,200	146	118.4
15.2mm	138.7	1,860	1,674	1,200	205	166.4

Aps : Area of prestressing steel
fps : Stress in prestressed reinforcement at nominal strength
fpu : Specified tensile strength of prestressing steel
fpy : Specified yielding strength of prestressing steel (0.90* fpu= 0.90*1,860Mpa = 1,674Mpa)
fpi : Initial prestress stress of prestressing steel
fpe : Effective prestress stress of prestressing steel (0.65* fpu= 0.65*1,860Mpa = 1,200Mpa)
Fst : Max. prestress force (Min[0.94 fpy, 0.8 fpu] *Aps = Min[1,573 or 1,485] *138.7 = 205kN)
Fse : Effective prestress force (fpe*Aps = 1,200Mpa*138.7 = 166.4kN)
Fps : Ultimate prestress force

9. Design Steps

After Jacking Stage

- Activity of anchorage device
- Tension force loss due to friction
- Tension loss due to elastic shrinkage of concrete

After Transfer Stage

- Tension loss due to creep
- Tension loss due to shrinkage
- Tension loss due to strand relaxation

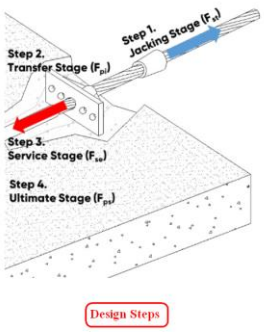


Figure 8. Design Steps

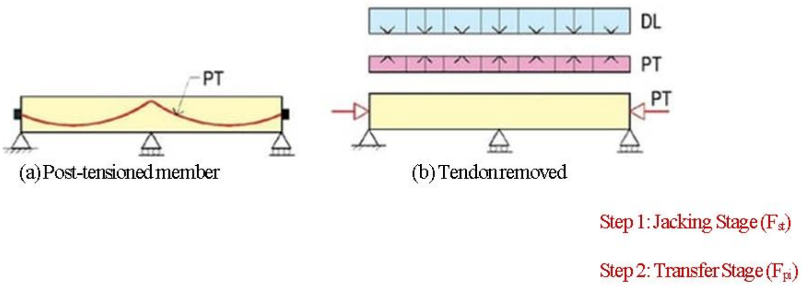


Figure 9. Post-Tensioned Member and Tendon Removed

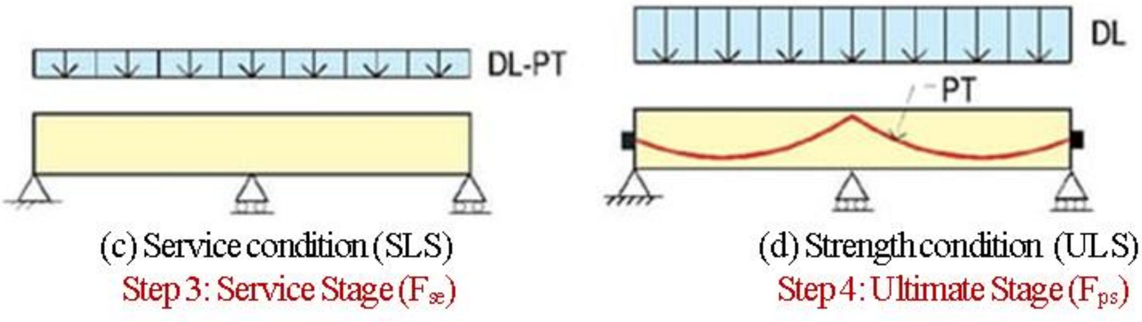


Figure 10. Service Condition (SLS) and Strength Condition (ULS)

10. Loading Conditions

Transfer Stage

• Using Prestress Force → Fsi (before short/long-term tension loss occurs, Max. prestress)
• Using Concrete strength : fci (compressive strength of concrete when prestress is introduced, Min. strength)
• Loading : only Self-weight (before adding a finishing and live loads)
• Checking item : Tensile cracking and crushing of concrete, failure of anchorage part.

Service Stage

• Using Prestress Force → Fse (Effective tension after short/long-term tension loss occurs)
• Using Concrete strength : fck (Max. design strength)
• Loading : All design load (Unfactored Load)
• Checking item : Deflection, Crack Width.

Ultimate Stage

• Using Prestress Force → Nominal Strength
• Using Concrete strength : fck (Max. design strength)
• Loading : All design load (Factored loads)
• Checking item : Flexural failure or compression stress under flexural behavior.

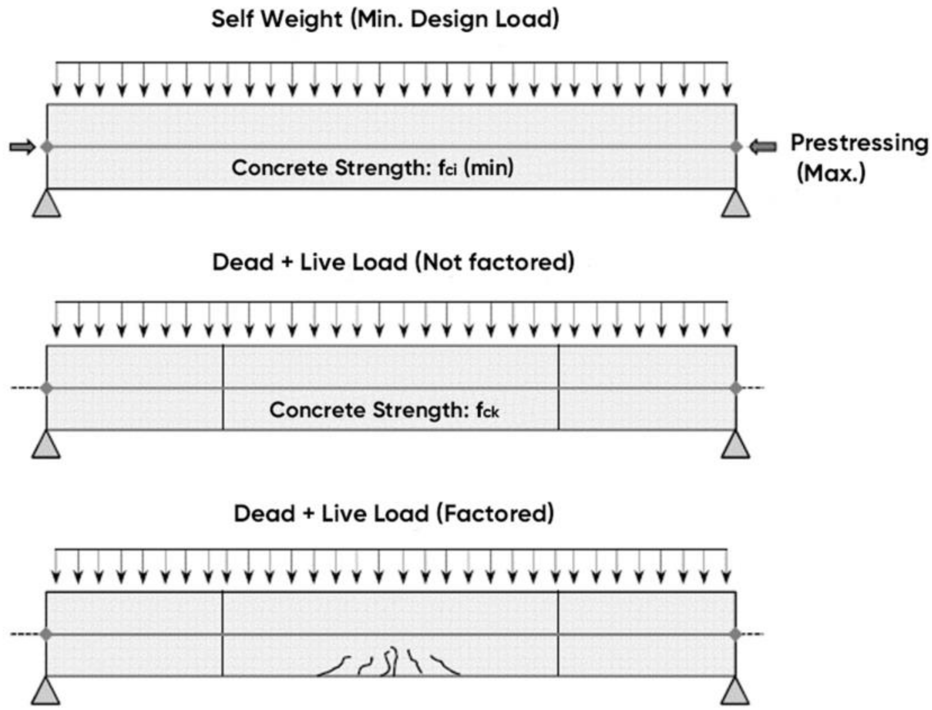


Figure 11. Load Conditions

11. Definition of Member Forces

Example 1: Continuous Beam

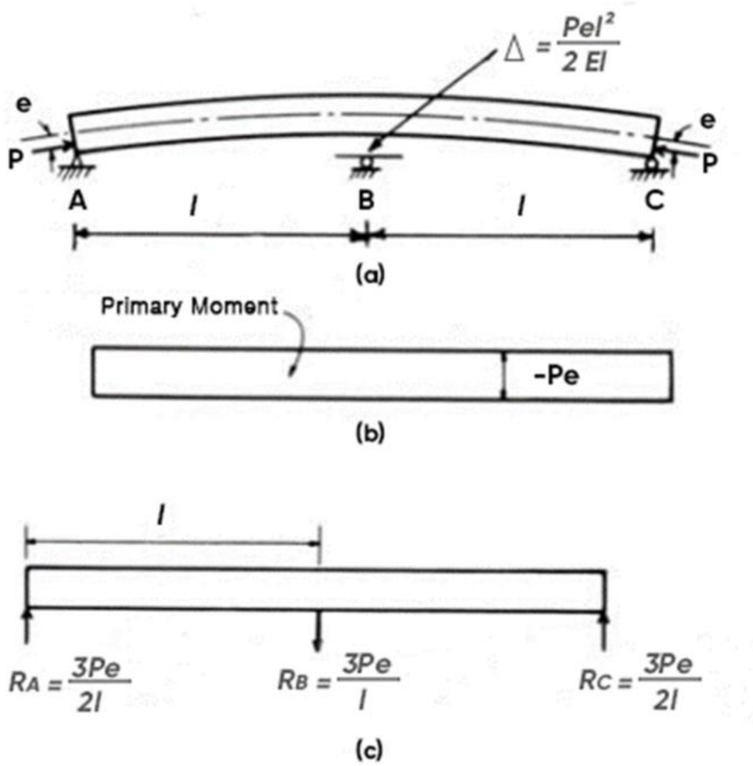
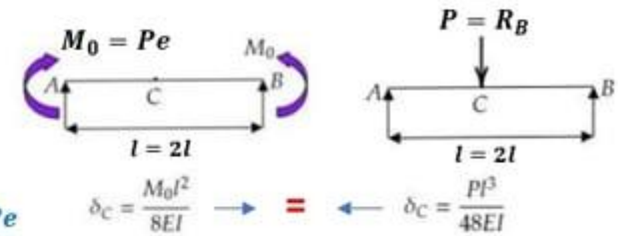


Figure 12. Primary Moment (a), (b) and (c)

MS : Moment due to own weight of concrete section.
MO : Moment due to other applied loads.
M1 : Primary moment → Moment by the distance between the section center and the prestressing point.
In example 1: M = Prestressing force x Eccentricity distance = P x -e = - Pe
Δ : Deflection by M1 →Deflection at point B when considered as a simple beam.
In example 1 : "Δ"=(Mol2)⁄8EI= (Pe(2l)2) ⁄8EI = (Pel2) ⁄2EI
R : Reaction by Δ → Point B should not be deflected by the support, so a reaction force is generated so that deformation as much as (-)Δ occurs.

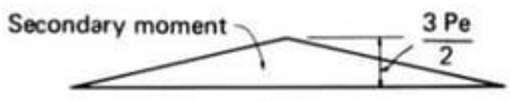
In example 1



$$\frac{Pe(2l)^2}{8EI} = \frac{-R_B(2l)^3}{48EI} \Rightarrow R_B = \frac{-3Pe}{l}$$

$$R_A = R_B * 0.5 = \frac{3Pe}{2l}$$

:



(d)

(e)

$M_{Secondary}$: Secondary Moment → Moment caused by R

* $M_{Secondary}$ means the moment created by the reaction force that restrains the deformation caused by M1.

In example 1 : $M_{Secondary}$ *at point* $B=(3Pe/2l)\times l=3Pe/2$

M_{Net} : Net final Moment = $M_1 + M_{Secondary}$: Moment acting on the actual continuous beam by prestressing.

In example 1 : M_u *at point* $B=-Pe+(3Pe/2)=Pe/2$

12. Thickness or Depth of Section

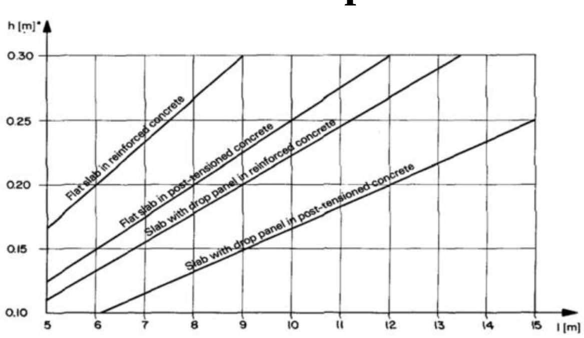


Figure 13. Thickness-Span Correlation by Each Slab Systems

Table 3. RC Member

Span/Depth	Continuous span	Simple span
Beam	21	16
2-way slab	30	-
1-way slab	28	20

Table 4. Post Tension Member

Span/Depth	Continuous span		Simple span	
	Roof	Not Roof	Roof	Not Roof
Beam	60%	70%	53%	62%
2-way slab	63%	71%	-	-
1-way slab	56%	62%	44%	50%

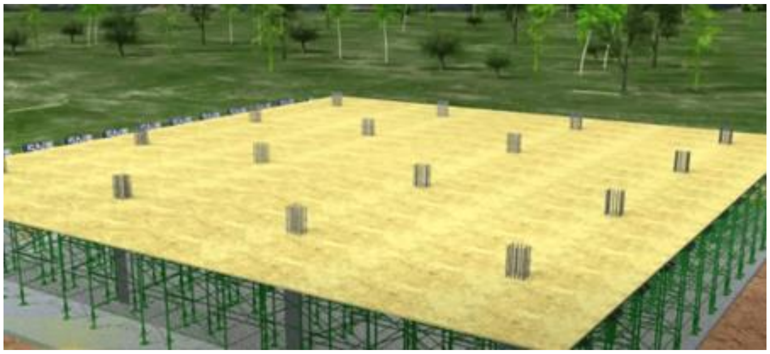
Table 5. Reduction ratio of thickness or depth when PT is applied

RC/PT (%)	Continuous Span		Simple span	
	Roof	Not Roof	Roof	Not Roof
Beam	60%	70%	53%	62%
2-way slab	63%	71%	-	-
1-way slab	56%	62%	44%	50%

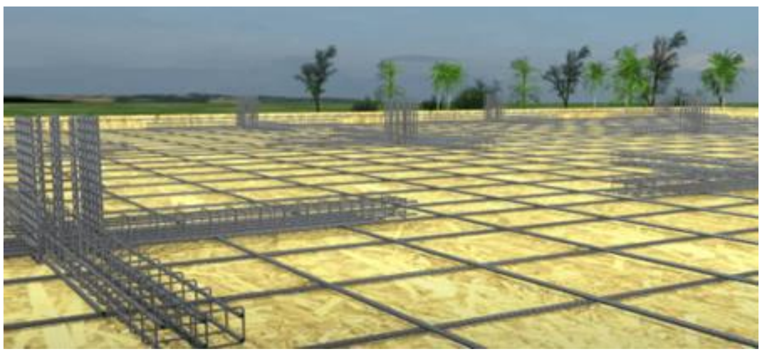
The thickness is reduced by 30-50% compared to the RC member. Alternatively, an economical design can be made by reducing the amount of rebar or tendon required for the same thickness.

13. Post-Tension Slab Procedure

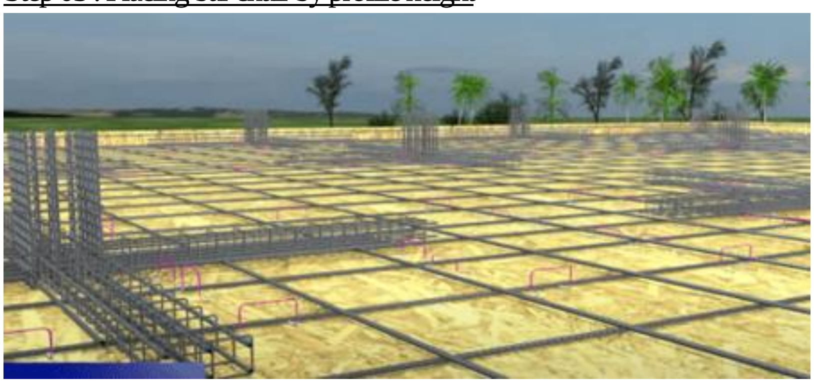
Step 01 : Installing slab formwork



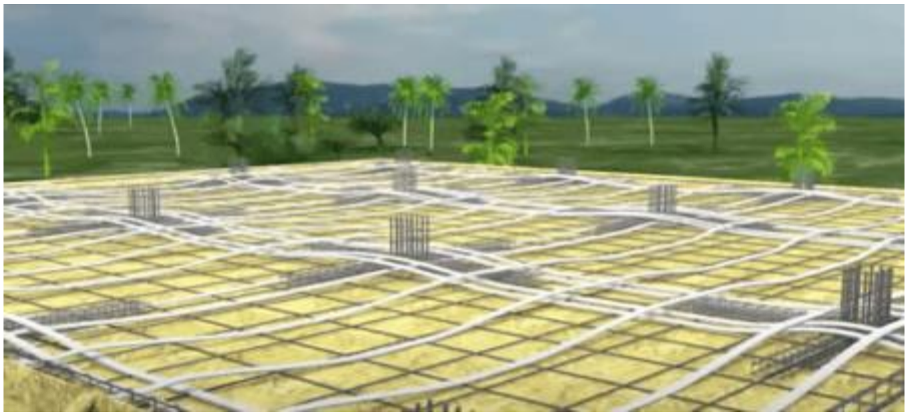
Step 02 : Installing slab rebar



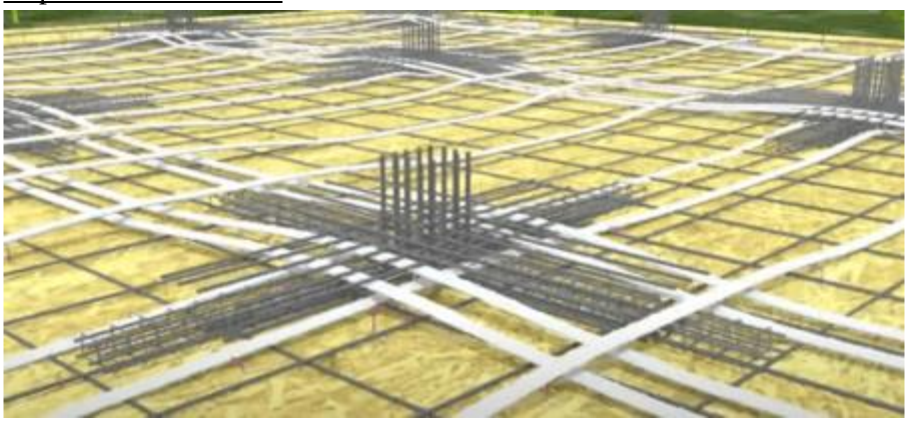
Step 03 : Placing bar chair by profile height



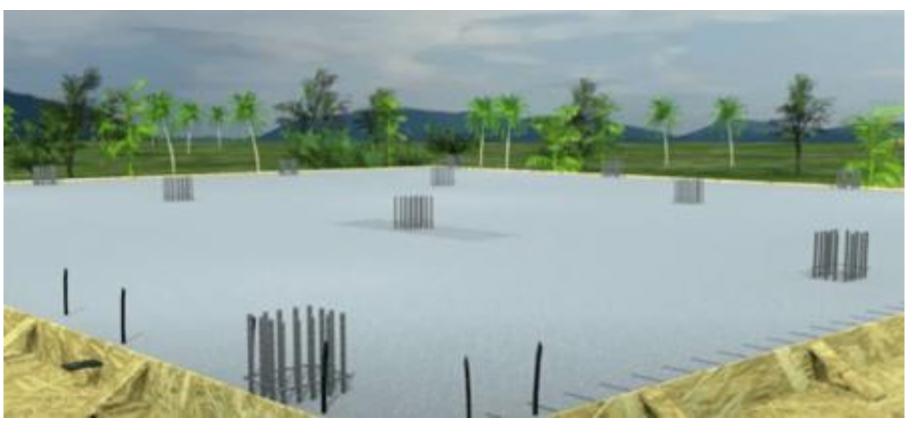
Step 04 : Placing tendon on the bar chair



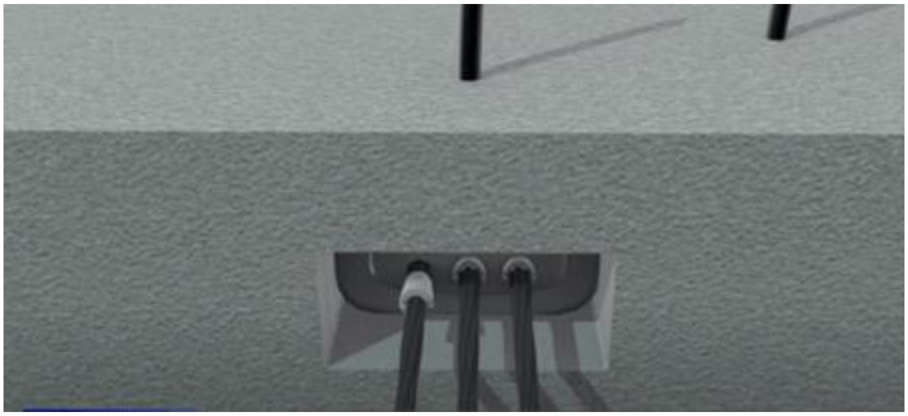
Step 05 : Add extra rebar



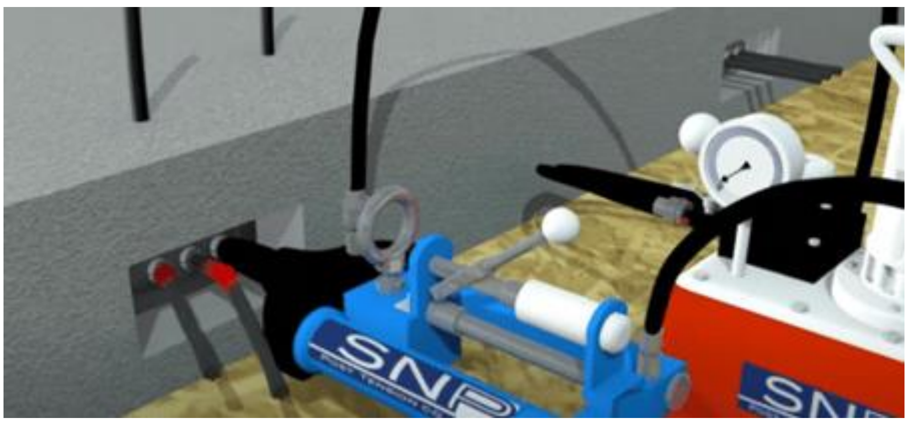
Step 06 : Pouring concrete



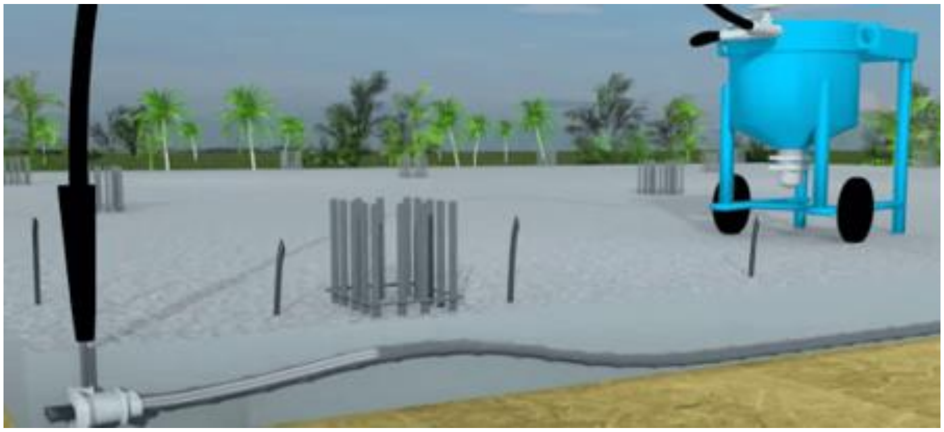
Step 07 : Insert block and jaws bar chair



Step 08 : Stressing and measuring elongation



Step 09 : Grouting



14. Design Flow Chart for Post-Tension

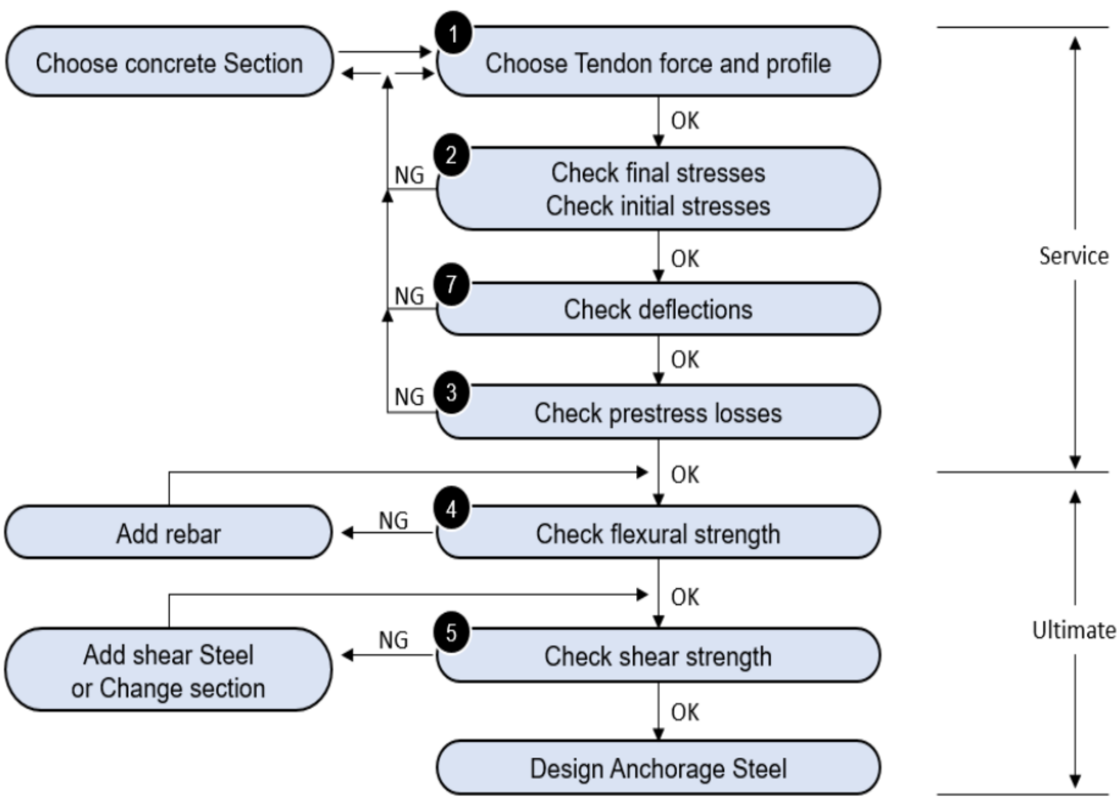


Figure 14. Design Flow Chart for Post-Tension

15. Choose Tendon Force and Profile

15.1 Tendon profile type

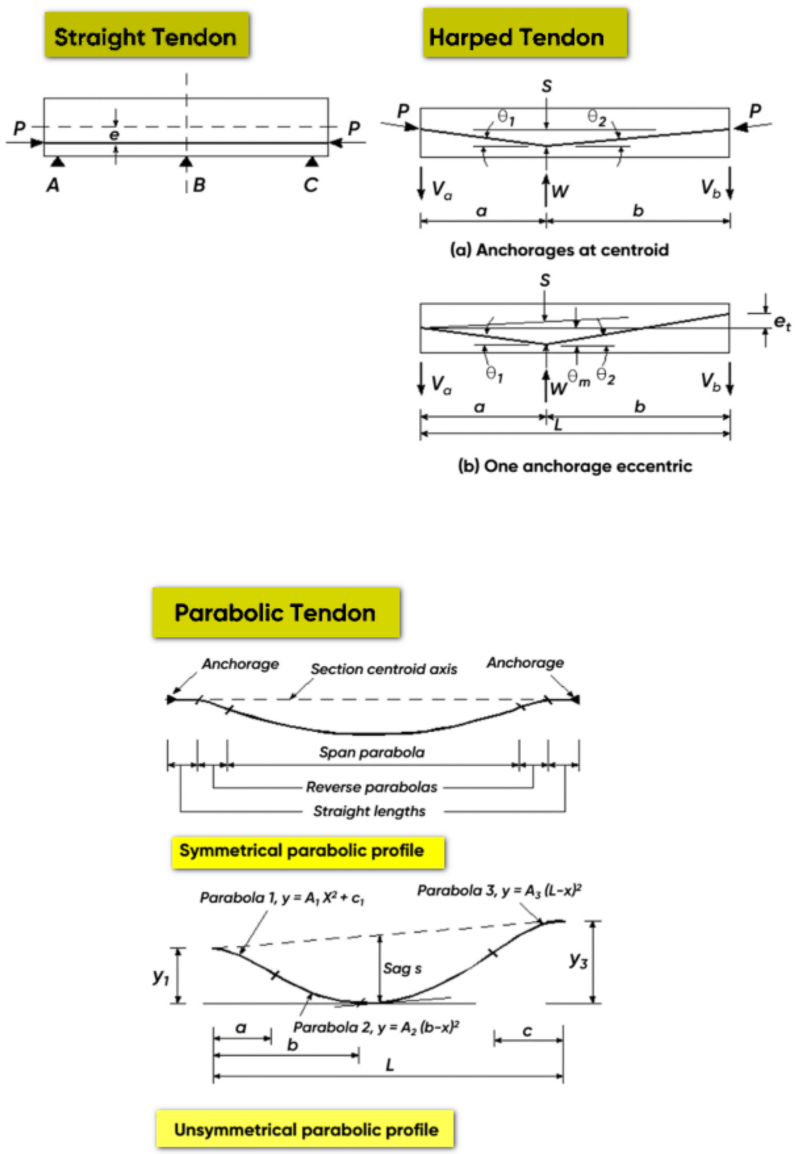


Figure 15. Tendon Profile Types

15.2 How to arrange tendon of parabolic shape?

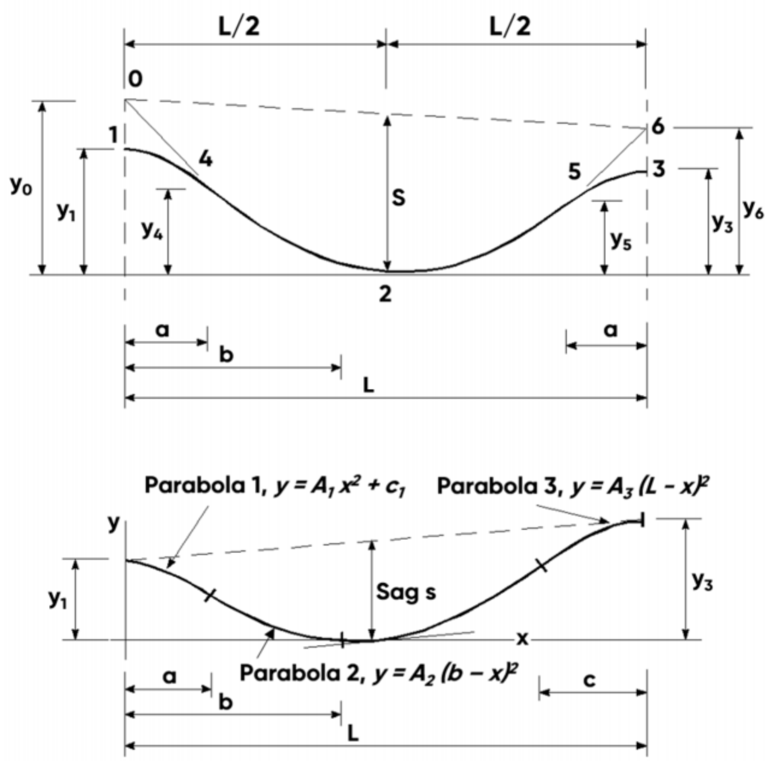


Figure 16. Tendon of Parabolic Shape

Table 6. After Transfer Stage

a/L = c/L	y_3/y_1	b/L	y_0/y_1	y4/y1	y_5/y_3	y_6/y_3
0.1	0.1	0.730	1.159	0.863	0.630	1.588
	0.2	0.669	1.176	0.851	0.698	1.434
	0.3	0.630	1.189	0.841	0.730	1.370
	0.4	0.600	1.200	0.833	0.750	1.333
	0.5	0.576	1.210	0.826	0.764	1.309
	0.6	0.556	1.219	0.820	0.775	1.291
	0.7	0.540	1.228	0.815	0.783	1.277
	0.8	0.525	1.235	0.809	0.790	1.267
	0.9	0.512	1.243	0.805	0.795	1.258
	1.0	0.500	1.250	0.800	0.800	1.250
0.05	0.1	0.746	1.072	0.933	0.803	1.245
	0.2	0.681	1.079	0.927	0.843	1.186
	0.3	0.638	1.085	0.922	0.862	1.160
	0.4	0.607	1.090	0.918	0.873	1.146
	0.5	0.581	1.094	0.914	0.881	1.136
	0.6	0.560	1.098	0.911	0.886	1.128
	0.7	0.542	1.102	0.908	0.891	1.123
	0.8	0.526	1.105	0.905	0.894	1.118
	0.9	0.512	1.108	0.902	0.897	1.114
	1.0	0.500	1.111	0.900	0.900	1.111

16. Check final stresses and check initial stresses

16.1 Allowable stress for Concrete

Table 7. Allowable stress for Concrete (in MPa)

Checking Stage	Conditions	Allowable stress
under Initial Service Load (Initial)	1. Extreme fiber stress in compression	$p_{ci} = 0.60\ f_{ci}$
	2. Extreme fiber stress in tension	$p_{ti} = 0.25\ f_{ci}^{0.5}$
	3. Extreme fiber stress in tension at ends of simply supported members	$p_{ti} = 0.50\ f_{ci}^{0.5}$
under Service Load (Final)	1. Extreme fiber stress in compression (at Long-Term Service Load)	$p_{cf} = 0.45\ f_{ck}$
	2. Extreme fiber stress in compression (prestress + total load)	$p_{cf} = 0.60\ f_{ck}$
	3. Extreme fiber stress in tension	$p_{tf} = 0.50\ f_{ck}^{0.5}$

16.2 Allowable stress for Tendon (Strand)

Table 8. Allowable stress for Tendon (MPa)

Checking Stage	Conditions	Allowable stress
During Stressing	-	Max [0.94 f_{py}, 0.8f_{pu}]
Immediately after stressing	-	0.70f_{pu}

16.3 Calculate & check stresses in simple beam

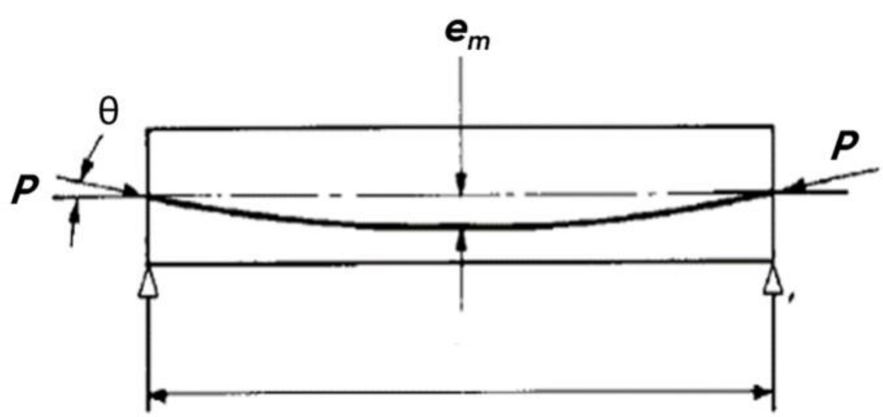


Figure 17. Stresses in Simple Beam

1. Due to initial prestressing force

At Top: $\sigma_{pti} = P_i/A_c - P_i e/Z_t = (1 - eA_c/Z_t)(P_i/A_c) = S_t(P_i/A_c)$

At Bottom: $\sigma_{pbi} = P_i/A_c + P_i e/Z_b = (1 + eA_c/Z_b)(P_i/A_c) = S_b(P_i/A_c)$

2. Check initial stress

At Top: $\sigma ti = \sigma pti + M0/Zt > pti$ (Tensile stress), *if N.G., the area of tendon must be increased.*

At Bottom: $\sigma bi = \sigma pbi - M0/Zb < pci$ (Compressive stress), *if N.G., the concrete section must be increased.*

3. Due to final prestressing force

At Top: $\sigma_{ptf} = S_t(P_f/A_c)$

At Bottom: $\sigma_{pbf} = S_b(P_f/A_c)$

4. Check final stress

At Top: $\sigma_{tf} = \sigma_{ptf} + M_0/Z_t < p_{cf}$ *(Compressive stress), if N.G., the concrete section must be increased.*

At Bottom: $\sigma_{bf} = \sigma_{pbf} - M_0/Z_b > p_{tf}$ *(Tensile stress), if N.G., the area of tendon must be increased.*

5. Check final prestressing force (P_f)

Min. P_f: $P_{f,min} = [p_{tf} + (M_0+M_s)/Z_b]\, A_c/S_b$

Max. P_f: $P_{f,max} = R_p\,(p_{ci} + M_0/Z_b]\, A_c/S_b$ ** $R_p = P_f/P_i$ *(The ratio of final to initial prestressing force)*

$P_{f,max} > P_{f,min}$ → *If* $P_{f,max} > P_{f,min}$*, the concrete section in inadequate and it must be increased.*

16.4 Stress distribution according to tendon arrangement

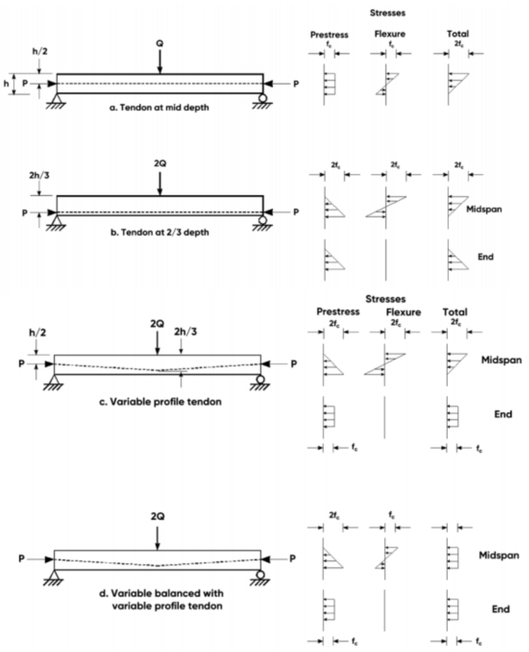


Figure 18. Tendon Arrangement

17. Check Pre-Stress Losses

17.1 What is pre-stress losses?

The pre-stress losses are defined as the loss of tensile stress in the pre-stress steel which acts on the concrete component of the pre-stressed concrete section. In pre-tensioned concrete, the four major sources of pre-stress losses are elastic shortening (ES), creep (CR), shrinkage (SH) and relaxation (RE).

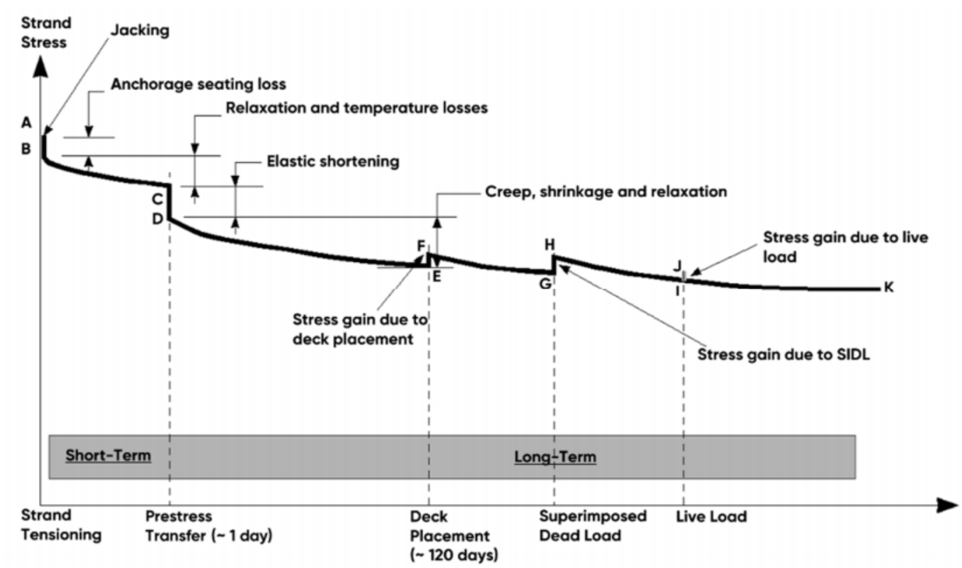


Figure 19. Correlation between Strand Stress and Time

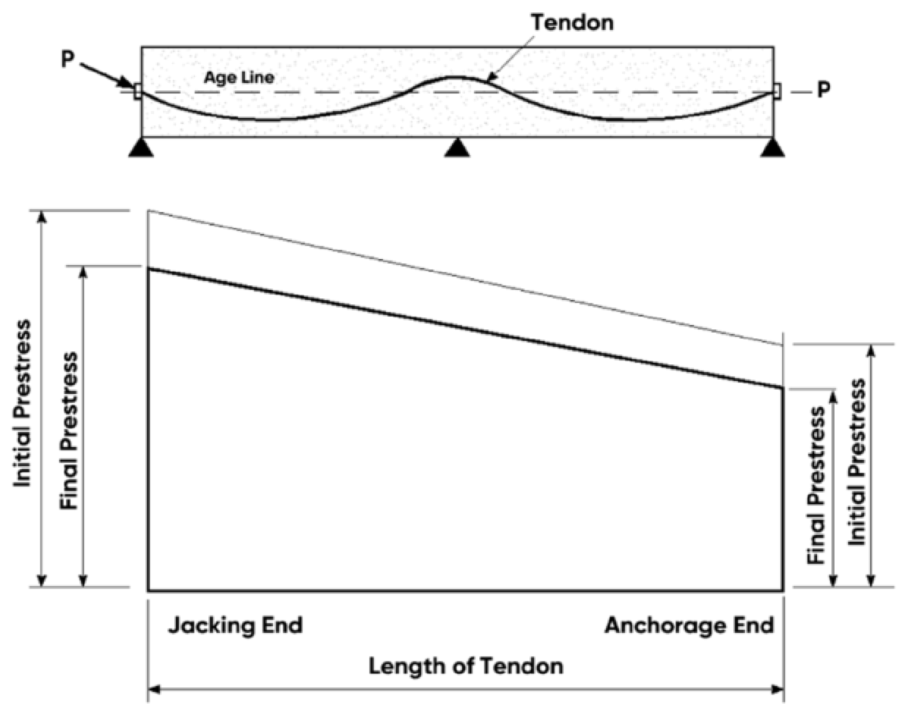


Figure 20. Length of Tendon and Prestress

18. Kinds and Calculation of Losses

18.1 Stress loss due to friction (Curvature and Wobble)

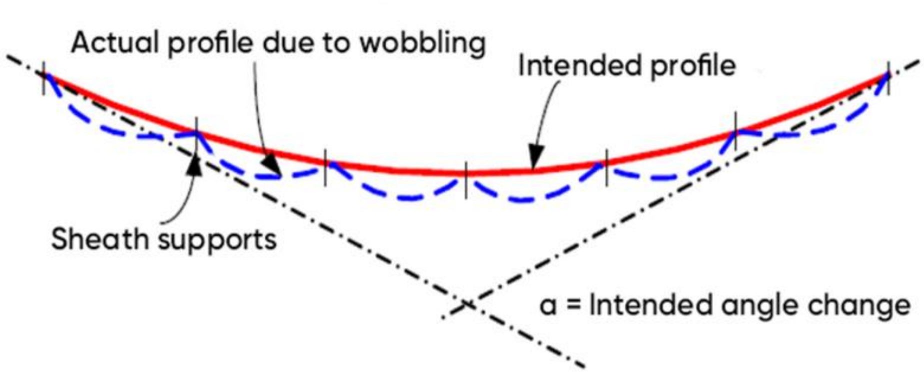


Figure 21. Stress Loss due to Friction-Curvature and Wobble

Values of μ and K

Duct material	BS 8110		ACI 318 Commentary		
	μ	K/m	μ	K/metre	K/ft
Rigid galvanized	0.25	0.0017	0.15-0.25	0.0005-0.0020	0.15-0.61 x 10^{-3}
Greased plastic	0.12	0.0025	0.05-0.15	0.0003-0.0020	0.09-0.61 x 10^{-3}
Non-rigid		0.0033			

Percentage can be simplified to:

$P_x = P_0(1- \mu\theta - K_x)$

Percentage Loss = $100(\mu\theta + K_x)$

$P_{(x)}$ = P0e-($\mu\alpha$+K_x) , **where**

μ = Curvature Friction Coefficient

α or **θ** = Sum of the Tendon Angular Change from the Tendon Jacking End to a Distance x

K = Wobble Friction Coefficient (rad/unit length^2)

$P_{(x)}$ = Post-Tensioning Force at a Distance x

P_0 = Post-Tensioning Force at Stressing

18.2 Anchorage Set Slip Losses

At the last stage of the stressing operation, the tendons usually are anchored with two-piece conical wedges. Anchoring operations normally result in an additional prestress loss due to seating of the wedges, considering that the strand retracts when it is released and pulls the wedges into the anchoring device. Calculation of the stress losses is typically performed in an iterative manner. As shown in the following figure, the distance "c" refers to the extent of influence of an anchor set. Procedurally, anchor set is chosen first (usually about 0.25 to 0.375 in or 6 to 8 mm), then the distance "c" is set, and finally the corresponding stress is computed, with the assumption that the stresses vary linearly from the jacking point.

The seating loss is then calculated using the following equation:

$$\text{SL} \approx a = \frac{\int(\sigma_j - \sigma_x)dx}{E_s}$$

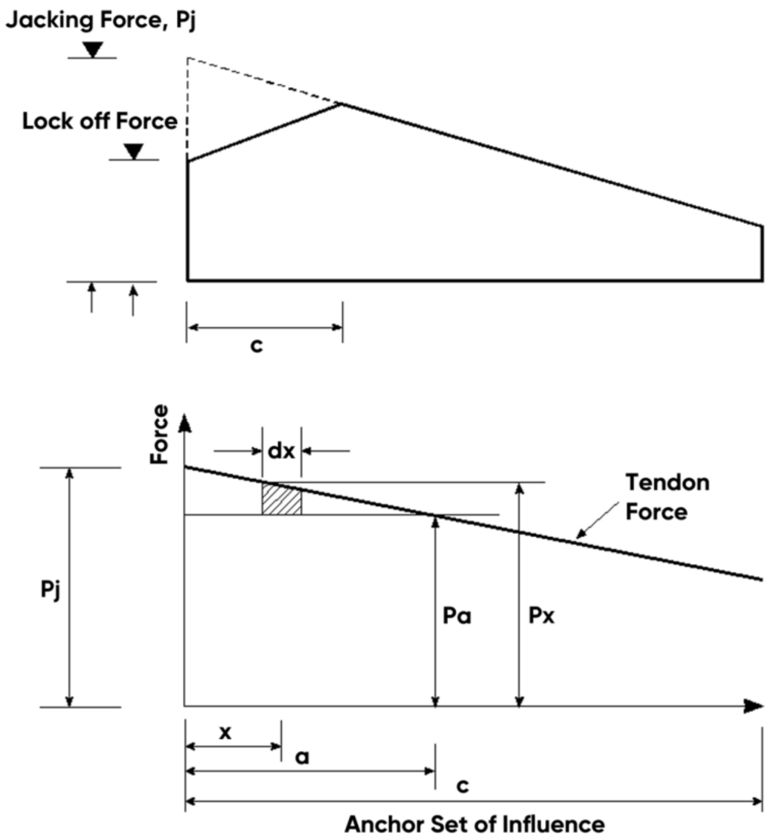


Figure 22. Anchor Set Influence Distance Diagram

18.2 Elastic Shortening of Concrete

Elastic shortening refers to the shortening of the concrete as the post-tensioning force is applied. As the concrete shortens, the tendon length also shortens, resulting in a loss of prestress. If sequential jacking steps are used, the first tendon jacked and locked off will suffer the maximum amount of loss from elastic shortening. Conversely, there will be no loss because of elastic shortening for the last tendon in a sequence or in a single tendon because the elastic shortening will take place before the tendon is locked into the anchoring device. The user specified amount of prestress loss from elastic shortening is applied uniformly over the entire length of the tendon.

18.3 Long-Term Losses

The long-term pre-stress losses of a member include creep, shrinkage, and steel relaxation effects. Creep, shrinkage, and steel relaxation effects are governed by material properties and, in some cases, other environmental conditions that need to be accounted for when specifying the long-term loss values. Each stress loss is treated separately and then summed up, as follows:

$$TL = CR + SH + RE$$

Where TL is the total loss of stress; CR is the stress loss due to creep of the concrete; SH is the stress loss due to shrinkage of the concrete; and RE is the stress loss due to relaxation in the tendon steel. The sum of these losses is applied to the initial (jacking) load of the tendon. All of the longterm losses are uniformly applied over the length of the tendon.

19. Check Flexural Strength

19.1 Calculation of flexural strength

The flexural strength review of members follows the same strength installation method as that of reinforced concrete members. However, the tension member stress (f_{ps}) when the nominal strength is expressed is calculated according to the strain-appropriate condition.

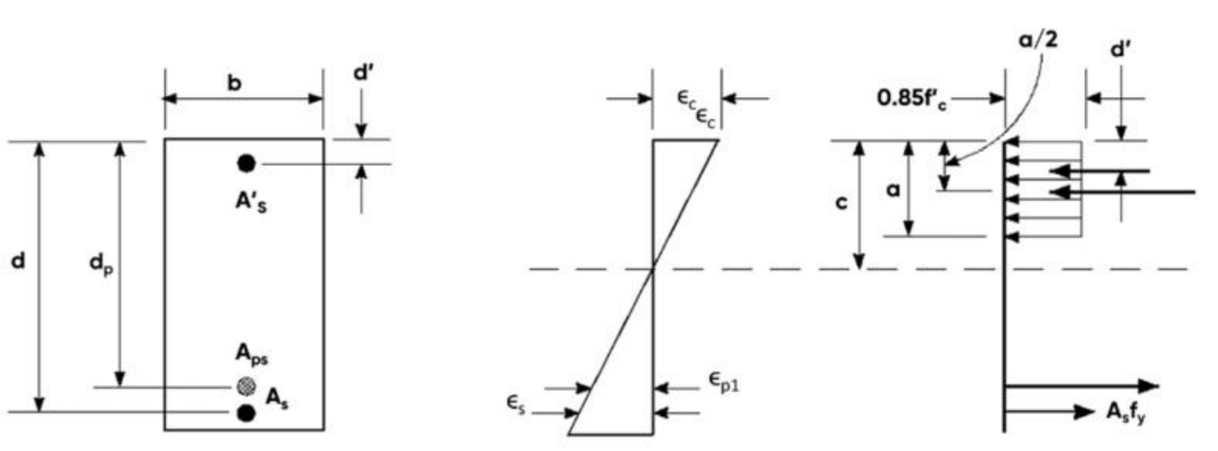


Figure 23. Compression Block Depth Ratio

Compression Block Depth Ratio, ACI 318 (Metric Units)

f'_c	30	35	40	45	50	55 N/mm^2
β_1	0.85	0.81	0.77	0.73	0.69	0.65

y_p = Factor for the type of tendon

= 0.55 for f_{py}/f_{pu} not less than 0.80

= 0.40 for f_{py}/f_{pu} not less than 0.85

= 0.28 for f_{py}/f_{pu} not less than 0.90

$\beta_1 = d_c/d_n$

$\omega = A_s f_y/(f'_c bd)$

$\omega' = A'_s f_y/(f'_c bd)$

$r_p = a_p/bd_p$ = ratio of tendon area

In case of $f_{pe} \geq 0.5\, f_{pu}$

Bonded Type: $f_{ps} = f_{pu}\,[1 - \frac{\gamma_p}{\beta_1}\left\{r_p \frac{f_{pu}}{f_{ck}} + \frac{d}{d_p}(\omega - \omega')\right\}]$

Unbonded Type: $f_{ps} = f_{pe} + 70 + \frac{f_{ck}}{k\rho_p}$

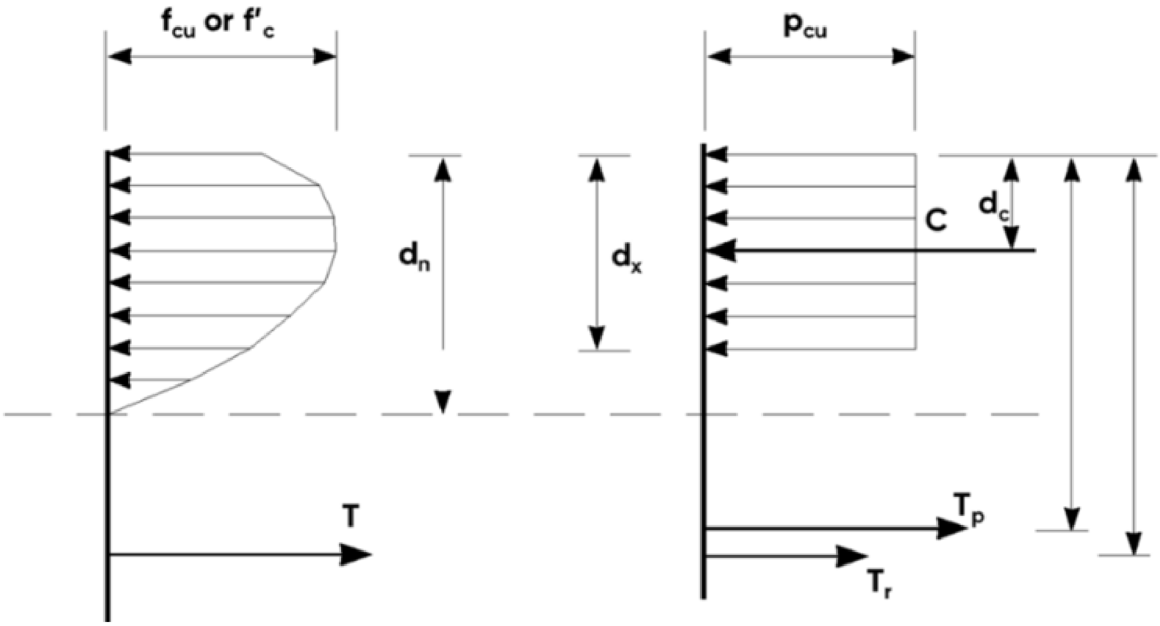


Figure 24. Ultimate State Stress Diagrams

$\mathrm{C} = \mathrm{Compression} = p_{cu} b d_x$

$\mathrm{T} = \mathrm{Tension} = f_{pb} A_P + f_{sb} A_s = T_p + T_r$

Where,

$p_{cu} = Compressive\ stress\ in\ concrete\ at\ failure.$

$T_p = f_{pb} A_P = Tension\ in\ prestresing\ tendons$

$T_r = f_{sb} A_s = Tension\ in\ bonded\ rod\ reinforcement$

$f_{sb} = Stress\ in\ bonded\ reinforcement$

Taking moments of the tensile forces about the center of compression C gives the ultimate capacity of the section M_u, which, of course, should not be less than the required ultimate moment of resistance M_r.

$$\mathrm{M_u} = f_{pb} A_p (d_p - d_c) + f_{sb} A_s (d_r - d_c)$$

where $\mathrm{d_c} = The\ depth\ from\ compression\ face\ to\ the\ center\ of\ the\ compressive\ force$

The procedure for the ultimate state check.

1. Calculate the required moment of resistance M_r.
2. Calculate T_r and T_p, initially T_r may be assumed zero.
3. Calculate d_x and d_c.
4. Calculate M_u.
5. If $M_u < M_r$ then add bonded reinforcement and repeat from 2.

19.2 Check Shear Strength

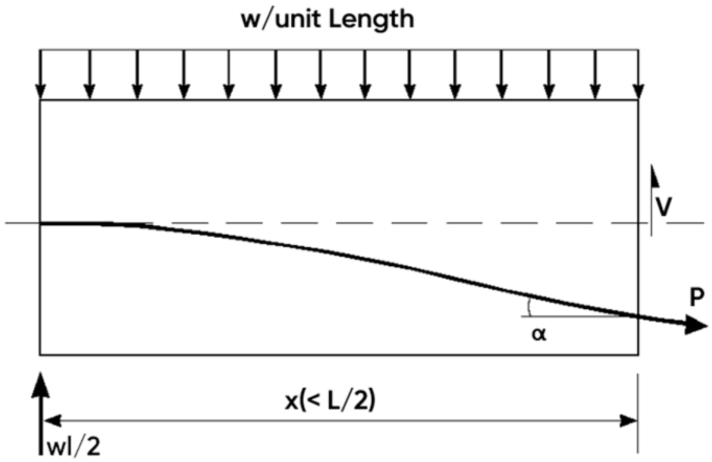


Figure 25. Effect of Inclined Tendon on Effective Shear Force

$$V = -\left(\frac{wL}{2}\right) + wx + P\sin\alpha$$

The factor of 0.85 is introduced after the calculation of shear strength.

Uncracked section

$$V_{co} = [\beta_p (f_c')^{0.5} + 0.3 p_{av}] b_v d + V_p$$

where, for a one-way spanning member,

$$\beta_p = 0.3 \qquad N - mm\ units$$

The vertical component of the prestres, V_p

Cracked section

$$V_{cr} = 0.05 (f_c')^{0.5} b_v d + \frac{m_{ct} V}{M} in\ N - mm\ units$$

$$or\ = 0.60 (f_c')^{0.5} b_v d + \frac{m_{ct} V}{M} in\ 1b - in\ units$$

where, $M_{ct} = Live\ load\ moment\ required\ to\ cause\ cracking$

$$= Z_t [0.5 (f_c')^{0.5} + f_{ct}] \quad N - mm\ units$$

$$or\ Z_t [(f_c')^{0.5} + f_{ct}] \quad 1b - in\ units$$

$$f_{ct} = Stress\ at\ extreme\ tension\ fibre\ due\ to\ dead\ loads$$

Shear reinforcement for beam and 1-way slab

$$A_{sv}/S_v \geq \frac{V - 0.85V_c}{0.85 f_{yv} d}$$

where $A_{sv} = Total\ cross-sectional\ area\ of\ the\ two\ vertical\ legs\ of\ a\ link$

$S_v = Longitudinal\ spacing\ of\ links$

$f_{yv} = Yield\ strength\ of\ shear\ steel$

$= 460 N/mm\ (66.7\ ksi)\ \ for\ high\ tensile\ steel$

$= 250 N/mm\ (36.3\ ksi)\ \ for\ mild\ steel$

The multiplied value of 0.87 is a material partial safety factor for the shear reinforcement.

Min. shear reinforcement: only when $V_u > 0.5V_c$

$$\frac{A_{sv}}{S_v} \geq \frac{b_v}{3f_{yv}}$$

or

$$\frac{A_{sv}}{S_v} \geq \left[\frac{A_p f_{pu}}{80 f_{yv} d}\right] \frac{d}{b_v}^{0.5}$$

Example of one-way shear calculation

What is the value of the one-way shear capacity of a solid slab continuous over two equal spans?

The two equal spans are supported on 250mm thick walls. Suppose that the tendon profile is concordant and the tendon reverse curvature over the support is calculated by the parabola

$$e = 0.000375x^2 - 65 \; in\; mm\; units$$

with a downward eccentricity taken as positive. And it is proportion to an origin at the intersection of the slab and the interior wall centerline.

Here is additional data:

Span	9.0 m
Imposed Live Load	2.5 kN/m^2
Slab Depth	200 mm
Concrete Strength f_{cu}	40 N/mm^2 (f_c' = 32 N/mm^2)
Rod Reinforcement	0.2 %
Steel yield Point f_y	460 N/mm^2
Tendons	15.7 mm @ 300 mm centers
Tendon Ultimate Stress	1770 N/mm^2
Tendon Force, Final	170 kN each

Solution: Using ACI 318.

Factored Load = $24 \times 1.4 \times 0.2 + 1.7 \times 2.5 = 10.97\text{kN/m}^2$

Reaction at outer support = $0.375 \times 10.97 \times 9.0 = 37.02\text{kN/m}$

Moment at critical section = $37.02 \times 8.875 - 10.97 \times 8.875^2 2 = -103.5kNm/m$

Shear at critical section = $0.625 \times 10.97 \times 9.0 - 10.97 \times \frac{0.25}{2} = 60.30kN/m$

The stress at the extreme fibre stress by prestress = $(\frac{P}{A_c}) \times (1 + eA_c/Z)$

$$= \left[\frac{170\times\frac{1000}{0.3}}{200} \times 1000\right] \times \left[1 + \frac{59\times170\times\frac{1000}{0.3}}{0.00667\times10^9}\right] = \frac{7.90\text{N}}{\text{mm}^2}$$

From Eq (10.7), $M_{ct} = 6.67 \times 10^6 \times (0.5\sqrt{32} + 7.90) = 71.5kNm/m$

The actual moment is over this value. The section is cracked, thus use Equation (10.6)

$$V_{cr} = (0.05\sqrt{32}) \times 165 + 71.5 \times \frac{60.3}{103.5} = 89.7kN/m$$

The value which is including a shear strength factor of 0.85 has the shear strength of 76.3kN/m, and it is over the actual shear force of 60.3kN/m. Thus, the shear reinforcement is not needed.

20. Major differences between normal and post-tension slabs

1. One of the greatest differences that lie between commercial foundations and post-tension foundations is the amount of steel that is used in both. While in the case of residential construction slabs, tendons that are used for the centre are around 48 inches. On the other hand, commercial foundations contain a lot more steel than that.
2. Compared to a flat slab, a PT slab requires more formwork. Even conventional slabs do not require the provision of column caps.
3. A PT slab or post-tension slab contains a purse-stressed concrete structure, also known as PSC, while a normal slab contains a reinforced concrete structural element which is also known as RCC.
4. In a PT slab, the reinforcement which is conducted to resist the compression is carried out with a replacement of cables or steel tendons, and therefore the slabs that have been tensioned or pressured after construction are known as post-tension slabs.
5. Conventional slabs cannot work to overcome the weakness of the concrete that is present naturally, while post-tensioning removes all the natural weakness present in the concrete through tension, and they have a better advantage of strength in compression.
6. Post-tension slabs provide a greater benefit when used in the construction of multi-storey buildings due to the greater support as well as, the more floor-to-floor ratio that is provided due to the thinnest of the slabs and the strength accumulated through the pressure.
7. Unlike conventional slabs, post-tension slabs are compressed at the edge of the structure, which results in the strengthening of the concrete for resistance to tensile stresses. The placing of high tensile steel tendons in the structure is also unlike the conventional slabs and therefore has greater strength.

21. Post-Tension Slab versus Reinforced Concrete Slab ~ A Cost - Benefit Ratio:

- PT reduces the concrete volume by 10 to 20%
- Cost of reinforcing is typically 20 to 30% less as compared to conventional reinforced structure.
- Formwork can best ripped off after 6-7 days(as soon as stressing is completed), thereby saving time & money by achieving project target completion before the due date.

- Average bay(Column) spacing is 25 to 30 feet without increase in the slab thickness, thus saving construction cost.
- Concrete Slabs are thinner and consequently lighter and less costly.
- More clear Headroom obtained through PT Assembly Installation. Cost Benefit in Electrical Conduits (per ft.) & relative consumption of accessories, fixtures, thereby enhancing uninterrupted electrical work.
- For flats lab in 8m x 8m or 9m x 9m Grid, PT costs approximately Rs.45 to 50 per sq. ft. with any kind of desired geometry availed better than R.C.C.
- Since the reinforcement is protected, PT reinforced structures have lower annual maintenance costs over time (life cycle costs).

References

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4. How to install post-tensioning, https://www.concretenetwork.com/post-tension/basics.html