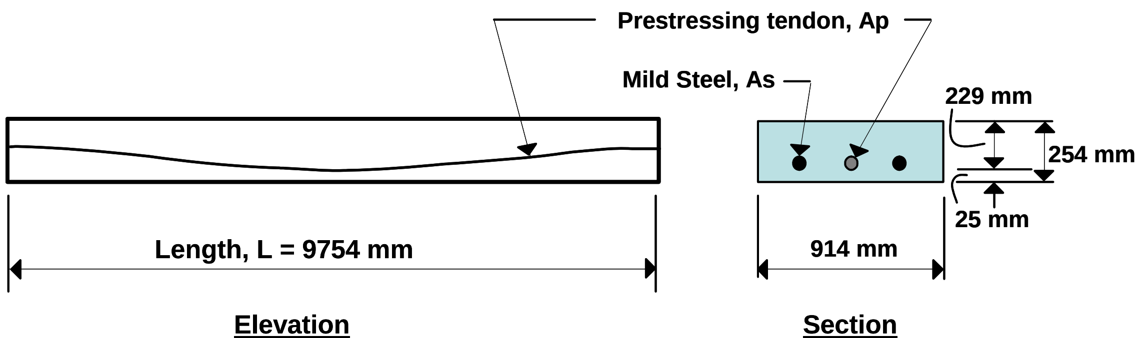
SS CP 65-99 PT-SL EXAMPLE 001

Post-Tensioned Slab Design

PROBLEM DESCRIPTION

The purpose of this example is to verify the slab stresses and the required area of mild steel strength reinforcing for a post-tensioned slab.

A one-way, simply supported slab is modeled in ETABS. The modeled slab is 254 mm thick by 914 mm wide and spans 9754 mm, as shown in shown in Figure 1.



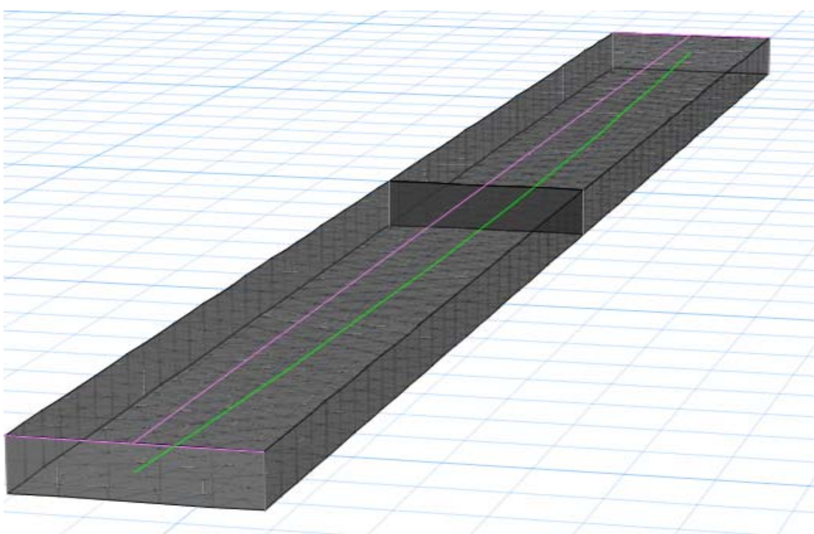


Figure 1 One-Way Slab

A 254-mm-wide design strip is centered along the length of the slab and has been defined as an A-Strip. B-strips have been placed at each end of the span, perpendicular to Strip-A (the B-Strips are necessary to define the tendon profile). A tendon with two strands, each having an area of 99 mm^2, has been added to the A-Strip. The self weight and live loads have been added to the slab. The loads and post-tensioning forces are as follows.

Loads: Dead = self weight, Live = 4.788 kN/m^2

The total factored strip moments, required area of mild steel reinforcement, and slab stresses are reported at the mid-span of the slab. Independent hand calculations are compared with the ETABS results and summarized for verification and validation of the ETABS results.

GEOMETRY, PROPERTIES AND LOADING

Thickness	T, h	=	254	mm
Effective depth	d	=	229	mm
Clear span	L	=	9754	mm
Concrete strength	f'_c	=	30	MPa
Yield strength of steel	f_y	=	400	MPa
Prestressing, ultimate	f_{pu}	=	1862	MPa
Prestressing, effective	f_e	=	1210	MPa
Area of Prestress (single strand)	A_p	=	198	mm^2
Concrete unit weight	w_c	=	23.56	kN/m^3
Modulus of elasticity	E_c	=	25000	N/mm^3
Modulus of elasticity	E_s	=	200,000	N/mm^3
Poisson's ratio	ν	=	0	
Dead load	w_d	=	self	kN/m^2
Live load	w_l	=	4.788	kN/m^2

TECHNICAL FEATURES OF ETABS TESTED

- Calculation of the required flexural reinforcement
- Check of slab stresses due to the application of dead, live, and post-tensioning loads

RESULTS COMPARISON

Table 1 shows the comparison of the ETABS total factored moments, required mild steel reinforcing, and slab stresses with the independent hand calculations.

Table 1 Comparison of Results

FEATURE TESTED	INDEPENDENT RESULTS	ETABS RESULTS	DIFFERENCE
Factored moment, Mu (Ultimate) (kN-m)	174.4	174.4	0.00%
Area of Mild Steel req'd, As (sq-cm)	19.65	19.80	0.76%
Transfer Conc. Stress, top ($D+PT_I$), MPa	–5.058	–5.057	-0.02%
Transfer Conc. Stress, bot ($D+PT_I$), MPa	2.839	2.839	0.00%
Normal Conc. Stress, top ($D+L+PT_F$), MPa	–10.460	–10.467	0.07%
Normal Conc. Stress, bot ($D+L+PT_F$), MPa	8.402	8.409	0.08%

COMPUTER FILE: SS CP 65-1999 PT-SL EX001.EDB

CONCLUSION

The ETABS results show an acceptable comparison with the independent results.

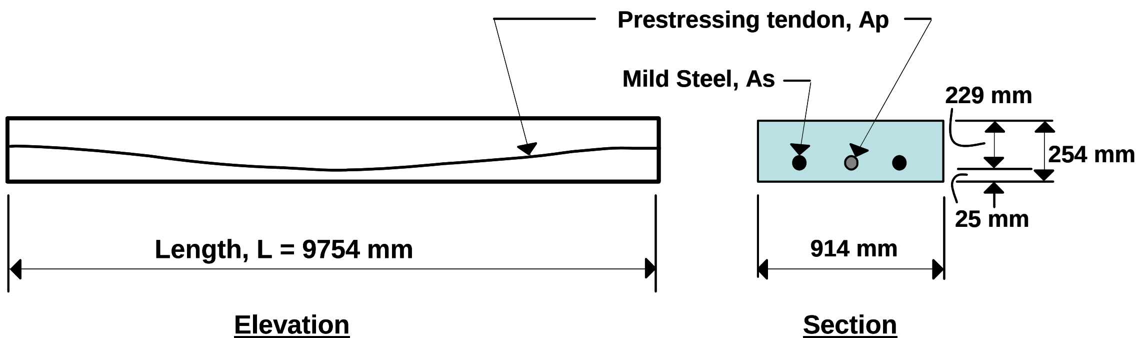
HAND CALCULATIONS:

Design Parameters:

Mild Steel Reinforcing	Post-Tensioning
$f'c$ = 30MPa	f_{pu} = 1862 MPa
fy = 400MPa	f_{py} = 1675 MPa
	Stressing Loss = 186 MPa
	Long-Term Loss = 94 MPa
	f_i = 1490 MPa
	f_e = 1210 MPa

$\gamma_{m,\, steel} = 1.15$

$\gamma_{m,\, concrete} = 1.50$



Loads:

Dead, self-wt = 0.254 m × 23.56 kN/m^3 = 5.984 kN/m^2 (D) × 1.4 = 8.378 kN/m^2 (D_u)

Live, = 4.788 kN/m^2 (L) × 1.6 = 7.661 kN/m^2 (L_u)

Total = 10.772 kN/m^2 (D+L) = 16.039 kN/m^2 (D+L)ult

ω =10.772 kN/m^2 × 0.914 m = 9.846 kN/m, ω_u = 16.039 kN/m^2 × 0.914 m = 14.659 kN/m

Ultimate Moment, $M_U = \dfrac{wl_1^2}{8}$ = 14.659 × (9.754)^2/8 = 174.4 kN-m

Ultimate Stress in strand, $f_{pb} = f_{pe} + \frac{7000}{l/d}\left(1 - 1.7\frac{f_{pu}A_p}{f_{cu}bd}\right)$

$$= 1210 + \frac{7000}{9754/229}\left(1 - 1.7\frac{1862(198)}{30(914)(229)}\right)$$

$$= 1358 \text{ MPa} \le 0.7 f_{pu} = 1303 \text{ MPa}$$

K factor used to determine the effective depth is given as:

$$K = \frac{M}{f_{cu}bd^2} = \frac{174.4}{30000(0.914)(0.229)^2} = 0.1213 < 0.156$$

$$z = d\left(0.5 + \sqrt{0.25 - \frac{K}{0.9}}\right) \le 0.95d = 192.2 \text{ mm}$$

Ultimate force in PT, $F_{ult,PT} = A_P(f_{PS}) = 2(99)(1303)/1000 = 258.0 \text{ kN}$

Ultimate moment due to PT,

$$M_{ult,PT} = F_{ult,PT}(z)/\gamma = 258.0(0.192)/1.15 = 43.12 \text{ kN-m}$$

Net Moment to be resisted by As,

$$M_{NET} = M_U - M_{PT}$$

$$= 174.4 - 43.12 = 131.28 \text{ kN-m}$$

The area of tensile steel reinforcement is then given by:

$$A_s = \frac{M_{NET}}{0.87 f_y z_X} = \frac{131.28}{0.87(400)(192)}(1e6) = 1965 \text{ mm}^2$$

Check of Concrete Stresses at Midspan:

Initial Condition (Transfer), load combination (D+PT_i) = 1.0D+0.0L+1.0PT_I

Tendon stress at transfer = jacking stress − stressing losses = 1490 − 186 = 1304 MPa

The force in the tendon at transfer, = $1304(197.4)/1000 = 257.4 \text{ kN}$

Moment due to dead load, $M_D = 5.984(0.914)(9.754)^2/8 = 65.04 \text{ kN-m}$

Moment due to PT, $M_{PT} = F_{PTI}(\text{sag}) = 257.4(102 \text{ mm})/1000 = 26.25 \text{ kN-m}$

Stress in concrete, $f = \frac{F_{PTI}}{A} \pm \frac{M_D - M_{PT}}{S} = \frac{-257.4}{0.254(0.914)} \pm \frac{65.04 - 26.23}{0.00983}$

where S = 0.00983m^3

$$f = -1.109 \pm 3.948 \text{ MPa}$$

$$f = -5.058(\text{Comp})\max,\ 2.839(\text{Tension})\max$$

Normal Condition, load combinations: $(D+L+PT_F) = 1.0D+1.0L+1.0PT_F$

Tendon stress at normal = jacking – stressing – long-term = 1490 – 186 – 94 = 1210 MPa
The force in tendon at normal, = $1210(197.4)/1000 = 238.9$ kN
Moment due to dead load, $M_D = 5.984(0.914)(9.754)^2/8 = 65.04$ kN-m
Moment due to live load, $M_L = 4.788(0.914)(9.754)^2/8 = 52.04$ kN-m
Moment due to PT, $M_{PT} = F_{PTI}\,(\text{sag}) = 238.9(102\text{ mm})/1000 = 24.37$ kN-m

Stress in concrete for $(D+L+PT_F)$,

$$f = \frac{F_{PTI}}{A} \pm \frac{M_{D+L} - M_{PT}}{S} = \frac{-238.8}{0.254(0.914)} \pm \frac{117.08 - 24.37}{0.00983}$$

$$f = -1.029 \pm 9.431$$

$$f = -10.460(\text{Comp})\max,\ 8.402(\text{Tension})\max$$