IS 456-2000 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.

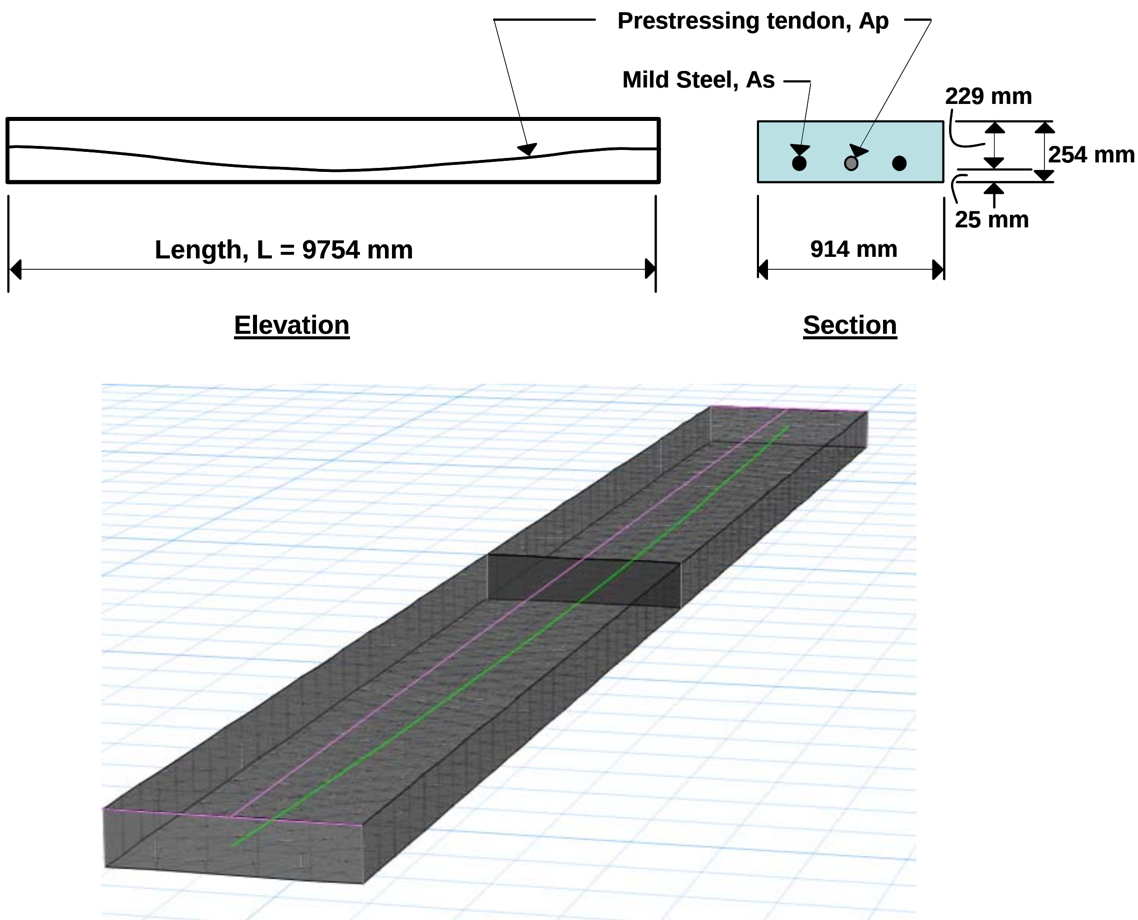


Figure 1 One-Way Slab

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 were 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)	175.60	175.69	0.05%
Area of Mild Steel req'd, As (sq-cm)	19.53	19.775	1.25%
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: IS 456-2000 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_{ck} = 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

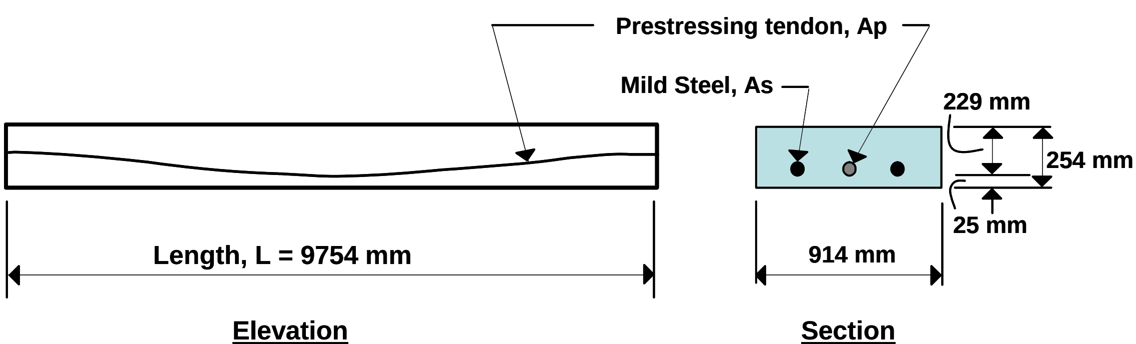
$\gamma_s = 1.15$

$\gamma_c = 1.50$

$\alpha = 0.36$

$\beta = 0.42 \qquad \frac{x_{\max}}{d} = 0.53 - 0.05\frac{f_y - 250}{165} \quad \text{if} \quad 250 < f_y \le 415 \text{ MPa}$

$$\frac{x_{u,\max}}{d} = 0.484$$



Loads:

Dead, self-wt = 0.254 m × 23.56 kN/m^3 = 5.984 kN/m^2 (D) × 1.50 = 8.976 kN/m^2 (D_u)

Live, = 4.788 kN/m^2 (L) × 1.50 = 7.182 kN/m^2 (L_u)

Total = 10.772 kN/m^2 (D+L) = 16.158 kN/m^2 (D+L)ult

ω =10.772 kN/m^2 × 0.914 m = 9.846 kN/m, ω_u = 16.158 kN/m^2 × 0.914 m = 14.768 kN/m

Ultimate Moment, $M_U = \frac{wl_1^2}{8} = 14.768 \times (9.754)^2 / 8$ = 175.6 kN-m

Ultimate Stress in strand, f_{PS} = from Table 11: f_p = 1435 MPa

Ultimate force in PT, $F_{ult,PT} = A_P(f_{PS}) = 197.4(1435)/1000 = 283.3$ kN

Compression block depth ratio: $m = \dfrac{M}{bd^2 \alpha f_{ck}}$

$$= \frac{175.6}{(0.914)(0.229)^2(0.36)(30000)} = 0.3392$$

Required area of mild steel reinforcing,

$$\frac{x_u}{d} = \frac{1-\sqrt{1-4\beta m}}{2\beta} = \frac{1-\sqrt{1-4(0.42)(0.3392)}}{2(0.42)} = 0.4094 \quad > \quad \frac{x_{u,\max}}{d} = 0.484$$

The area of tensile steel reinforcement is then given by:

$$z = d\left\{1-\beta\frac{x_u}{d}\right\} = 229\big(1-0.42(0.4094)\big) = 189.6\,\text{mm}$$

$$A_{NET} = \frac{M_u}{(f_y/\gamma_s)\,z} = \frac{175.6}{(400/1.15)189.6}(1e6) = 2663\,\text{mm}^2$$

$$A_s = A_{NET} - A_P\left(\frac{f_P}{f_y}\right) = 2663 - 198\left(\frac{1435}{400}\right) = 1953\,\text{mm}^2$$

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, = $1304(197.4)/1000 = 257.4$ kN

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

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

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

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),

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

$$f = -1.029 \pm 9.431$$

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