ACI 318-14 PT-SL EXAMPLE 001

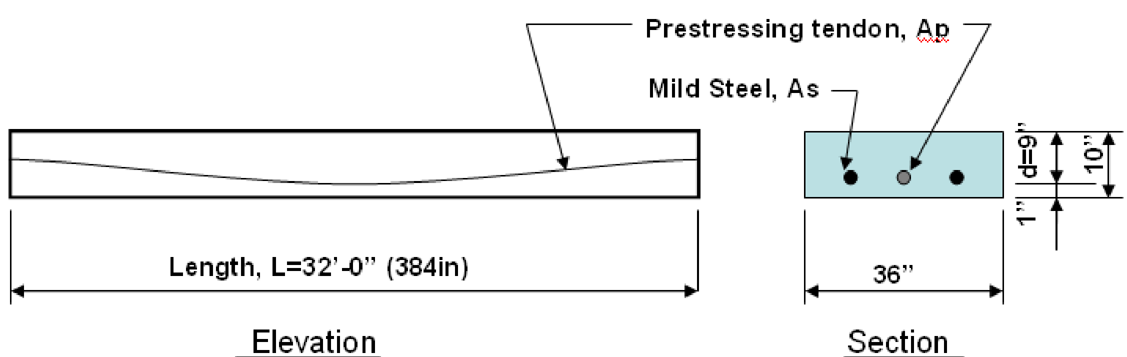
Design Verification of Post-Tensioned Slab using the ACI 318-14 code

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 10 inches thick by 36 inches wide and spans 32 feet, as shown in shown in Figure 1. A 36-inch-wide design strip was centered along the length of the slab and was defined as an A-Strip. B-strips were placed at each end of the span perpendicular to the Strip-A (the B-Strips are necessary to define the tendon profile). A tendon, with two strands having an area of 0.153 square inches each, was added to the A-Strip. The self weight and live loads were added to the slab. The loads and post-tensioning forces are shown below. 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.

Loads: Dead = self weight, Live = 100psf



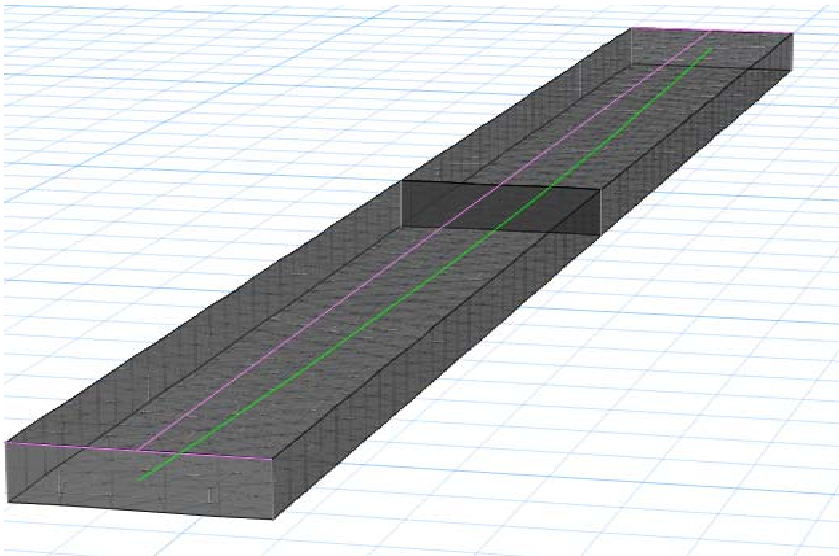


Figure 1 One-Way Slab

GEOMETRY, PROPERTIES AND LOADING

Thickness,	T, h	=	10	in
Effective depth,	d	=	9	in
Clear span,	L	=	384	in
Concrete strength,	f'_c	=	4,000	psi
Yield strength of steel,	f_y	=	60,000	psi
Prestressing, ultimate	f_{pu}	=	270,000	psi
Prestressing, effective	f_e	=	175,500	psi
Area of Prestress (single strand),	A_P	=	0.153	sq in
Concrete unit weight,	w_c	=	0.150	pcf
Modulus of elasticity,	E_c	=	3,600	ksi
Modulus of elasticity,	E_s	=	29,000	ksi
Poisson's ratio,	ν	=	0	
Dead load,	w_d	=	self	psf
Live load,	w_l	=	100	psf

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

The ETABS total factored moments, required mild steel reinforcing and slab stresses are compared to the independent hand calculations in Table 1.

Table 1 Comparison of Results

FEATURE TESTED	INDEPENDENT RESULTS	ETABS RESULTS	DIFFERENCE
Factored moment, Mu (Ultimate) (k-in)	1429.0	1428.3	-0.05%
Area of Mild Steel req'd, As (sq-in)	2.21	2.21	0.00%
Transfer Conc. Stress, top ($D+PT_I$), ksi	–0.734	–0.735	0.14%
Transfer Conc. Stress, bot ($D+PT_I$), ksi	0.414	0.414	0.00%
Normal Conc. Stress, top ($D+L+PT_F$), ksi	–1.518	–1.519	0.07%
Normal Conc. Stress, bot ($D+L+PT_F$), ksi	1.220	1.221	0.08%
Long-Term Conc. Stress, top ($D+0.5L+PT_{F(L)}$), ksi	–1.134	–1.135	0.09%
Long-Term Conc. Stress, bot ($D+0.5L+PT_{F(L)}$), ksi	0.836	0.837	0.12%

COMPUTER FILE: ACI 318-14 PT-SL Ex001.EDB

CONCLUSION

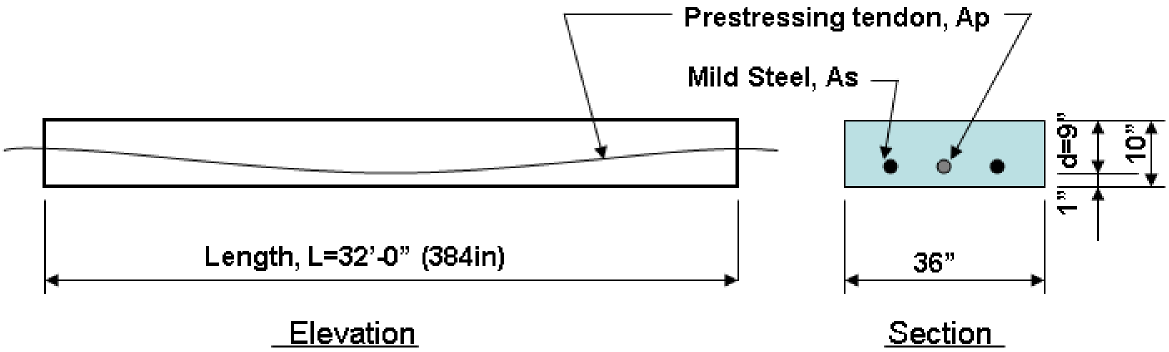
The ETABS results show an acceptable comparison with the independent results.

CALCULATIONS:

Design Parameters:

$\phi = 0.9$

Mild Steel Reinforcing	Post-Tensioning		
$f'c$ = 4000 psi	f_j	=	216.0 ksi
fy = 60,000 psi	Stressing Loss	=	27.0 ksi
	Long-Term Loss	=	13.5 ksi
	f_i	=	189.0 ksi
	f_e	=	175.5 ksi



Loads:

Dead, self-wt = 10 / 12 ft × 0.150 kcf = 0.125 ksf (D) × 1.2 = 0.150 ksf (D_u)

Live, 0.100 ksf (L) × 1.6 = 0.160 ksf (L_u)

Total = 0.225 ksf (D+L) 0.310 ksf (D+L)ult

ω = 0.225 ksf × 3 ft = 0.675 klf, ω_u = 0.310 ksf × 3ft = 0.930 klf

Ultimate Moment, $M_U = \dfrac{wl_1^2}{8}$ = 0.310 klf × 32^2/8 = 119.0 k-ft = 1429.0 k-in

Ultimate Stress in strand, $f_{PS} = f_{SE} + 10000 + \dfrac{f'c}{300\rho_P}$ (span-to-depth ratio > 35)

$$= 175,500 + 10,000 + \frac{4,000}{300(0.000944)}$$

$$= 199,624 \text{ psi} \le 205,500 \text{ psi}$$

Ultimate force in PT, $F_{ult,PT} = A_P\left(f_{PS}\right) = 2(0.153)(199.62) = 61.08 \text{ kips}$

Ultimate force in RC, $F_{ult,RC} = A_s\left(f\right)_y = 2.00(\text{assumed})(60.0) = 120.0 \text{ kips}$

Total Ultimate force, $F_{ult,Total} = 61.08 + 120.0 = 181.08 \text{ kips}$

Stress block depth, $a = \dfrac{F_{ult,Total}}{0.85 f'cb} = \dfrac{181.08}{0.85(4)(36)} = 1.48 \text{ in}$

Ultimate moment due to PT, $M_{ult,PT} = F_{ult,PT}\left(d - \dfrac{a}{2}\right)\phi = 61.08\left(9 - \dfrac{1.48}{2}\right)(0.9) = 454.1 \text{ k-in}$

Net ultimate moment, $M_{net} = M_U - M_{ult,PT} = 1429.0 - 454.1 = 974.9 \text{ k-in}$

Required area of mild steel reinforcing, $A_S = \dfrac{M_{net}}{\phi f_y\left(d - \dfrac{a}{2}\right)} = \dfrac{974.9}{0.9(60)\left(9 - \dfrac{1.48}{2}\right)} = 2.18 \text{ in}^2$

Note: The required area of mild steel reinforcing was calculated from an assumed amount of steel. Since the assumed value and the calculated value are not the same a second iteration can be performed. The second iteration changes the depth of the stress block and the calculated area of steel value. Upon completion of the second iteration the area of steel was found to be 2.21in^2

Check of Concrete Stresses at Mid-Span:

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

The stress in the tendon at transfer = jacking stress − stressing losses = 216.0 − 27.0
= 189.0 ksi

The force in the tendon at transfer, = $189.0(2)(0.153) = 57.83$ kips

Moment due to dead load, $M_D = 0.125(3)(32)^2/8 = 48.0 \text{ k-ft} = 576 \text{ k-in}$

Moment due to PT, $M_{PT} = F_{PTI}(\text{sag}) = 57.83(4 \text{ in}) = 231.3 \text{ k-in}$

Stress in concrete, $f = \dfrac{F_{PTI}}{A} \pm \dfrac{M_D - M_{PT}}{S} = \dfrac{-57.83}{10(36)} \pm \dfrac{576.0 - 231.3}{600}$, where S = 600 in^3

$$\boldsymbol{f} = -0.161 \pm 0.5745$$

$$f = -0.735(\text{Comp})\text{max}, 0.414(\text{Tension})\text{max}$$

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

Tendon stress at normal = jacking − stressing − long-term = 216.0 − 27.0 − 13.5 = 175.5 ksi
The force in tendon at Normal, = $175.5(2)(0.153) = 53.70$ kips

Moment due to dead load, $M_D = 0.125(3)(32)^2/8 = 48.0 \text{ k-ft} = 576 \text{ k-in}$

Moment due to dead load, $M_L = 0.100(3)(32)^2/8 = 38.4 \text{ k-ft} = 461 \text{ k-in}$

Moment due to PT, $M_{PT} = F_{PTI}(\text{sag}) = 53.70(4 \text{ in}) = 214.8 \text{ k-in}$

Stress in concrete for (D + L+ PT_F), $f = \dfrac{F_{PTI}}{A} \pm \dfrac{M_{D+L} - M_{PT}}{S} = \dfrac{-53.70}{10(36)} \pm \dfrac{1037.0 - 214.8}{600}$

$$\boldsymbol{f} = -0.149 \pm 1.727 \pm 0.358$$

$$f = -1.518(\text{Comp})\,\text{max}, 1.220(\text{Tension})\,\text{max}$$

Long-Term Condition, load combinations: (D + 0.5L + $PT_{F(L)}$) = 1.0D + 0.5L + 1.0PT_F

Tendon stress at normal = jacking − stressing − long-term = 216.0 − 27.0 − 13.5 = 175.5 ksi
The force in tendon at Normal, = $175.5(2)(0.153) = 53.70$ kips

Moment due to dead load, $M_D = 0.125(3)(32)^2/8 = 48.0 \text{ k-ft} = 576 \text{ k-in}$

Moment due to dead load, $M_L = 0.100(3)(32)^2/8 = 38.4 \text{ k-ft} = 460 \text{ k-in}$

Moment due to PT, $M_{PT} = F_{PTI}(\text{sag}) = 53.70(4 \text{ in}) = 214.8 \text{ k-in}$

Stress in concrete for (D + 0.5L + $PT_{F(L)}$),

$$f = \frac{F_{PTI}}{A} \pm \frac{M_{D+0.5L} - M_{PT}}{S} = \frac{-53.70}{10(36)} \pm \frac{806.0 - 214.8}{600}$$

$$f = -0.149 \pm 0.985$$

$$f = -1.134(\text{Comp})\max, 0.836(\text{Tension})\max$$