ACI 318-14 RC-PN EXAMPLE 001

Slab Punching Shear Design

PROBLEM DESCRIPTION

The purpose of this example is to verify slab punching shear design in ETABS.

The numerical example is a flat slab that has three 24-foot-long spans in each direction, as shown in Figure 1.

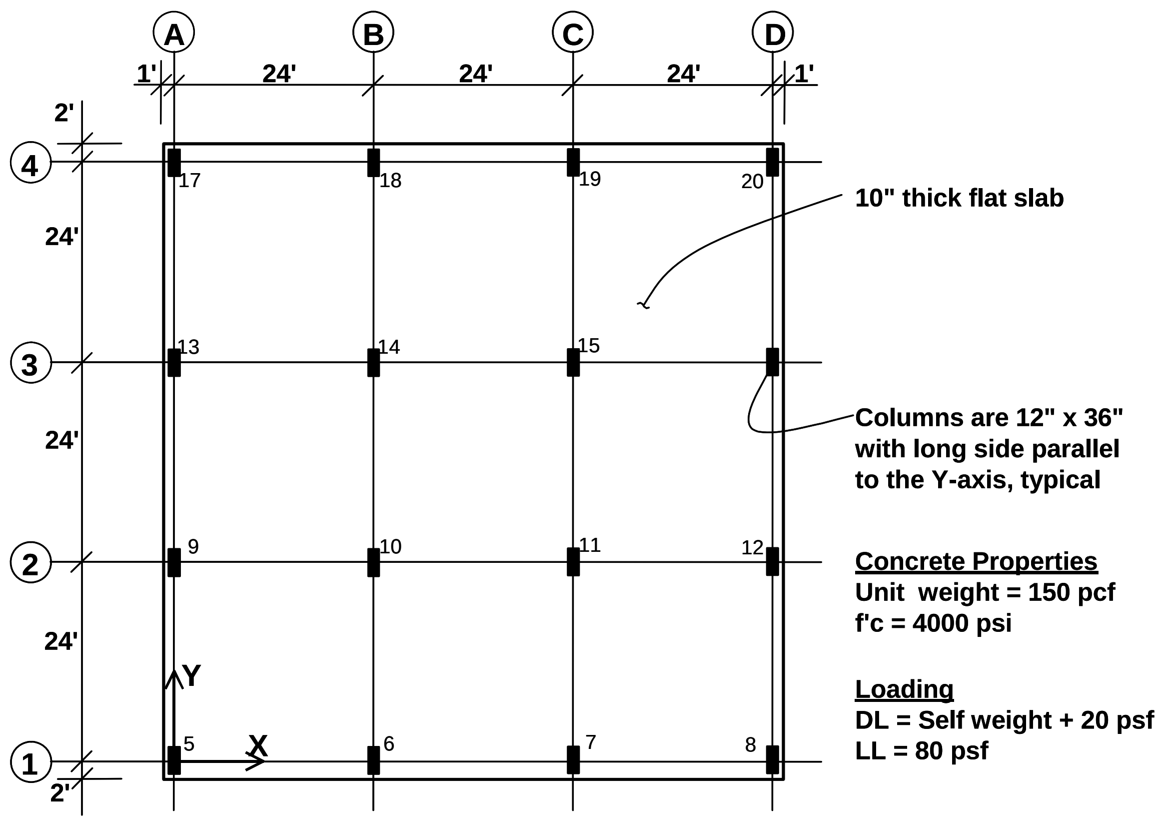

Figure 1: Flat Slab For Numerical Example

The slab overhangs the face of the column by 6 inches along each side of the structure. The columns are typically 12 inches wide by 36 inches long, with the long side parallel to the Y-axis. The slab is typically 10 inches thick. Thick shell properties are used for the slab.

The concrete has a unit weight of 150 pcf and an f'c of 4000 psi. The dead load consists of the self weight of the structure plus an additional 20 psf. The live load is 80 psf.

TECHNICAL FEATURES OF ETABS TESTED

- Calculation of punching shear capacity, shear stress, and D/C ratio.

RESULTS COMPARISON

Table 1 shows the comparison of the ETABS punching shear capacity, shear stress ratio, and D/C ratio with the punching shear capacity, shear stress ratio and D/C ratio obtained by the analytical method. They match exactly for this example.

Table 1 Comparison of Design Results for Punching Shear at Grid B-2

Method	Shear Stress (ksi)	Shear Capacity (ksi)	D/C ratio
ETABS	0.1930	0.158	1.22
Calculated	0.1930	0.158	1.22

COMPUTER FILE: ACI 318-14 RC-PN Ex001.EDB

CONCLUSION

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

HAND CALCULATION

Hand Calculation for Interior Column Using ETABS Method

d = [(10 - 1) + (10 - 2)] / 2 = 8.5"

Refer to Figure 2.

b_0 = 44.5 + 20.5 + 44.5 + 20.5 = 130"

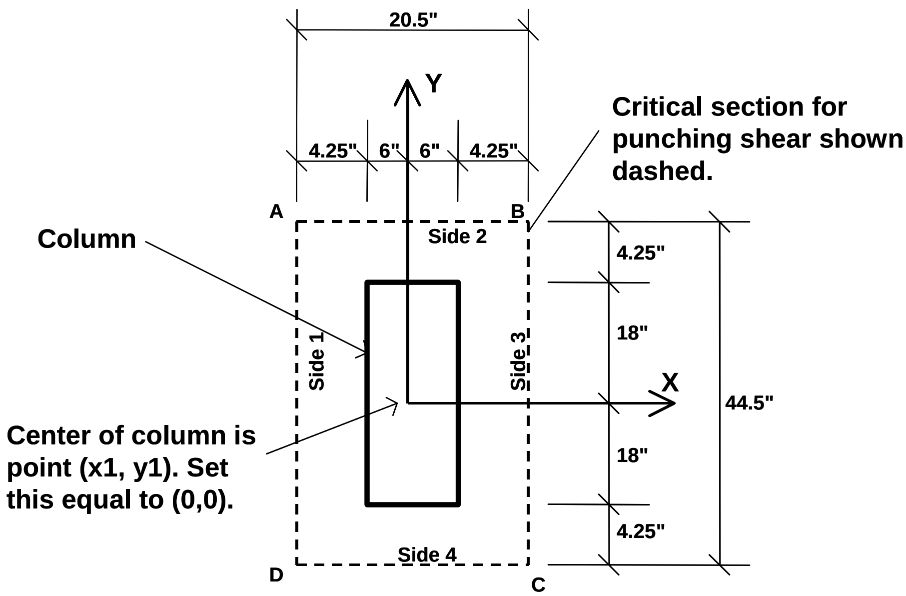

Figure 2: Interior Column, Grid B-2 in ETABS Model

$$\gamma_{V2} = 1 - \frac{1}{1 + \left(\frac{2}{3}\right)\sqrt{\frac{44.5}{20.5}}} = 0.4955$$

$$\gamma_{V3} = 1 - \frac{1}{1 + \left(\frac{2}{3}\right)\sqrt{\frac{20.5}{44.5}}} = 0.3115$$

The coordinates of the center of the column (x_1, y_1) are taken as (0, 0).

The following table is used for calculating the centroid of the critical section for punching shear. Side 1, Side 2, Side 3, and Side 4 refer to the sides of the critical section for punching shear, as identified in Figure 2.

Item	Side 1	Side 2	Side 3	Side 4	Sum
x_2	–10.25	0	10.25	0	N.A.
y_2	0	22.25	0	–22.25	N.A.
L	44.5	20.5	44.5	20.5	b_0 = 130
d	8.5	8.5	8.5	8.5	N.A.
Ld	378.25	174.25	378.25	174.25	1105
Ldx_2	–3877.06	0	3877.06	0	0
Ldy_2	0	3877.06	0	–3877.06	0

$$x_3 = \frac{\sum Ldx_2}{Ld} = \frac{0}{1105} = 0''$$

$$y_3 = \frac{\sum Ldy_2}{Ld} = \frac{0}{1105} = 0''$$

The following table is used to calculate I_{XX}, I_{YY} and I_{XY}. The values for I_{XX}, I_{YY} and I_{XY} are given in the "Sum" column.

Item	Side 1	Side 2	Side 3	Side 4	Sum
L	44.5	20.5	44.5	20.5	N.A.
d	8.5	8.5	8.5	8.5	N.A.
x_2 - x_3	–10.25	0	10.25	0	N.A.
y_2 - y_3	0	22.25	0	–22.25	N.A.
Parallel to	Y-Axis	X-axis	Y-Axis	X-axis	N.A.
Equations	5b, 6b, 7	5a, 6a, 7	5b, 6b, 7	5a, 6a, 7	N.A.
I_{XX}	64696.5	86264.6	64696.5	86264.6	301922.3
I_{YY}	39739.9	7151.5	39739.9	7151.5	93782.8
I_{XY}	0	0	0	0	0

From the ETABS output at Grid B-2:

V_U = 189.45 k

$\gamma_{V2} M_{U2}$ = –156.39 k-in

$\gamma_{V3} M_{U3}$ = 91.538 k-in

At the point labeled A in Figure 2, $x_4 = -10.25$ and $y_4 = 22.25$, thus:

$$v_U = \frac{189.45}{130 \bullet 8.5} - \frac{156.39\left[93782.8\left(22.25-0\right)-\left(0\right)\left(-10.25-0\right)\right]}{(301922.3)(93782.8)-(0)^2} - \frac{91.538\left[301922.3\left(-10.25-0\right)-\left(0\right)\left(22.25-0\right)\right]}{\left(301922.3\right)\left(93782.8\right)-\left(0\right)^2}$$

v_U = 0.1714 – 0.0115 – 0.0100 = **0.1499 ksi** at point A

At the point labeled B in Figure 2, $x_4 = 10.25$ and $y_4 = 22.25$, thus:

$$v_U = \frac{189.45}{130 \bullet 8.5} - \frac{156.39\left[93782.8\left(22.25-0\right)-\left(0\right)\left(10.25-0\right)\right]}{\left(301922.3\right)\left(93782.8\right)-\left(0\right)^2} - \frac{91.538\left[301922.3\left(10.25-0\right)-\left(0\right)\left(22.25-0\right)\right]}{\left(301922.3\right)\left(93782.8\right)-\left(0\right)^2}$$

v_U = 0.1714 – 0.0115 + 0.0100 = **0.1699 ksi** at point B

At the point labeled C in Figure 2, $x_4 = 10.25$ and $y_4 = -22.25$, thus:

$$v_U = \frac{189.45}{130 \bullet 8.5} - \frac{156.39\left[93782.8\left(-22.25-0\right)-\left(0\right)\left(10.25-0\right)\right]}{\left(301922.3\right)\left(93782.8\right)-\left(0\right)^2} - \frac{91.538\left[301922.3\left(10.25-0\right)-\left(0\right)\left(-22.25-0\right)\right]}{\left(301922.3\right)\left(93782.8\right)-\left(0\right)^2}$$

v_U = 0.1714 + 0.0115 + 0.0100 = **0.1930 ksi** at point C

At the point labeled D in Figure 2, $x_4 = -10.25$ and $y_4 = -22.25$, thus:

$$v_U = \frac{189.45}{130 \bullet 8.5} - \frac{156.39\left[93782.8\left(-22.25-0\right)-\left(0\right)\left(-10.25-0\right)\right]}{\left(301922.3\right)\left(93782.8\right)-\left(0\right)^2} - \frac{91.538\left[301922.3\left(-10.25-0\right)-\left(0\right)\left(-22.25-0\right)\right]}{\left(301922.3\right)\left(93782.8\right)-\left(0\right)^2}$$

v_U = 0.1714 + 0.0115 - 0.0100 = **0.1729 ksi** at point D

Point C has the largest absolute value of v_u, thus $v_{max} = 0.1930$ ksi

The shear capacity is calculated based on the smallest of ACI 318-14 equations 11-34, 11-35 and 11-36 with the b_0 and d terms removed to convert force to stress.

$$\varphi v_C = \frac{0.75\left(2 + \frac{4}{36/12}\right)\sqrt{4000}}{1000} = 0.158 \text{ ksi in accordance with equation 11-34}$$

$$\varphi v_C = \frac{0.75\left(\frac{40 \bullet 8.5}{130} + 2\right)\sqrt{4000}}{1000} = 0.219 \text{ ksi in accordance with equation 11-35}$$

$$\varphi v_C = \frac{0.75 \bullet 4 \bullet \sqrt{4000}}{1000} = 0.190 \text{ ksi in accordance with equation 11-36}$$

Equation 11-34 yields the smallest value of $\boxed{\phi v_C = 0.158 \text{ ksi}}$ and thus this is the shear capacity.

$$\boxed{Shear\ Ratio = \frac{v_U}{\varphi v_C} = \frac{0.193}{0.158} = 1.22}$$