EXAMPLE Italian NTC 2008 RC-PN-001

Slab Punching Shear Design

PROBLEM DESCRIPTION

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

The numerical example is a flat slab that has three 8-m spans in each direction, as shown in Figure 1.

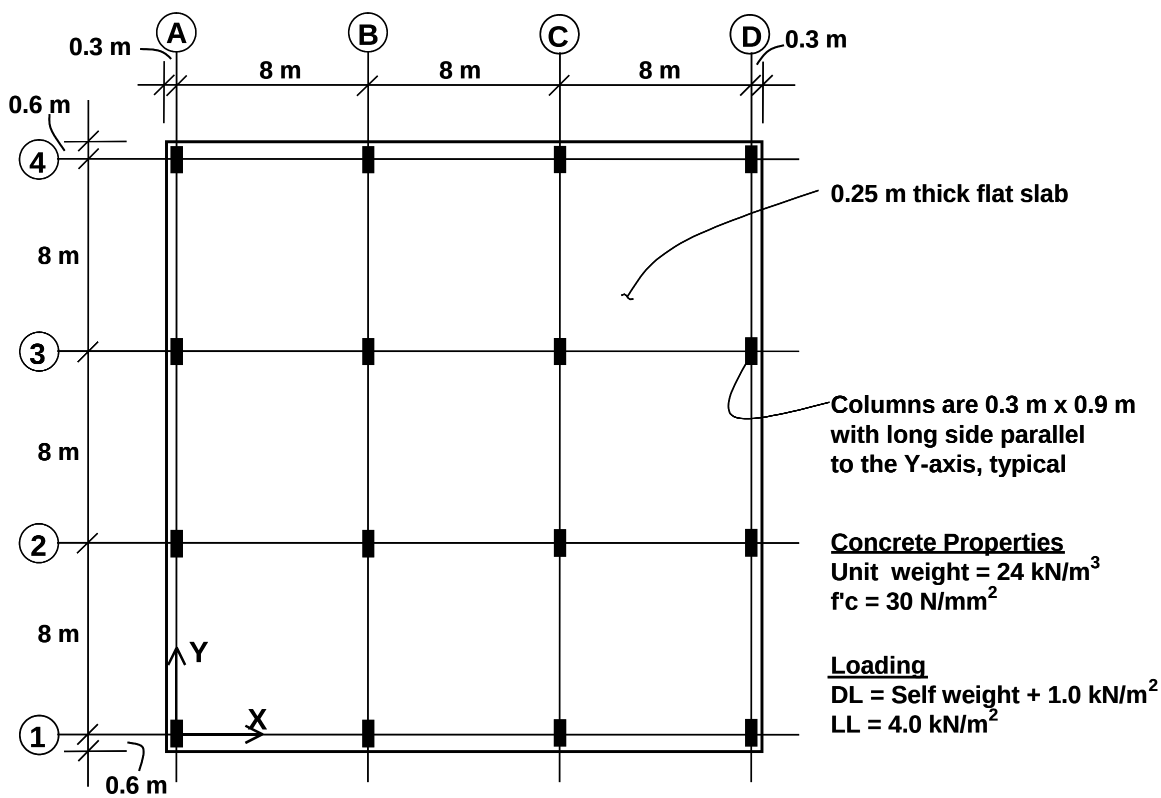

Figure 1: Flat Slab for Numerical Example

The slab overhangs beyond the face of the column by 0.15 m along each side of the structure. The columns are typically 0.3 m x 0.9 m with the long side parallel to the Y-axis. Thick plate properties are used for the slab.

The concrete has a unit weight of 24 kN/m^3 and a *f'c* of 30 N/mm^2. The dead load consists of the self weight of the structure plus an additional 1 kN/m^2. The live load is 4 kN/m^2.

TECHNICAL FEATURES OF SAFE TESTED

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

RESULTS COMPARISON

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

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

Method	Shear Stress (N/mm^2)	Shear Capacity (N/mm^2)	D/C ratio
SAFE	1.100	0.578	1.90
Calculated	1.099	0.578	1.90

COMPUTER FILE: ITALIAN NTC 2008 RC-PN-001.FDB

CONCLUSION

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

HAND CALCULATION

Hand Calculation for Interior Column using SAFE Method

$d = [(250-26)+(250-38)]/2 = 218$ mm

Refer to Figure 2.

$u_1 = u = 2 \bullet 300 + 2 \bullet 900 + 2 \bullet \pi \bullet 436 = 5139.468$ mm

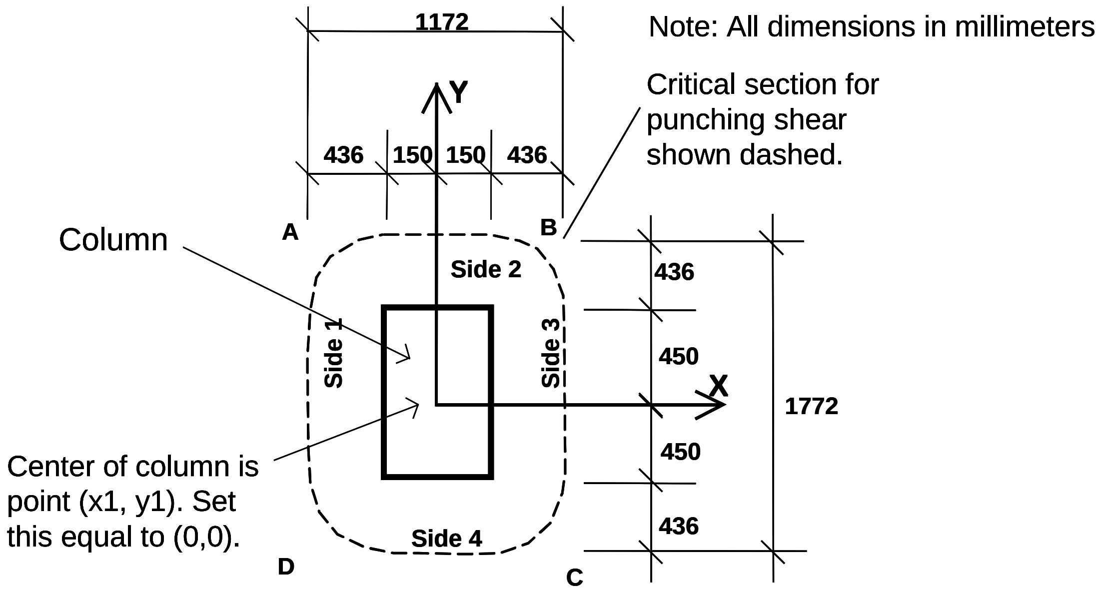

Figure 2: Interior Column, Grid B-2 in SAFE Model

From the SAFE output at Grid B-2:

V_{Ed} = 1112.197 kN

$k_2 M_{Ed2}$ = 41.593 kN-m

$k_3 M_{Ed3}$ = 20.576 kN-m

Maximum design shear stress in computed in along major and minor axis of column:

$$v_{Ed} = \frac{V_{Ed}}{ud}\left[1 + \frac{k_2 M_{Ed,2} u_1}{V_{Ed} W_{1,2}} + \frac{k_3 M_{Ed,3} u_1}{V_{Ed} W_{1,3}}\right] \quad \text{(EC2 6.4.4(2))}$$

$$W_1 = \frac{c_1^2}{2} + c_1 c_2 + 4c_2 d + 16d^2 + 2\pi d c_1$$

$$W_{1,2} = \frac{900^2}{2} + 300 \bullet 900 + 4 \bullet 300 \bullet 218 + 16 \bullet 218^2 + 2\pi \bullet 218 \bullet 900$$

$$W_{1,2} = 2{,}929{,}744.957 \text{ mm}^2$$

$$W_{1,3} = 3\frac{900^2}{2} + 900 \bullet 300 + 4 \bullet 900 \bullet 218 + 16 \bullet 218^2 + 2\pi \bullet 218 \bullet 300$$

$$W_{1,2} = 2{,}271{,}104.319 \text{ mm}^2$$

$$v_{Ed} = \frac{V_{Ed}}{ud}\left[1 + \frac{k_2 M_{Ed,2} u_1}{V_{Ed} W_{1,2}} + \frac{k_3 M_{Ed,3} u_1}{V_{Ed} W_{1,3}}\right]$$

$$v_{Ed} = \frac{1112.197 \bullet 10^3}{5139.468 \bullet 218}\left[1 + \frac{41.593 \bullet 10^6 \bullet 5139.468}{1112.197 \bullet 10^3 \bullet 2929744.957} + \frac{20.576 \bullet 10^6 \bullet 5139.468}{1112.197 \bullet 10^3 \bullet 2271104.319}\right]$$

$$v_{Ed} = 1.099 \text{ N/mm}^2$$

Thus v_{max} = **1.099 N/mm²**

$$C_{Rd,c} = 0.18/\gamma_c = 0.18/1.5 = 0.12 \quad \text{(EC2 6.4.4)}$$

The shear stress carried by the concrete, $V_{Rd,c}$, is calculated as:

$$V_{Rd,c} = \left[C_{Rd,c} k \left(100 \rho_1 f_{ck}\right)^{1/3} + k_1 \sigma_{cp}\right] \quad \text{(EC2 6.4.4)}$$

with a minimum of:

$$v_{Rd,c} = \left(v_{min} + k_1 \sigma_{cp}\right) \quad \text{(EC2 6.4.4)}$$

$$k = 1 + \sqrt{\frac{200}{d}} \le 2.0 = 1.9578 \quad \text{(EC2 6.4.4(1))}$$

$$k_1 = 0.15. \quad \text{(EC2 6.2.2(1))}$$

$$\rho_1 = \frac{A_{s1}}{b_w d} \le 0.02$$

Area of reinforcement at the face of column for design strip are as follows:

A_s in Strip Layer A = 9204.985 mm^2

A_s in Strip Layer B = 8078.337 mm^2

Average A_s = $(9204.985 + 8078.337)/2$ = 8641.661 mm^2

ρ_1 = $8641.661/(8000 \bullet 218)$ = 0.004955 ≤ 0.02

$$v_{\min} = 0.035k^{3/2} f_{ck}^{\ 1/2} = 0.035(1.9578)^{3/2}(30)^{1/2} = 0.525 \text{ N/mm}^2$$

$$v_{Rd,c} = \left[0.12 \bullet 1.9578(100 \bullet 0.004955 \bullet 30)^{1/3} + 0\right] = 0.5777 \text{ N/mm}^2$$

$$\text{Shear Ratio} = \frac{v_{\max}}{v_{Rd,c}} = \frac{1.099}{0.5777} = 1.90$$