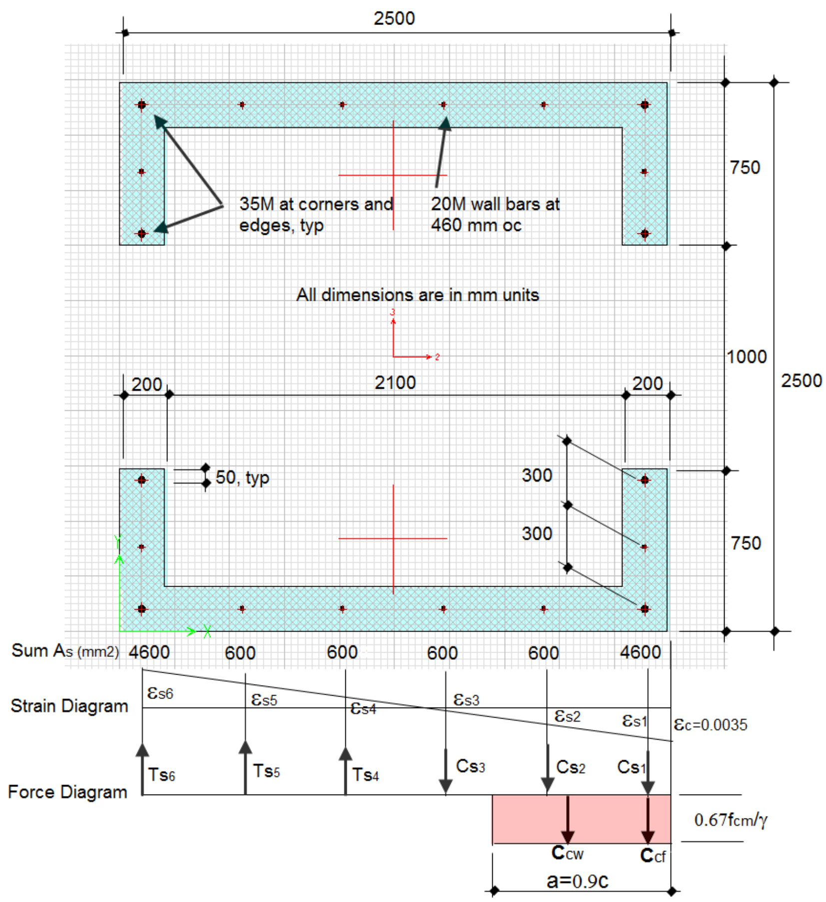
EXAMPLE Singapore CP65-99 Wall-002

P-M INTERACTION CHECK FOR A WALL

EXAMPLE DESCRIPTION

The Demand/Capacity ratio for a given axial load and moment are tested in this example. A reinforced concrete wall is subjected to a factored axial load P_u = 8368 kN and moments M_{uy} = 11967 kN-m. This wall is reinforced as noted below. The design capacity ratio is checked by hand calculations and the results are compared with ETABS program results.

GEOMETRY, PROPERTIES AND LOADING



Material Properties	Section Properties	Design Properties
E = 25000 MPa	tb = 200 mm	f'_c = 30 MPa
v = 0.2	H = 2500 mm	f_y = 460 MPa
	d = 2400 mm	
	s = 460 mm	
	As1= As5 = 4-35M+2-20M (4600 mm^2)	
	As2, As3, As4, As5 = 2-20M (600 mm^2)	

TECHNICAL FEATURES OF ETABS TESTED

- Concrete wall flexural demand/capacity ratio

RESULTS COMPARISON

Independent results are hand calculated and compared with ETABS design check.

Output Parameter	ETABS	Independent	Percent Difference
Wall Demand/Capacity Ratio	1.001	1.00	0.10%

COMPUTER FILE: SINGAPORE CP65-99 WALL-002

CONCLUSION

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

HAND CALCULATION

Wall Strength Determined as follows:

1) A value of e = 1430 mm was determined using $e = M_u / P_u$ where M_u and P_u were taken from the ETABS test model PMM interaction diagram for pier P1. Values for M_u and P_u were taken near the balanced condition and large enough to produce a flexural D/C ratio very close to or equal to one. The depth to the neutral axis, c, was determined by iteration using an excel spreadsheet so that equations 1 and 2 below were equal.

2) From the equation of equilibrium:

$$P_n = C_c + C_s - T$$

where

$C_c = C_{cw} + C_{cf}$, where C_{cw} and C_{cf} are the area of the concrete web and flange in compression

$$C_{cw} = \frac{0.67}{\gamma_m} f_{cu} \bullet 200 \bullet (a - 200)$$

$$C_{cf} = \frac{0.67}{\gamma_m} f_{cu} (200 \bullet 2500)$$

$$C_s = \frac{A'_{s1}}{\gamma_s}\left(f_{s1} - \frac{0.67}{\gamma_m} f'_c\right) + \frac{A'_{s2}}{\gamma_s}\left(f_{s2} - \frac{0.67}{\gamma_m} f'_c\right) + \frac{A'_{s3}}{\gamma_s}\left(f_{s3} - \frac{0.67}{\gamma_m} f'_c\right)$$

$$T = \frac{A_{s4}}{\gamma_s} f_{s4} + \frac{A_{s5}}{\gamma_s} f_{s5} + \frac{A_{s6}}{\gamma_s} f_{s6}$$

$$P_{n1} = \frac{0.67}{\gamma_m} f_{cu} \bullet 200 \bullet (a - 200) + \frac{0.67}{\gamma_m} f_{cu} (200 \bullet 2500) + \frac{A'_{s1}}{\gamma_s}\left(f_{s1} - \frac{0.67}{\gamma_m} f'_c\right) + \frac{A'_{s2}}{\gamma_s}\left(f_{s2} - \frac{0.67}{\gamma_m} f'_c\right) + \frac{A'_{s3}}{\gamma_s}\left(f_{s3} - \frac{0.67}{\gamma_m} f'_c\right) - \frac{A_{s4}}{\gamma_s} f_{s4} + \frac{A_{s5}}{\gamma_s} f_{s5} + \frac{A_{s6}}{\gamma_s} f_{s6} \quad \text{(Eqn. 1)}$$

3) Taking moments about A_{s6}:

$$P_{n2} = \frac{1}{e'}\left[C_{cf}(d - d') + C_{cw}\left(d - \frac{a - t_f}{2} - t_f\right) + C_{s1}(d - d') + C_{s2}(4s) + C_{s3}(3s) - T_{s4}(2s) - T_{s5}(s) \right] \quad \text{(Eqn. 2)}$$

where $C_{s1} = \dfrac{A_{s1}}{\gamma_s}\left(f_{s1} - \dfrac{0.67}{\gamma_m} f'_c \right)$; $C_{sn} = \dfrac{A_{sn}}{\gamma_s}\left(f_{sn} - \dfrac{0.67}{\gamma_m} f'_c \right)$; $T_{sn} = \dfrac{A_{sn}}{\gamma_s}\left(f_{sn} - \dfrac{0.67}{\gamma_m} f'_c \right)$ and the bar strains and stresses are determined below.

The plastic centroid is at the center of the section and d'' = 1150 mm

$$e' = e + d'' = 1430 + 1150 = 2580 \text{ mm.}$$

4) Using c = 1160 mm (from iteration),

$$a = \beta_1 c = 0.9 \bullet 1160 = 1044 \text{ mm}$$

5) Assuming the extreme fiber strain equals 0.0035 and c= 1160 mm, the steel stresses and strains can be calculated. When the bar strain exceeds the yield strain then, $f_s = f_y$:

$$\varepsilon_{s1} = \left(\frac{c - d'}{c} \right) 0.0035 = 0.00320; \; f_s = \varepsilon_s E \le F_y ; \quad f_{s1} = 460 \text{ MPa}$$

$$\varepsilon_{s2} = \left(\frac{c - s - d}{c} \right) 0.0035 = 0.00181 \qquad f_{s2} = 362.0 \text{ MPa}$$

$$\varepsilon_{s3} = \left(\frac{c - 2s - d'}{c} \right) 0.0035 = 0.00042 \qquad f_{s3} = 84.4 \text{ MPa}$$

$$\varepsilon_{s4} = \left(\frac{d - c - 2s}{d - c} \right) \varepsilon_{s6} = 0.00097 \qquad f_{s4} = 193.2 \text{ MPa}$$

$$\varepsilon_{s5} = \left(\frac{d - c - s}{d - c} \right) \varepsilon_{s6} = 0.00235 \qquad f_{s5} = 460.00 \text{ MPa}$$

$$\varepsilon_{s6} = \left(\frac{d - c}{c} \right) 0.0035 = 0.00374 \qquad f_{s6} = 460.00 \text{ MPa}$$

Substituting in Eqn. 1 and 2 and iterating the value of the neutral axis depth until the two equations are equal give

$$P_{n1} = 8368 \text{ kN}$$
$$P_{n2} = 8368 \text{ kN}$$

$$M_n = P_n e = 8368(1430)/1000 = 11{,}967 \text{ kN-m}$$