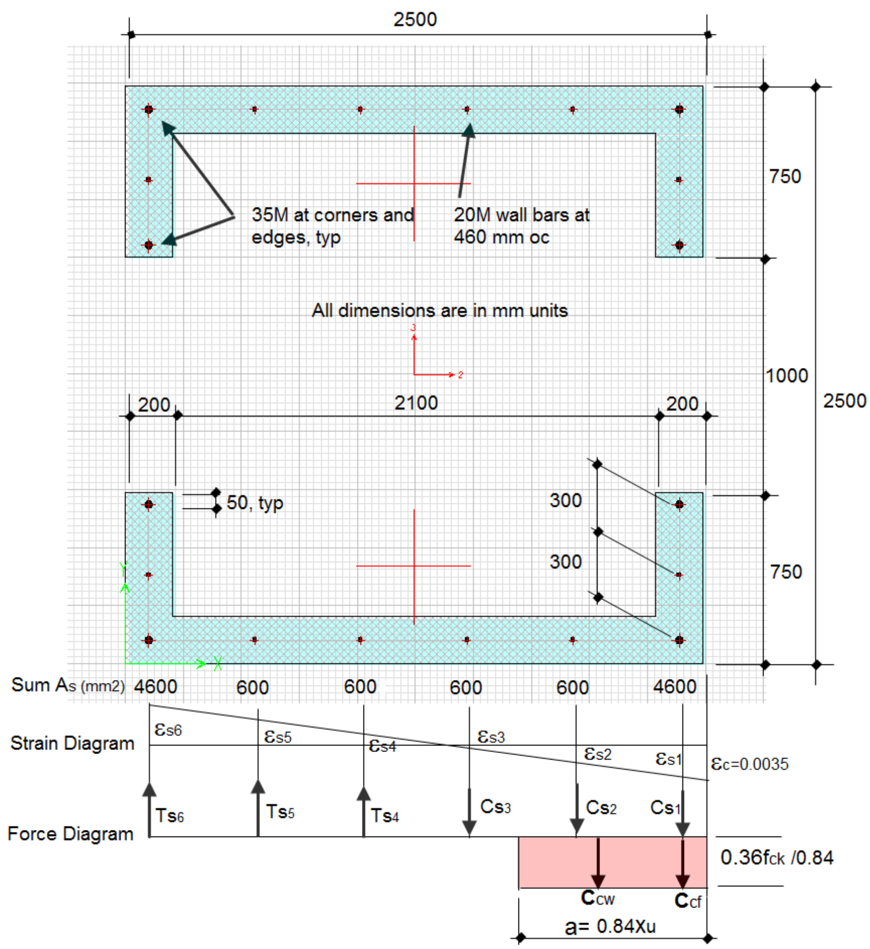
# EXAMPLE Indian IS 456-2000 Wall-002

## FRAME – 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 factored axial load $P_u$= 8426 kN and moments $M_{uy}$= 11670 kN-m. This wall is reinforced as noted below. The design capacity ratio is checked by hand calculations and results are compared with ETABS program.

## 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 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 | 1.003 | 1.00 | 0.30% |

**COMPUTER FILE:** INDIAN IS 456-2000 WALL-002

## CONCLUSION

The ETABS results show a very close match with the independent results.

## HAND CALCULATION

### WALL STRENGTH DETERMINED AS FOLLOWS:

**1)** A value of e = 1385 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 the 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

$$C_{cw} = \frac{0.36}{0.84} f_{ck} \bullet 200 \bullet (a - 200), \text{ where } a = 0.84 x_u$$

$$C_{cf} = \frac{0.36}{0.84} f_{ck} 200(2500\text{-}1000)$$

$$C_s = \frac{A'_{s1}}{\gamma_s}\left(f_{s1} - \frac{0.36}{0.84} f_{ck}\right) + \frac{A'_{s2}}{\gamma_s}\left(f_{s2} - \frac{0.36}{0.84} f_{ck}\right) + \frac{A'_{s3}}{\gamma_s}\left(f_{s3} - \frac{0.36}{0.84} f_{ck}\right)$$

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

$$P_{n1} = \frac{0.36}{0.84} f_{ck} \bullet 200 \bullet (a - 200) + \frac{0.36}{0.84} f_{ck} 200(2500\text{-}1000) + \frac{A'_{s1}}{\gamma_s}\left(f_{s1} - \frac{0.36}{0.84} f_{ck}\right) + \frac{A'_{s2}}{\gamma_s}\left(f_{s2} - \frac{0.36}{0.84} f_{ck}\right)$$
$$+ \frac{A'_{s3}}{\gamma_s}\left(f_{s3} - \frac{0.36}{0.84} f_{ck}\right) - \frac{A_{s4}}{\gamma_s} f_{s4} - \frac{A_{s5}}{\gamma_s} f_{s5} - \frac{A_{s6}}{\gamma_s} f_{s6}$$

(Eqn. 1)

**3) Taking moments about $A_{s6}$:**

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

(Eqn. 2)

Where $C_{s1} = \frac{A'_{s1}}{\gamma_s}\left(f_{s1} - \frac{0.36}{0.84} f_{ck}\right)$; $C_{s2} = \frac{A'_{sn}}{\gamma_s}\left(f_{sn} - \frac{0.36}{0.84} f_{ck}\right)$ ; $T_{s4} = \frac{A_{sn}}{\gamma_s}\left(f_{sn}\right)$ and the bar strains and stresses are determined below.

The plastic centroid is at the center of the section and $d'' = 1150$ mm
$e' = e + d'' = 1138 + 1150 = 2535$ mm.

**4)** Using $c$ = 1298.1 mm (from iteration)

$a = \beta_1 c = 0.84 \bullet 1298.1 = 1090.4$ mm

**5)** Assuming the extreme fiber strain equals 0.0035 and c= 1298.1 mm, the steel stresses and strains can be calculated. When the bar strain exceeds the yield strain then, $f_s = f_y$ :

$\varepsilon_{s1} = \left(\frac{c - d'}{c}\right)0.003$ =0.00323; $f_s = \varepsilon_s E \le F_y$ ; $f_{s1} =$ 460 MPa

$\varepsilon_{s2} = \left(\frac{c - s - d'}{c}\right)0.0035$ =0.00199 $f_{s2} =$ 398.0 MPa

$\varepsilon_{s3} = \left(\frac{c - 2s - d'}{c}\right)0.0035$ =0.00075 $f_{s3} =$ 150.0 MPa

$\varepsilon_{s4} = \left(\frac{d - c - 2s}{d - c}\right)\varepsilon_{s5}$ =0.00049 $f_{s4} =$ 98.1 MPa

$\varepsilon_{s5} = \left(\frac{d - c - s}{d - c}\right)\varepsilon_{s5}$ =0.00173 $f_{s5} =$ 346.1 MPa

$\varepsilon_{s6} = \left(\frac{d - c}{c}\right)0.0035$ =0.00297 $f_{s6} =$ 460.0 MPa

Substitute in Eqn. 1 and 2 and iterating the value of the neutral axis depth until the two equations are equal gives,

$$P_{n1} = 8426 \text{ kN}$$
$$P_{n2} = 8426 \text{ kN}$$

$$M_n = P_n e = 8426(1385)/1000 = 11670 \text{ kN-m}$$