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| | Section<br>Civil & Geotechnical Engineering | | | | Sheet no./rev. 1 | |
| | Calc. by<br>Dr. C. Sachpazis | Date<br>14/09/2014 | Chk'd by | Date | App'd by | Date |

# MASONRY COLUMN DESIGN

## In accordance with EN1996-1-1:2005 incorporating corrigenda February 2006 and July 2009 and the recommended values

**Geometry**

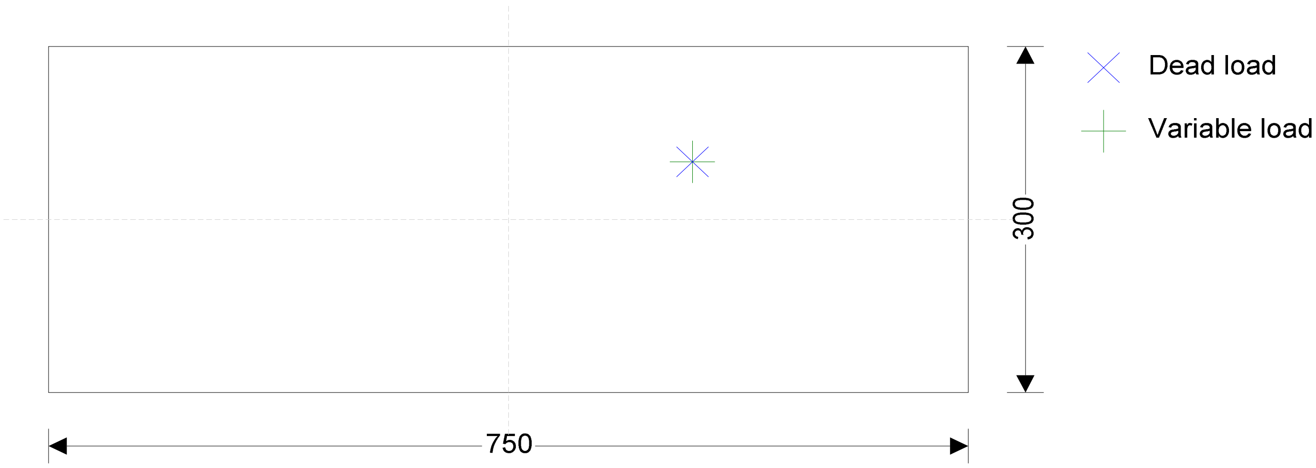
Width of column; $b$ = **750** mm

Thickness of column; $t$ = **300** mm

Height of column; $h$ = **2700** mm

Reduction factor for effective height; $\rho_2$ = **1.0**

Effective height of column (cl 5.5.1.2); $h_{eff} = h \times \rho_2$ = **2700** mm




Plan on column

**Loading**

Vertical dead load; $G_k$ = **100.0** kN

Eccentricity of dead load in x-direction; $e_{Gb}$ = **150** mm

Eccentricity of dead load in y-direction; $e_{Gt}$ = **50** mm

Vertical live load; $Q_k$ = **7.5** kN

Eccentricity of variable load in x-direction; $e_{Qb}$ = **150** mm

Eccentricity of variable load in y-direction; $e_{Qt}$ = **50** mm

Characteristic wind loading; $W_k$ = **0.7** kN/m$^2$

Vertical wind loading; $W_v$ = **0.0** kN

**Masonry details**

Masonry type; **Clay - Group 1**

Mean compressive strength of masonry unit; $f_b$ = **10** N/mm$^2$

Density of masonry; $\gamma$ = **18** kN/m$^3$

Mortar type; **M6 - General purpose mortar**

Compressive strength of masonry mortar; $f_m$ = **6** N/mm$^2$

Compressive strength factor - Table 3.3; K = **0.55**

Characteristic compressive strength of masonry - eq 3.2

$f_k = K \times f_b^{0.7} \times f_m^{0.3}$ = **4.719** N/mm$^2$

Characteristic flexural strength of masonry having a plane of failure parallel to the bed joints - cl 3.6.3

$f_{xk1}$ = **0.1** N/mm$^2$

**Partial factors for material strength**

Category of manufacturing control; **Category II**

Class of execution control; **Class 2**

Partial factor for masonry in compressive flexure; $\gamma_{Mc}$ = **3.00**

**Slenderness ratio**

Slenderness ratio minor axis (cl.5.5.2.1); $\lambda_t = h_{eff} / t$ = **9.00**

Slenderness ratio major axis (cl.5.5.2.1); $\lambda_b = h_{eff} / b$ = **3.60**

Maximum slenderness; $\lambda = \max(\lambda_t, \lambda_b)$ = **9.00**

***PASS - Slenderness ratio is less than 27***

**Load combinations derived from Eq 6.10a and Eq 6.10b for lateral loading (utilisation)**

Combination 1; 1.35 × perm unfav + 1 × perm fav + 1.5 × 0.7 × variable + 1.5 × 0.6 × wind (0.018)

Combination 2; 0.85 × 1.35 × perm unfav + 1 × perm fav + 1.5 × variable + 1.5 × 0.6 × wind (0.018)

Combination 3; 0.85 × 1.35 × perm unfav + 1 × perm fav + 1.5 × 0.7 × variable + 1.5 × wind (0.029)

**The following output relates to combination 3**

**Flexural strength of masonry**

Self weight at middle of column; $S_{wt} = 0.5 \times h \times t \times b \times \gamma$ = **5.468** kN

Design compressive strength of masonry; $f_d = f_k / \gamma_{Mc}$ = **1.573** N/mm$^2$

Design vertical compressive stress; $\sigma_d = \min(\gamma_{fGh} \times (G_k + S_{wt}) / (t \times b), 0.2 \times f_d)$ = **0.315** N/mm$^2$

Design flex masonry strength parallel to bed joints; $f_{xd1} = f_{xk1} / \gamma_{Mc}$ = **0.033** N/mm$^2$

Apparent design flex strength parallel to bed joints; $f_{xd1,app} = f_{xd1} + \sigma_d$ = **0.348** N/mm$^2$

**Column subject to lateral loading about the major axis - Section 6.3**

Elastic section modulus of column; $Z_b = t \times b^2 / 6$ = **28125000** mm$^3$

Moment of resist parallel to bed joints - eq.6.15; $M_{Rd1b} = f_{xd1,app} \times Z_b$ = **9.785** kNm

Bending moment coefficient; $\alpha$ = **0.125**

Design moment in column; $M_{Edb} = \gamma_{fWh} \times \alpha \times W_k \times h^2 \times t$ = **0.287** kNm

***PASS - Moment resistance greater than design moment in column***

**Column subject to lateral loading about the minor axis - Section 6.3**

Elastic section modulus of column; $Z_t = b \times t^2 / 6$ = **11250000** mm$^3$

Moment of resist parallel to bed joints - eq.6.15; $M_{Rd1t} = f_{xd1,app} \times Z_t$ = **3.914** kNm

Bending moment coefficient; $\alpha$ = **0.125**

Design moment in column; $M_{Edt} = \gamma_{fWh} \times \alpha \times W_k \times h^2 \times b$ = **0.718** kNm

***PASS - Moment resistance greater than design moment in column***

**Load combinations derived from Eq 6.10a and Eq 6.10b for vertical loading (utilisation)**

Combination 1; 1.35 × perm unfav + 1 × perm fav + 1.5 × 0.7 × variable + 1.5 × 0.6 × wind (0.748)

Combination 2; 0.85 × 1.35 × perm unfav + 1 × perm fav + 1.5 × variable + 1.5 × 0.6 × wind (0.662)

Combination 3; 0.85 × 1.35 × perm unfav + 1 × perm fav + 1.5 × 0.7 × variable + 1.5 × wind (0.663)

**The following output relates to combination 1**

**Flexural strength of masonry**

Self weight at middle of column; $S_{wt} = 0.5 \times h \times t \times b \times \gamma$ = **5.468** kN

Design compressive strength of masonry; $f_d = f_k / \gamma_{Mc}$ = **1.573** N/mm$^2$

Design vertical compressive stress; $\sigma_d = \min(\gamma_{fGh} \times (G_k + S_{wt}) / (t \times b), 0.2 \times f_d)$ = **0.315** N/mm$^2$

Design flex masonry strength parallel to bed joints; $f_{xd1} = f_{xk1} / \gamma_{Mc}$ = **0.033** N/mm$^2$

Apparent design flex strength parallel to bed joints; $f_{xd1,app} = f_{xd1} + \sigma_d$ = **0.348** N/mm$^2$

**Column subject to lateral loading about the major axis - Section 6.3**

Elastic section modulus of column; $Z_b = t \times b^2 / 6$ = **28125000** mm$^3$

Moment of resist parallel to bed joints - eq.6.15; $M_{Rd1b} = f_{xd1,app} \times Z_b$ = **9.785** kNm

Bending moment coefficient; $\alpha$ = **0.125**

Design moment in column; $M_{Edb} = \gamma_{fWh} \times \alpha \times W_k \times h^2 \times t$ = **0.172** kNm

***PASS - Moment resistance greater than design moment in column***

**Column subject to lateral loading about the minor axis - Section 6.3**

Elastic section modulus of column; $Z_t = b \times t^2 / 6$ = **11250000** mm$^3$

Moment of resist parallel to bed joints - eq.6.15; $M_{Rd1t} = f_{xd1,app} \times Z_t$ = **3.914** kNm

Bending moment coefficient; $\alpha$ = **0.125**

Design moment in column; $M_{Edt} = \gamma_{fWh} \times \alpha \times W_k \times h^2 \times b$ = **0.431** kNm

***PASS - Moment resistance greater than design moment in column***

**Reduction factor for slenderness and eccentricity about the major axis - Section 6.1.2.2**

Design bending moment top or bottom of column; $M_{idb} = abs(\gamma_{fGv} \times G_k \times e_{Gb} + \gamma_{fQv} \times Q_k \times e_{Qb})$ = **21.4** kNm

Design vertical load at top or bottom of column; $N_{idb} = abs(\gamma_{fGv} \times G_k + \gamma_{fQv} \times Q_k)$ = **142.9** kN

Initial eccentricity - cl.5.5.1.1; $e_{init} = h_{eff} / 450$ = **6.0** mm

Conservativley assume moment due to wind load at the top of the column is equal to that at mid height

Eccentricity due to horizontal load; $e_{hb} = M_{Edb} / N_{idb}$ = **1.2** mm

Eccentricity at top or bottom of column - eq.6.5; $e_{ib} = max(M_{idb} / N_{idb} + e_{hb} + e_{init}, 0.05 \times b)$ = **157.2** mm

Reduction factor top or bottom of column - eq.6.4; $\Phi_{ib} = max(1 - 2 \times e_{ib} / b, 0)$ = **0.581**

Ratio of top and middle mnts due to eccentricity; $\alpha_{mdb}$ = **1.0**

Design bending moment at middle of column; $M_{mdb} = \alpha_{mdb} \times abs(\gamma_{fGv} \times G_k \times e_{Gb} + \gamma_{fQv} \times Q_k \times e_{Qb})$ = **21.4** kNm

Design vertical load at middle of column; $N_{mdb} = \gamma_{fGv} \times G_k + \gamma_{fQv} \times Q_k + \gamma_{fGv} \times t \times b \times \gamma \times h / 2$ = **150.3** kN

Eccentricity due to horizontal load; $e_{hmb} = M_{Edb} / N_{mdb}$ = **1.1** mm

Eccentricity middle of column due to loads - eq.6.7; $e_{mb} = M_{mdb} / N_{mdb} + e_{hmb} + e_{init}$ = **149.8** mm

Eccentricity at middle of column due to creep; $e_{kb}$ = **0.0** mm

Eccentricity at middle of column - eq.6.6; $e_{mkb} = max(e_{mb} + e_{kb}, 0.05 \times b)$ = **149.8** mm

From eq.G.2; $A_{1b} = 1 - 2 \times e_{mkb} / b$ = **0.601**

Short term secant modulus of elasticity factor; $K_E$ = **1000**

Modulus of elasticity - cl.3.7.2; $E = K_E \times f_k$ = **4719** N/mm$^2$

Slenderness - eq.G.4; $\lambda_b = (h_{eff} / b) \times \sqrt{(f_k / E)}$ = **0.114**

From eq.G.3; $u_b = (\lambda_b - 0.063) / (0.73 - 1.17 \times e_{mkb} / b)$ = **0.102**

Reduction factor at middle of column - eq.G.1; $\Phi_{mb} = max(A_{1b} \times e_e^{-(u_b \times u_b)/2}, 0)$ = **0.597**

Reduction factor for slenderness and eccentricity; $\Phi_b = min(\Phi_{ib}, \Phi_{mb})$ = **0.581**

**Reduction factor for slenderness and eccentricity about the minor axis - Section 6.1.2.2**

Design bending moment top or bottom of column; $M_{idt} = abs(\gamma_{fGv} \times G_k \times e_{Gt} + \gamma_{fQv} \times Q_k \times e_{Qt})$ = **7.1** kNm

Design vertical load at top or bottom of column; $N_{idt} = abs(\gamma_{fGv} \times G_k + \gamma_{fQv} \times Q_k)$ = **142.9** kN

Initial eccentricity - cl.5.5.1.1; $e_{init} = h_{eff} / 450$ = **6.0** mm

Conservativley assume moment due to wind load at the top of the column is equal to that at mid height

Eccentricity due to horizontal load; $e_{ht} = M_{Edt} / N_{idt}$ = **3.0** mm

Eccentricity at top or bottom of column - eq.6.5; $e_{it} = max(M_{idt} / N_{idt} + e_{ht} + e_{init}, 0.05 \times t)$ = **59.0** mm

Reduction factor top or bottom of column - eq.6.4; $\Phi_{it} = max(1 - 2 \times e_{it} / t, 0)$ = **0.607**

Ratio of top and middle mnts due to eccentricity; $\alpha_{mdt}$ = **1.0**

Design bending moment at middle of column; $M_{mdt} = \alpha_{mdt} \times abs(\gamma_{fGv} \times G_k \times e_{Gt} + \gamma_{fQv} \times Q_k \times e_{Qt})$ = **7.1** kNm

Design vertical load at middle of column; $N_{mdt} = \gamma_{fGv} \times G_k + \gamma_{fQv} \times Q_k + \gamma_{fGv} \times t \times b \times \gamma \times h / 2$ = **150.3** kN

Eccentricity due to horizontal load; $e_{hmt} = M_{Edt} / N_{mdt}$ = **2.9** mm

Eccentricity middle of column due to loads - eq.6.7; $e_{mt} = M_{mdt} / N_{mdt} + e_{hmt} + e_{init}$ = **56.4** mm

Eccentricity at middle of column due to creep; $e_{kt}$ = **0.0** mm

Eccentricity at middle of column - eq.6.6; $e_{mkt} = \max(e_{mt} + e_{kt}, 0.05 \times t)$ = **56.4** mm

From eq.G.2; $A_{1t} = 1 - 2 \times e_{mkt} / t$ = **0.624**

Short term secant modulus of elasticity factor; $K_E$ = **1000**

Modulus of elasticity - cl.3.7.2; $E = K_E \times f_k$ = **4719** N/mm$^2$

Slenderness - eq.G.4; $\lambda_t = (h_{eff} / t) \times \sqrt{(f_k / E)}$ = **0.285**

From eq.G.3; $u_t = (\lambda_t - 0.063) / (0.73 - 1.17 \times e_{mkt} / t)$ = **0.435**

Reduction factor at middle of column - eq.G.1; $\Phi_{mt} = \max(A_{1t} \times e_e^{-(u_t \times u_t)/2}, 0)$ = **0.568**

Reduction factor for slenderness and eccentricity; $\Phi_t = \min(\Phi_{it}, \Phi_{mt})$ = **0.568**

**Columns subjected to mainly vertical loading - Section 6.1.2**

Design value of the vertical load; $N_{Ed} = \max(N_{idb}, N_{mdb}, N_{idt}, N_{mdt})$ = **150.256** kN

Design compressive strength of masonry; $f_d = f_k / \gamma_{Mc}$ = **1.573** N/mm$^2$

Vertical resistance of column - eq.6.2; $N_{Rd} = \min(\Phi_t, \Phi_b) \times t \times b \times f_d$ = **200.915** kN

***PASS - Design vertical resistance exceeds applied design vertical load***