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# CONCRETE MASONRY FENCES

**This data sheet is applicable to any free-standing, cantilever fence or wall for residential or commercial applications.**

## PART B: CONCRETE MASONRY FENCES BUILT ON CONCRETE STRIP FOOTINGS

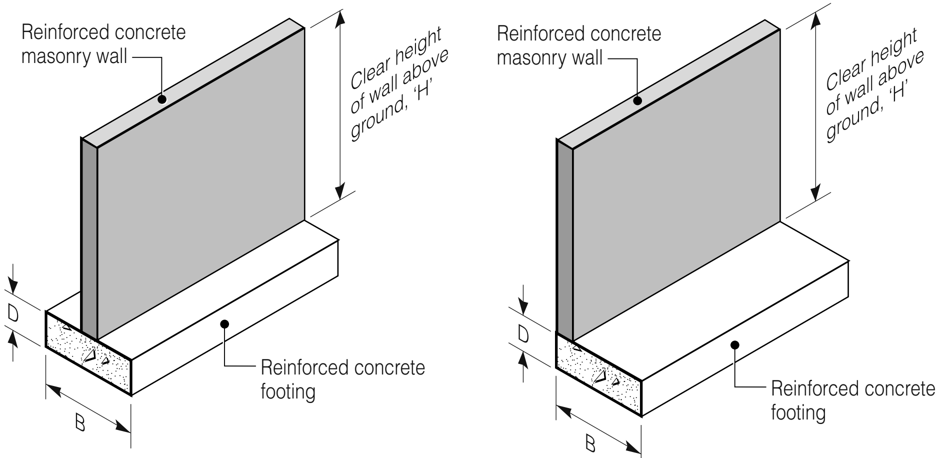
## 1 INTRODUCTION

Part B of this data sheet applies to 190mm wide partially reinforced concrete masonry walls located in the center of the footing or at the edge of the footing depending on the property boundary requirements.

Free standing concrete masonry fences and boundary walls must be designed and constructed to withstand a range of loads, and in particular, wind loads. This manual provides guidance to qualified and experienced structural engineers on the selection of strip footing dimensions, wall steel spacing and masonry details for free standing reinforced concrete masonry fences and walls subject to a range of wind loads.

There are many possible designs for concrete masonry fences and boundary walls. Two common arrangements are shown in **Figures 1** and **2**.

The vertical bars are N16 diameter and their spacing depends on the wall height and wind classification.




**Type "A" Footing** **Type "B" Footing**

**Figure 1** ***Reinforced Concrete Masonry Wall on Reinforced Concrete Strip Footings***

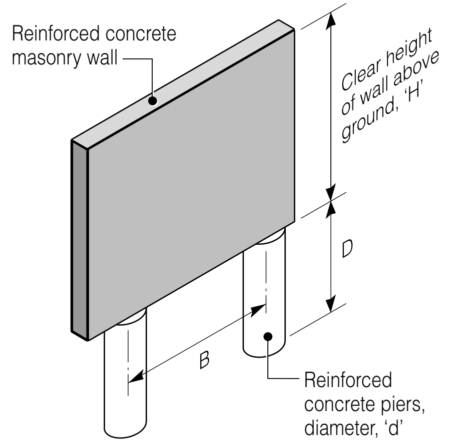



**Figure 2** ***Reinforced Concrete Masonry Wall with Reinforced Concrete Piers***

## 2 WALL CONSTRUCTION

The walls are built from 190 mm partially reinforced hollow concrete block work structurally tied to reinforced concrete strip footings at their base and with a reinforced bond beam at the top.

## 3 WIND LOADS

Wind loads on free-standing concrete masonry fences and boundary walls should be calculated using AS/NZS 1170.2. However, designers often associate these structures with the design of houses to AS 4055.

Strictly speaking, boundary walls and fences are outside the scope of AS 4055, although the nomenclature used therein is useful in classifying the wind exposure of housing sites for wind loads on such structures.

The nomenclature used in this Data Sheet for the "Wind Classification for Free-Standing Fences and Walls" ($N1_f$ to $C4_f$) has been adopted to differentiate it from the corresponding nomenclature, "Wind Classification for Housing" (N1 to C4), which is set out in AS 4055 for houses. Although the resulting ultimate free-stream gust dynamic wind pressures, designated $q_{zu}$, are the same, their derivation is different. The worked example below demonstrates the derivation for a "Wind Classification for Free-Standing Fences and Walls" of$N1_f$.

Refer to Table 1

## 4 WALL RESISTANCE TO OVER TURNING

The resistance to overturning is provided by the combined weight of the wall acting about an assumed point of rotation close to the toe of the footing. The distance from the toe to the point of rotation depends on the bearing capacity of the foundation soil, including its compaction. If the soil is firm with a high bearing capacity, the point of the rotation will be close to the toe. If the soil is soft with a low bearing capacity, the point of rotation will move closer to the centre of the footing. A reasonably conservative assumption is that the point about which the footing rotates is approximately B/3 from the toe of the footing, where B is the total footing width. This conservative approach has been used in this Data Sheet and as such customary bearing failure analysis has not been performed, however, if it is considered bearing failure analysis is necessary eg. low friction angle or poor quality soil) Please refer to typical CMAA manual, MA 51 Reinforced Concrete Masonry Canitilever Retaining Walls for guidance.

**Table 1** *Wind Classification for Free-Standing Fences and Walls*

| Wind Classification | Design gust wind speed at height 'h' $V_{zu}$ (m/s) | Ultimate free-stream gust dynamic wind pressure $q_{zu}$ (kPa) | Ultimate net wind pressure on free-standing wall $p_{nu}$ (kPa) |
|---|---|---|---|
| $N1_f$ | 34 | 0.69 | 0.83 |
| $N2_f$ | 40 | 0.96 | 1.15 |
| $N3_f$ $C1_f$ | 50 | 1.50 | 1.80 |
| $N4_f$ $C2_f$ | 61 | 2.23 | 2.68 |
| $N5_f$ $C3_f$ | 74 | 3.29 | 3.94 |
| $N6_f$ $C4_f$ | 86 | 4.44 | 5.33 |

Note: Design pressure is based on an aerodynamic shape factor, $C_{fig}$, of 1.20

**Table 2** *Strip Footing Width And Wall Reinforcement Spacing*

| Wind Classification | Fence Height 'H' | Strip footing width Type A or B 'W' | Wall reinforcement maximum spacing 'S' (m) | 190mm wall reinforcement size |
|---|---|---|---|---|
| $N1_f$ | 1.80 | 1.1 | 2.0 | N16 |
| | 1.60 | 1.0 | 2.0 | N16 |
| | 1.40 | 0.9 | 2.0 | N16 |
| | 1.20 | 0.8 | 2.0 | N16 |
| | 1.0 | 0.7 | 2.0 | N16 |
| $N2_f$ | 1.80 | 1.3 | 2.0 | N16 |
| | 1.60 | 1.2 | 2.0 | N16 |
| | 1.40 | 1.0 | 2.0 | N16 |
| | 1.20 | 0.9 | 2.0 | N16 |
| | 1.0 | 0.8 | 2.0 | N16 |
| $N3_f$ | 1.8 | 1.7 | 1.2 | N16 |
| | 1.6 | 1.5 | 1.6 | N16 |
| | 1.4 | 1.4 | 2.0 | N16 |
| | 1.2 | 1.2 | 2.0 | N16 |
| | 1.0 | 1.0 | 2.0 | N16 |
| $N4_f$ | 1.8 | 2.1 | 1.2 | N16 |
| | 1.6 | 1.9 | 1.6 | N16 |
| | 1.4 | 1.7 | 2.0 | N16 |
| | 1.2 | 1.5 | 2.0 | N16 |
| | 1.0 | 1.3 | 2.0 | N16 |
| $N5_f$ | 1.8 | 2.7 | 1.0 | N16 |
| | 1.6 | 2.4 | 1.2 | N16 |
| | 1.4 | 2.1 | 1.6 | N16 |
| | 1.2 | 1.9 | 2.0 | N16 |
| | 1.0 | 1.6 | 2.0 | N16 |
| $N6_f$ | 1.8 | 3.1 | 0.8 | N16 |
| | 1.6 | 2.8 | 1.0 | N16 |
| | 1.4 | 2.5 | 1.2 | N16 |
| | 1.2 | 2.5 | 1.6 | N16 |
| | 1.0 | 1.9 | 2.0 | N16 |

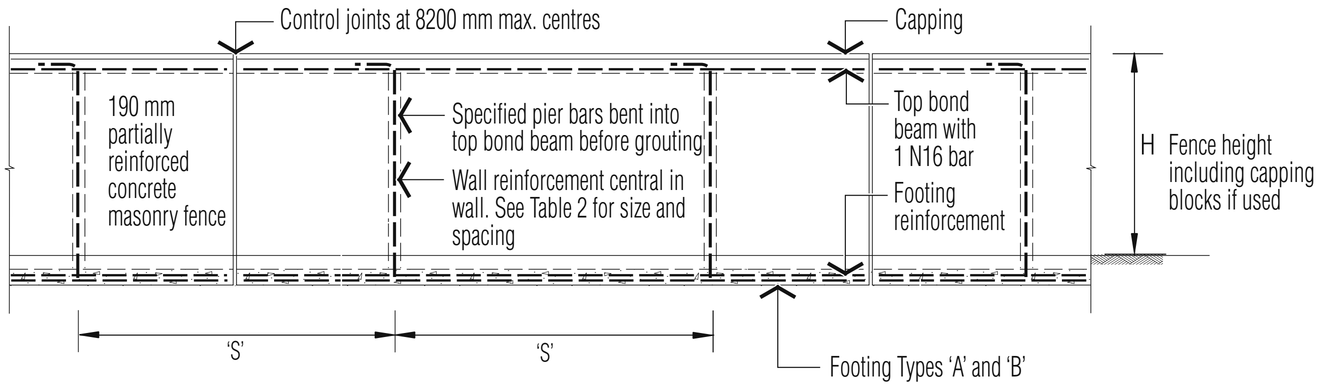
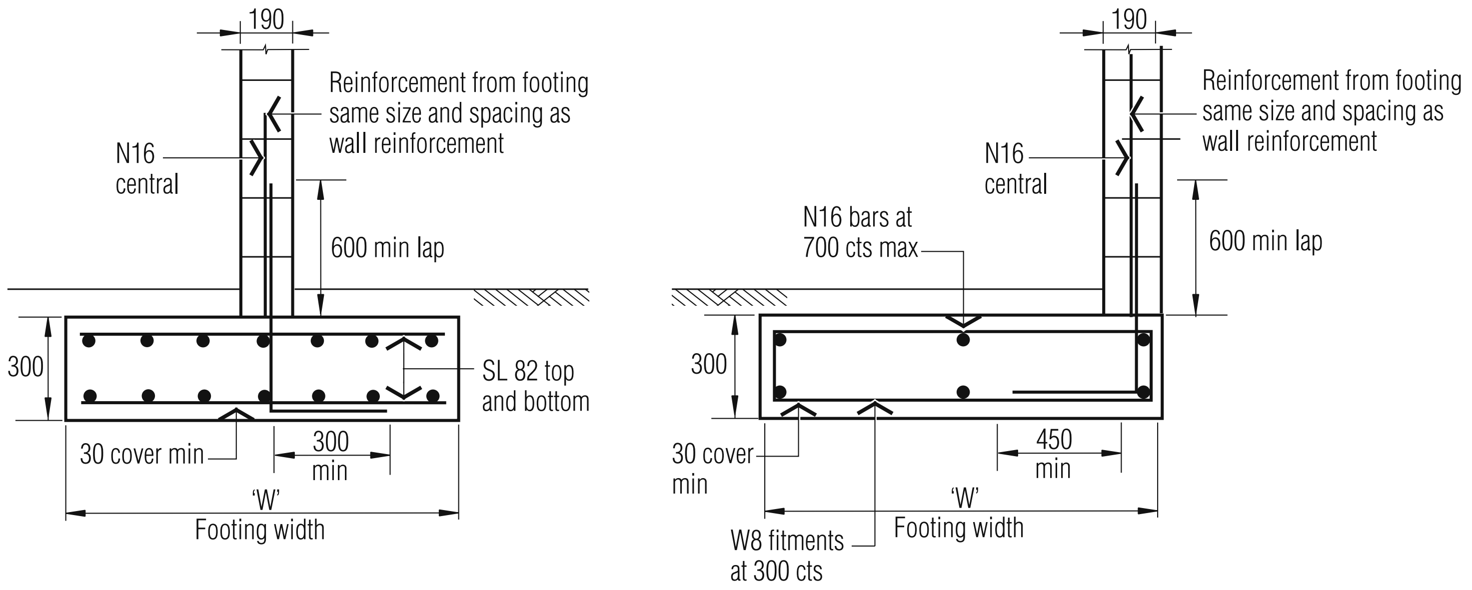



**Figure 3** *Typical Reinforcement Details and Control Joint Locations*




FOOTING TYPE 'A'

FOOTING TYPE 'B'

**Figure 4** *Typical 'A' And 'B' Footing Details*

**DESIGN BRIEF**

Design a 1.8 m high free-standing concrete masonry boundary wall located in a Sydney suburb, on a gentle slope (with 60 metres upwind distance to the crest of a 4.0 m hill) and shielded by houses of 3.0 m roof height and 7.0 m width. The wall is to be partially reinforced with N16 reinforcing steel at S = 2.0 m vertical centres. The footing is to be strip footing Type A. i.e., with the wall stem located in the centre of the footing width B.

**WIND LOAD USING AS/NZS 1170.2:2002**

Region A

Degree of hazard 2

Location Non-cyclonic

Design event for safety 1 in 500

Regional wind speed

$V_R = 45$ m/s *AS/NZS 1170.2 Table 3.1*

Regional wind multiplier

$M_d = 1.0$ *AS/NZS 1170.2 Clause 3.3.1*

Terrain category multiplier

$M_{z,cat} = 0.91$ For h < 3.0 m *AS/NZS 1170.2 Table 4.1(A)*

Number of upwind shielding buildings within a 45° sector of 20 h radius

$n_s = 2$

Average roof height of shielding buildings

$h_s = 3.0$ m

Average spacing of shielding buildings

$l_s = h(10/n_s + 5)$

$= 1.8([10/2] + 5)$

$= 18.0$ m

Average breadth of shielding buildings

$b_s = 7.0$ m

Shielding parameter

$s = l_s/(h_s\, b_s)^{0.5}$ *AS/NZS 1170.2 Clause 4.3.3*

$= 18.0/(3.0 \times 7.0)^{0.5}$

$= 3.93$

Shielding multiplier

$M_s = 0.830$ *Interpolated from AS/NZS 1170.2 Table 4.3*

Heigth of the hill, ridge or escarpment

$H = 4.0$ m

Horizontal distance upwind from the crest of a hill, ridge or excarpment to a level half the height below the crest

$L_u = 60.0$ m

Windward slope

$H/2L_u = 4.0/(2 \times 60.0)$

$= 0.033 \quad < 0.05$

Topography multiplier

$M_t = 1.00$ *AS/NZS 1170.2 Clause 4.4.2*

Ultimate design gust wind speed

$V_{zu} = V_R M_d (M_{z,cat}\, M_s\, M_t)$

$= 45.0 \times 1.0 \times 0.91 \times 0.830 \times 1.0$

$= 34.0$ m/s

Ultimate free stream gust dynamic wind pressure

$q_{zu} = 0.0006\, V_{zu}^2$ *AS/NZS 1170.2 Clause 2.4.1*

$= 0.0006 \times 34.0^2$

$= 0.694$ kPa

*Notes:*

*This pressure is taken to represent a Wind Classification for Free-Standing Fences and Walls of $N1_f$.*

***The corresponding Wind Loads for Housing (on the same site) can be derived using AS 4055***

*Region*

*A AS 4055 Fig 2.1 For Sydney*

*Terrain Category*

*TC 3 AS 4055 Clause 2.3*

*For numerous closely spaces obstructions the size of houses*

*Average slope*

*$\phi_s = 4 : 60$*

*$= 1 : 15$*

*Topography*

*T1 For $\phi_s < 1 : 10$ AS 4055 Clause 2.4, Table 2.3*

*Shielding*

*Partial Shielding (PS) AS 4055 Clause 2.5*

*Classification*

*N1 AS 4055 Clause 2.2, Table 2.2*

*Ultimate design gust wind speed*

*$V_{hu}$ = 34.0 m/s* — *AS 4055 Clause 2.1, Table 2.1*

*Ultimate free stream gust dynamic wind pressure*

$q_{zu} = 0.0006\, V_{zu}^2$

$= 0.0006 \times 34.0^2$

$= 0.694$ kPa

*Note*

*For convenience, design tables will be prepared using the the ultimate design gust wind speed, $V_{hu}$, and the resulting ultimate free-stream gust dynamic wind pressure, $q_{zu}$, determined using AS 4055. This will enable the use of a wind classification nomenclature similar to that used in AS 4055. As indicated above, this may lead to small errors in the determination of pressure, but these are not considered significant.*

**Structure Geometry**

Height of wall

h = 1.8 m

Solid height of wall

c = 1.8 m

Total length of wall

b = 9.0 m

Length/solid height

b/c = 9.0/1.8

= 5.0

Solid height/total height

c/h = 1.8/1.8

= 1.0

Angle of incident wind (Normal = 0)

$\Phi = 0$

Porosity reduction factor

$K_p = 1 - (1 - \delta)^2$ — *AS/NZS 1170.2 D2.1*

$= 1 - (1 - 1)^2$

$= 1.0$

Length of wall used for calculations

B′ = 1.0 m

**Wind loads**

Net pressure coefficient

$C_{pn} = 1.3 + 0.5\,(0.3 + \log_{10}(b/c])\,(0.8 - c/h)$ — *AS/NZS 1170.2 Table D2(A)*

$= 1.3 + 0.5\,(0.3 + \log_{10}(5.0])\,(0.8 - 1.0)$

$= 1.20$

*Note:*

*If b < 2c, $C_{pn}$ will increase from 1.2 to 1.3*

Aerodynamic shape factor

$C_{fig} = C_{pn}\, K_p$ — *AS/NZS 1170.2 D2.1*

$= 1.20 \times 1.0$

$= 1.20$

*Note*

*For convenience, design tables will be prepared using the aerodynamic shape factor, $C_{fig}$, of 1.20*

*This may lead to small errors in the determination of pressure, but these are not considered significant.*

Ultimate net wind pressure on free-standing wall — *AS/NZS 1170.2 Clause 2.4.1*

$p_{nu} = C_{fig}\, q_{zu}$

$= 1.20 \times 0.695$

$= 0.834$ kPa

**LOAD FACTORS AND CAPACITY REDUCTION FACTORS**

Load factor on overturning wind pressure

$G_w = 1.0$ — *AS 1170.0 2002 Clause 4.2.1(b)(iv)*

Load factor on restoring forces

$G_r = 0.8$ — *AS 4678 2002 Clause J3(c)*

**SHEAR FORCE AND BENDING MOMENTS AT THE BASE OF WALL**

Shear force at base support of exposed wall

$V_b = G_w p_{nu} B' h$

$= 1.0 \times 0.834 \times 1.0 \times 1.80$

$= 1.50$ kN/m

Bending moment at base of support of exposed wall

$M_b = 0.5\ G_w\ p_{nu}\ B'\ h^2$

$= 0.5 \times 1.0 \times 0.834 \times 1.0 \times 1.80^2$

$= 1.35$ kN/m

**OVERTURNING ANALYSIS**

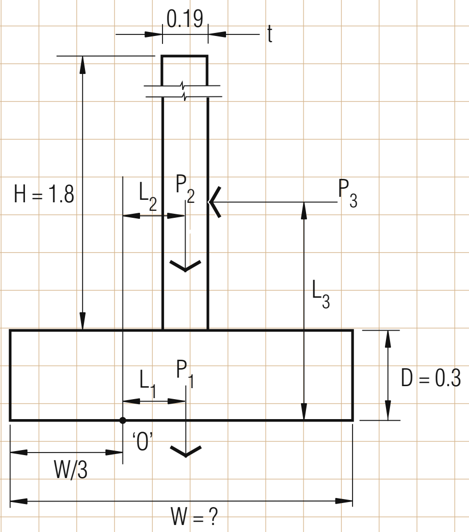
As the horizontal force increases, (i.e., normally from wind) the wall will rotate about its base.

The resistance to this movement is provided by the weight and width of base and wall stem providing restoring moments about a point assumed to be one third along the base from either end (toe) depending on which side of wall the wind is blowing. Note one third base location is conservative and will provide adequate bearing capacity for most average strength soils.

**METHOD TO FIND STRIP FOOTING WIDTH B**

To find the required base width 'W' for any given wind pressure and known 300 mm base depth D. Set up either a quadratic equation or an iterative process to solve for 'W'.

**STRIP FOOTING DETAILS**




$N_{1f}$ wind pressure

$p_{nu} = 0.83$ kN/m$^2$

Density of Partially reinforced wall

$\rho_W = 16.0$ kN/m$^3$

Density of concrete footing

$\gamma_f = 23.5$ kN/m$^3$

$P_1$ factored weight of base

$= G_r \gamma_f D W$

$= 0.8 \times 23.5 \times 0.3 \times W$

$P_1 = 5.64\ W$

$L_1$ lever arm base

$= \frac{W}{2} - \frac{W}{3}$

$L_1 = \frac{W}{6}$

Base restoring moment about point 'O'

$M_B = P_1 \times L_1$

$= 5.64\ W \times W/6$

$= 0.94\ W^2$ kNm/m

$P_2$ factored weight of wall

$= G_r \gamma_w H\ t$

$= 0.8 \times 16.0 \times 1.8 \times 0.19$

$P_2 = 4.38$ kN/m

$L_2$ lever arm of wall weight about point 'o'

$= \frac{W}{2} - \frac{W}{3}$

$L_2 = \frac{W}{6}$

Wall restoring moment about point 'O'

$M_w = P_2 \times L_2$

$= 4.38 \times W/6$

$= 0.73\ W$ kNm/m

$P_3$ factored wind force per meter run of wall

$= G_w\ p_{nu}\ H\ 1.0$

$= 1.0 \times 0.83 \times 1.8 \times 1.0$

$P_3 = 1.49$ kN/m

$L_3$ lever arm of wind force about point 'O'

$= H/2 + D$

$= 1.8/2 + 0.3$

$L_3 = 1.2$ m

Wind force overturning moment about point 'O'

$M_w = P_3 \times L_3$

$= 1.49 \times 1.2$

$= 1.79$ kNm/m

Sum of moments about point 'O' = 0

$M_B + M_w - M_w = 0$

$0.94\ W^2 + 0.73W - 1.79 = 0$

Quadratic equation

$$= \frac{-B \pm \sqrt{B^2 - 4ac}}{2a}$$

$$= \frac{-0.73 \sqrt{0.73^2 - 4 \times 0.94 \times (-1.79)}}{2 \times 0.94}$$

$$= \frac{-0.73 + 2.69}{1.88}$$

∴ Base width W required = 1.04 m

But Say = 1.1 m

Check:

$0.94 \times 1.04^2 + 0.73 \times 1.04 - 1.79 = 0$

OK

*Notes :*

1. *A similar approach can be used to determined footing width W for strip footings with the wall stem located at the edge of the footing. (See Figure 1 Type B footing*

2. *The footing Type B width values shown in Table 2 are the same as footing Type A width values and hence are conservative*

## SPACING OF REINFORCED MASONRY 'POSTS'

- Concrete blocks: Width 190 mm, strength grade 15 MPa
- Blockwork will be built continuous for a length of 2.4 m, with a pier located at the centre and articulation joints at each end.
- Main reinforcement, 1 N16 bar in the centre of the pier

**Masonry Properties**

Masonry unit characteristic unconfined compressive strength

$f'_{uc} = 15.0$ MPa

Units are hollow

Block type factor

$k_m = 1.6$

Equivalent brickwork strength

$f'_{mb} = k_m(f'_{uc})^{0.5}$

$= 1.6(15.0)^{0.5}$

$= 6.20$ MPa

Mortar joint height

$h_j = 10$ mm

Masonry unit height

$h_b = 190$ mm

Ratio of block to joint thickness

$h_b/h_j = 190/10$

$= 19.0$

Block height factor

$k_h = 1.3$

Characteristic masonry strength

$f'_m = k_h\, f'_{mb}$

$= 1.3 \times 6.20$

$= 8.06$ MPa

**Concrete Grout Properties**

*Concrete grout specification:*

*Concrete grout shall comply with AS 3700 and have:*

- *minimum portland cement content of 300 kg/cubic metre;*
- *10 mm maximum aggregate size;*
- *sufficient slump to completely fill the cores; and*
- *minimum compressive cylinder strength of 20 MPa.*

Specified characteristic grout cylinder strength

$f'_c = 20$ MPa

> 12 MPa OK

*AS 3700 Clause 5.6*

Design characteristic grout strength

$f'_{cg} = \min[(1.3 \times f'_{uc}),\ 20.0]$

*AS 3700 Clause 3.5*

$= \min[(1.3 \times 15),\ 20.0]$

$= \min[19.5,\ 20.0]$

$= 19.5$ MPa

**Main Reinforcement Properties**

Main reinforcement yield strength

$f_{sy} = 500$ MPa

Main reinforcement shear strength (dowel action)

$f_{sv} = 17.5$ MPa

Number of main tensile reinforcing bars

$N_t = 1$

Diameter of main tensile reinforcing bars

$D_{dia.t} = 16$ mm

Area of main reinforcment

$A_{st} = N_t(3.1416\, D_{dia.t}{}^2/4)$ (approx)

$= 1 \times 3.1416 \times 16^2/4$

$= 200\ mm^2$

**Dimensions**

The most adverse loading is on the pier near the middle of the wall

Width of pier (along the wall)

$B = 390$ mm

Depth of pier (through the wall)

$D = 190$ mm

Density of reinforced concrete masonry

$\rho_{mas} = 2{,}200$ kg/m$^3$

Modulus of elasticity

$E = 1{,}000\ f'_m$

$= 1{,}000 \times 8.06$

$= 8{,}060$ MPa

Second moment of area of reinforced concrete masonry pier

$I = B\,D^3/12$

$= 390 \times 190^3/12$

$= 222.9 \times 10^6$ mm$^4$

**Main Reinforcement**

Effective depth of reinforcement

For centrally located reinforcement:

$d = D/2$

For reinforcement near one face shell:

$d = D - d_1 + D_{dia.t}/2$

$= 190/2$

$= 95$ mm

Effective width of reinforced section

$b = \min(4D$ or

$2D +$ length to structural end)

$= 4 \times 190$

$= 760$ mm *AS 3700 Clause 8.5*

Shear width of reinforced section

$b_v = 200$ mm

*Note: Only one core is grouted*

Design area of main tensile reinforcement

$A_{sd} = \min[0.29(1.3 f'_m) b\, d / f_{sy},\ \ A_{st}]$

$= \min[(0.29 \times 1.3 \times 8.06 \times 760 \times 95 / 500),\ \ 200]$

$= \min[462, 200]$

$= 200$ mm$^2$

**Fitments**

There are no shear reinforcement fitments required in this type of construction, which incorporates a single vertical reinforcing bar

Fitment yield strength

$f_{sy.f} =$ NA

Fitment area

$A_f =$ NA

Fitment spacing

$s =$ NA

**Reinforced Masonry Capacity**

From Table 2 maximum spacing of the N16 reinforcing steel is 2.0m

*Clause 8.6 (a) AS 3700*

$\phi = 0.75$ *AS 3700 Clause 4.4*

$f'_{vm} = 0.35$ *AS 3700 Clause 8.8*

Shear capacity

$\phi V = \phi(f'_{vm}\, b_w\, d + f_{vs}\, A_{st} + f_{sy.f}\, A_{sv}\, d/s)$

$= 0.75[(0.35 \times 200 \times 95) + (17.5 \times 200) + 0]/1000$

$= 0.75(6.65 + 3.50 + 0)$

$= 7.61$ kN

Bending Moment Capacity

$\phi M = \phi f_{sy}\, A_{sd}\, d[1 - 0.6\, f_{sy}\, A_{sd}\, d/(1.3\, f'_m\, b\, d)]$

$= 0.75 \times 500 \times 200 \times 95[1 - (0.6 \times 500 \times 200)/(1.3 \times 8.06 \times 760 \times 95)]/10^6$

$= 6.56$ kN.m

Check actual theoretical spacing of reinforcing steel

$\phi M = p_{nu}\, S\, H\, H/2$

$S = \dfrac{2\phi M}{p_{nu}\, H^2}$

$= \dfrac{2 \times 6.56}{0.83 \times 1.8^2}$

$= 4.9$ m

$\therefore$ *> 2.0 allowed*

$S = 2.0$ m OK

Height of cantilever wall above the strip footing base

$H_c = 1.800$ m

Limiting deflection

$\Delta_a = H_c/50$

$= 1,800/50$

$= 36$ mm

Load capacity (limited by shear)

$W_{vu} = 1.0\, \phi V/(B'\, H_c)$

$= 1.0 \times 7.61/(1.0 \times 1.800)$

$= 4.22$ kPa

Load capacity (limited by bending moment)

$W_{mu} = 2\, \phi M/B'\, H_c^2$

$= 2 \times 6.56/(1.0 \times 1.800^2)$

$= 4.04$ kPa

Load capacity (limited by deflection)

$W_{\Delta u} = \Delta_a\, E\, I/48\, H_c^4\, B')$

$= [36 \times 8,060 \times 222.9 \times 10^6/(48 \times 1.800^4 \times 1.0)]10^{-9}$

$= 128$ kPa

Load capacity (limited by shear, bending moment or deflection)

$W_{lu} = \min(W_{vu},\ W_{mu},\ W_{\Delta u})$

$= \min(4.22,\ 4.04,\ 128)$

$= 4.04$ kPa

$> 0.834$ kPa OK