

Title: **Structural Calculations**

Project: **Ty Newydd, Brondeg, Heolgerrig,
Merthyr Tydfil, CF48 1TW**

Client: **Paul Withers**

Document No: 001
Project No: 15863
Prepared By: BR
Checked By: CN

Revision: -
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DESIGN STATEMENT

The design has been completed in accordance with British Standards BS6399, BS5628 (Masonry), BS5268 (Timber) & BS 5950 (Steel).

Information for this has been collated from survey/site visit and information provided by the client.

The design is for a reinforced cavity retaining wall (max 2.8m high)

The steel fabricator and contractor must check all site dimensions for the steel beams and posts prior to fabrication.

Ground bearing pressure assumed to be 100kPa, to be confirmed on site.

Contractor to check suitability of existing masonry for padstone and steel bearing.

Existing & proposed blockwork assumed to have minimum 7.3N/mm² compressive strength.

Refer to our sketches 15863 SK01 for references.

All dimensions, weights, member lengths, member tables, and any other relevant design information contained within this package is for analysis, and design purposes only, for submission to building control, and must not be used for pricing or fabrication purposes. All queries are to be directed to the engineer prior to tendering, pricing or fabrication.

CDM Comments:

- All temporary propping/support is to correspond to contractor's specification and details.



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RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.16

Retaining wall details

Stem type	Cantilever
Stem height	$h_{stem} = 3300 \text{ mm}$
Stem thickness	$t_{stem} = 400 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{stem} = 25 \text{ kN/m}^3$
Toe length	$l_{toe} = 1100 \text{ mm}$
Heel length	$l_{heel} = 350 \text{ mm}$
Base thickness	$t_{base} = 300 \text{ mm}$
Base density	$\gamma_{base} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{ret} = 2800 \text{ mm}$
Angle of soil surface	$\beta = 0 \text{ deg}$
Depth of cover	$d_{cover} = 500 \text{ mm}$
Depth of excavation	$d_{exc} = 500 \text{ mm}$

Retained soil properties

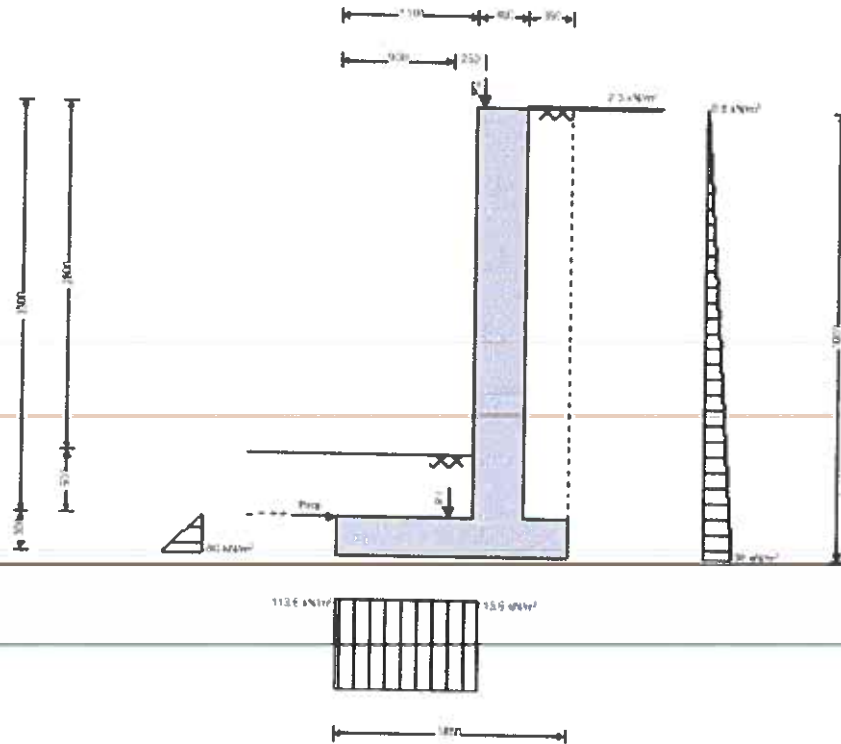
Soil type	Medium dense well graded sand
Moist density	$\gamma_{mr} = 19.5 \text{ kN/m}^3$
Saturated density	$\gamma_{sr} = 21.5 \text{ kN/m}^3$

Base soil properties

Soil type	Medium dense well graded sand
Soil density	$\gamma_b = 18 \text{ kN/m}^3$

Loading details

Variable surcharge load	Surcharge _Q = 1.5 kN/m^2
Vertical line load at 900 mm	$P_{G1} = 6.9 \text{ kN/m}$
	$P_{Q1} = 6.2 \text{ kN/m}$
Vertical line load at 1150 mm	$P_{G2} = 1.2 \text{ kN/m}$
	$P_{Q2} = 1.2 \text{ kN/m}$



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length

Moist soil height

Length of surcharge load

- Distance to vertical component

Effective height of wall

- Distance to horizontal component

Area of wall stem

- Distance to vertical component

Area of wall base

- Distance to vertical component

Area of moist soil

- Distance to vertical component

- Distance to horizontal component

Area of base soil

- Distance to vertical component

- Distance to horizontal component

$$l_{base} = l_{toe} + l_{stem} + l_{heel} = 1850 \text{ mm}$$

$$h_{moist} = h_{soil} = 3300 \text{ mm}$$

$$l_{sur} = l_{heel} = 350 \text{ mm}$$

$$x_{sur_v} = l_{base} - l_{heel} / 2 = 1675 \text{ mm}$$

$$h_{eff} = h_{base} + d_{cover} + h_{rel} = 3600 \text{ mm}$$

$$x_{sur_h} = h_{eff} / 2 = 1800 \text{ mm}$$

$$A_{stem} = h_{stem} \times l_{stem} = 1.32 \text{ m}^2$$

$$x_{stem} = l_{toe} + l_{stem} / 2 = 1300 \text{ mm}$$

$$A_{base} = l_{base} \times t_{base} = 0.555 \text{ m}^2$$

$$x_{base} = l_{base} / 2 = 925 \text{ mm}$$

$$A_{moist} = h_{moist} \times l_{heel} = 1.155 \text{ m}^2$$

$$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} = 1675 \text{ mm}$$

$$x_{moist_h} = h_{eff} / 3 = 1200 \text{ mm}$$

$$A_{pass} = d_{cover} \times l_{toe} = 0.55 \text{ m}^2$$

$$x_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 550 \text{ mm}$$

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 = 267 \text{ mm}$$

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set

A1

Permanent unfavourable action

$\gamma_G = 1.350$

Permanent favourable action

$$\gamma_{Gf} = 1.000$$

Variable unfavourable action

$$\gamma_{Qf} = 1.500$$

Variable favourable action

$$\gamma_{Qr} = 0.000$$

Partial factors for soil parameters – Table A.4 - Combination 1

Soil parameter set

M1

Angle of shearing resistance

$$\gamma_{\psi} = 1.00$$

Effective cohesion

$$\gamma_{c'} = 1.00$$

Weight density

$$\gamma_r = 1.00$$

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_r = 19.5 \text{ kN/m}^3$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_r = 21.5 \text{ kN/m}^3$$

Base soil properties

Design soil density

$$\gamma_b' = \gamma_b / \gamma_r = 18 \text{ kN/m}^3$$

Soil coefficients

Coefficient of friction to back of wall

$$K_{fr} = 0.325$$

Coefficient of friction to front of wall

$$K_{fb} = 0.325$$

Coefficient of friction beneath base

$$K_{bb} = 0.325$$

Active pressure coefficient

$$K_A = 0.371$$

Passive pressure coefficient

$$K_P = 3.473$$

Overturning check
Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 33 \text{ kN/m}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 13.9 \text{ kN/m}$$

Line loads

$$F_{P_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1} + \gamma_{Gf} \times P_{G2} + \gamma_{Qf} \times P_{Q2} = 8.1 \text{ kN/m}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 22.5 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{P_v} + F_{moist_v} = 77.4 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 3 \text{ kN/m}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = 63.3 \text{ kN/m}$$

Base soil

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = -2.8 \text{ kN/m}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = 63.5 \text{ kN/m}$$

Overturning moments on wall

Surcharge load

$$M_{sur_{OT}} = F_{sur_h} \times X_{sur_h} = 5.4 \text{ kNm/m}$$

Moist retained soil

$$M_{moist_{OT}} = F_{moist_h} \times X_{moist_h} = 75.9 \text{ kNm/m}$$

Total

$$M_{total_{OT}} = M_{sur_{OT}} + M_{moist_{OT}} = 81.3 \text{ kNm/m}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = 42.9 \text{ kNm/m}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = 12.8 \text{ kNm/m}$$

Line loads

$$M_{P_R} = (\text{abs}(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1 + (\text{abs}(\gamma_{Gf} \times P_{G2} + \gamma_{Qf} \times P_{Q2})) \times p_2 = 7.5 \text{ kNm/m}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = 37.7 \text{ kNm/m}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{P_R} + M_{moist_R} = 101 \text{ kNm/m}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = 1.242$$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check
Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = 44.6 \text{ kN/m}$$

Wall base

$$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = 18.7 \text{ kN/m}$$

Surcharge load

$$F_{sur_v} = \gamma_Q \times \text{Surcharge}_Q \times l_{heel} = 0.8 \text{ kN/m}$$

Line loads

$$F_{P_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} + \gamma_G \times P_{G2} + \gamma_Q \times P_{Q2} = 21.9 \text{ kN/m}$$

Moist retained soil

$$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = 30.4 \text{ kN/m}$$

Base soil

$$F_{pass_v} = \gamma_G \times A_{pass} \times \gamma_b' = 13.4 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{moist_v} + F_{pass_v} = 129.7 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 3 \text{ kN/m}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = 63.3 \text{ kN/m}$$

Base soil

$$F_{pass_h} = -\gamma_G \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = -20 \text{ kN/m}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{pass_h} = 46.3 \text{ kN/m}$$

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times X_{stem} = 57.9 \text{ kNm/m}$$

Wall base

$$M_{base} = F_{base} \times X_{base} = 17.3 \text{ kNm/m}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = -4.1 \text{ kNm/m}$$

Line loads

$$M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 + (\gamma_G \times P_{G2} + \gamma_Q \times P_{Q2}) \times p_2 = 20.6 \text{ kNm/m}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = -25 \text{ kNm/m}$$

Base soil

$$M_{pass} = F_{pass_v} \times X_{pass_v} = 7.4 \text{ kNm/m}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass} = 74.1 \text{ kNm/m}$$

Check bearing pressure

Propping force

$$F_{prop_base} = F_{total_h} = 46.3 \text{ kN/m}$$

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = 571 \text{ mm}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = -354 \text{ mm}$$

Loaded length of base

$$l_{load} = 2 \times \bar{x} = 1142 \text{ mm}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{load} = 113.6 \text{ kN/m}^2$$

Bearing pressure at heel

$$q_{heel} = 0 \text{ kN/m}^2$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = 1.1$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1
Partial factors on actions - Table A.3 - Combination 2

Partial factor set

A2

Permanent unfavourable action

 $\gamma_G = 1.000$

Permanent favourable action

 $\gamma_{Gf} = 1.000$

Variable unfavourable action

 $\gamma_Q = 1.300$

Variable favourable action

 $\gamma_{Qf} = 0.000$

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set	M2
Angle of shearing resistance	$\gamma_{\psi} = 1.25$
Effective cohesion	$\gamma_c = 1.25$
Weight density	$\gamma_r = 1.00$

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_r = 19.5 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_r = 21.5 \text{ kN/m}^3$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_r = 18 \text{ kN/m}^3$
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Soil coefficients

Coefficient of friction to back of wall	$K_R = 0.325$
Coefficient of friction to front of wall	$K_{Rb} = 0.325$
Coefficient of friction beneath base	$K_{Rbb} = 0.325$
Active pressure coefficient	$K_A = 0.371$
Passive pressure coefficient	$K_P = 3.473$

Overturning check
Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 33 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 13.9 \text{ kN/m}$
Line loads	$F_{P_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1} + \gamma_{Gf} \times P_{G2} + \gamma_{Qf} \times P_{Q2} = 8.1 \text{ kN/m}$
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 22.5 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{P_v} + F_{moist_v} = 77.4 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 2.6 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = 46.9 \text{ kN/m}$
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = -2.8 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = 46.7 \text{ kN/m}$

Overturning moments on wall

Surcharge load	$M_{sur_{OT}} = F_{sur_h} \times X_{sur_h} = 4.7 \text{ kNm/m}$
Moist retained soil	$M_{moist_{OT}} = F_{moist_h} \times X_{moist_h} = 56.3 \text{ kNm/m}$
Total	$M_{total_{OT}} = M_{sur_{OT}} + M_{moist_{OT}} = 60.9 \text{ kNm/m}$

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times X_{stem} = 42.9 \text{ kNm/m}$
Wall base	$M_{base_R} = F_{base} \times X_{base} = 12.8 \text{ kNm/m}$
Line loads	$M_{P_R} = (\text{abs}(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1 + (\text{abs}(\gamma_{Gf} \times P_{G2} + \gamma_{Qf} \times P_{Q2})) \times p_2 = 7.5 \text{ kNm/m}$
Moist retained soil	$M_{moist_R} = F_{moist_v} \times X_{moist_v} = 37.7 \text{ kNm/m}$
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{P_R} + M_{moist_R} = 101 \text{ kNm/m}$

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{total_R} / M_{total_{OT}} = 1.657$ PASS - Maximum restoring moment is greater than overturning moment
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Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = 33 \text{ kN/m}$$

Wall base

$$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = 13.9 \text{ kN/m}$$

Surcharge load

$$F_{sur_v} = \gamma_Q \times \text{Surcharge}_Q \times l_{heel} = 0.7 \text{ kN/m}$$

Line loads

$$F_{P_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} + \gamma_G \times P_{G2} + \gamma_Q \times P_{Q2} = 17.6 \text{ kN/m}$$

Moist retained soil

$$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = 22.5 \text{ kN/m}$$

Base soil

$$F_{pass_v} = \gamma_G \times A_{pass} \times \gamma_b' = 9.9 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{moist_v} + F_{pass_v} = 97.6 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 2.6 \text{ kN/m}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = 46.9 \text{ kN/m}$$

Base soil

$$F_{pass_h} = -\gamma_G \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = -20 \text{ kN/m}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{pass_h} = 29.5 \text{ kN/m}$$

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times X_{stem} = 42.9 \text{ kNm/m}$$

Wall base

$$M_{base} = F_{base} \times X_{base} = 12.8 \text{ kNm/m}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = -3.5 \text{ kNm/m}$$

Line loads

$$M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 + (\gamma_G \times P_{G2} + \gamma_Q \times P_{Q2}) \times p_2 = 16.5 \text{ kNm/m}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = -18.5 \text{ kNm/m}$$

Base soil

$$M_{pass} = F_{pass_v} \times X_{pass_v} = 5.4 \text{ kNm/m}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass} = 55.6 \text{ kNm/m}$$

Check bearing pressure

Propping force

$$F_{prop_base} = F_{total_h} = 29.5 \text{ kN/m}$$

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = 570 \text{ mm}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = -355 \text{ mm}$$

Loaded length of base

$$l_{load} = 2 \times \bar{x} = 1140 \text{ mm}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{load} = 85.6 \text{ kN/m}^2$$

Bearing pressure at heel

$$q_{heel} = 0 \text{ kN/m}^2$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = 1.461$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1 and EN1996-1-1:2005 incorporating Corrigenda dated February 2006 and July 2009 and the UK National Annex

Tedds calculation version 2.9.16

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class

C32/40

Characteristic compressive cylinder strength

$$f_{ck} = 32 \text{ N/mm}^2$$

Characteristic compressive cube strength

$$f_{ck,cube} = 40 \text{ N/mm}^2$$

Mean value of compressive cylinder strength

$$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = 40 \text{ N/mm}^2$$

Mean value of axial tensile strength

$$f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = 3.0 \text{ N/mm}^2$$

5% fractile of axial tensile strength

$$f_{ctk,0.05} = 0.7 \times f_{ctm} = 2.1 \text{ N/mm}^2$$



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Secant modulus of elasticity of concrete

$$E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = 33346 \text{ N/mm}^2$$

Partial factor for concrete - Table 2.1N

$$\gamma_c = 1.50$$

Compressive strength coefficient - cl.3.1.6(1)

$$\alpha_{cc} = 0.85$$

Design compressive concrete strength - exp.3.15

$$f_{cd} = \alpha_{cc} \times f_{ek} / \gamma_c = 18.1 \text{ N/mm}^2$$

Maximum aggregate size

$$h_{agg} = 20 \text{ mm}$$

Ultimate strain - Table 3.1

$$\epsilon_{cu2} = 0.0035$$

Shortening strain - Table 3.1

$$\epsilon_{cu3} = 0.0035$$

Effective compression zone height factor

$$\lambda = 0.80$$

Effective strength factor

$$\eta = 1.00$$

Bending coefficient k_1

$$K_1 = 0.40$$

Bending coefficient k_2

$$K_2 = 1.00 \times (0.6 + 0.0014 / \epsilon_{cu2}) = 1.00$$

Bending coefficient k_3

$$K_3 = 0.40$$

Bending coefficient k_4

$$K_4 = 1.00 \times (0.6 + 0.0014 / \epsilon_{cu2}) = 1.00$$

Reinforcement details

Characteristic yield strength of reinforcement

$$f_{yk} = 500 \text{ N/mm}^2$$

Modulus of elasticity of reinforcement

$$E_s = 200000 \text{ N/mm}^2$$

Partial factor for reinforcing steel - Table 2.1N

$$\gamma_s = 1.15$$

Design yield strength of reinforcement

$$f_{yd} = f_{yk} / \gamma_s = 435 \text{ N/mm}^2$$

Cover to reinforcement

Top face of base

$$C_{bt} = 50 \text{ mm}$$

Bottom face of base

$$C_{bb} = 75 \text{ mm}$$

Masonry details - Section 3.1

Masonry type

Aggregate concrete - Group 1

Normalised mean compressive strength

$$f_b = 10.4 \text{ N/mm}^2$$

Characteristic flexural strength - cl.6.3.4(1)

$$f_{fk} = 0 \text{ N/mm}^2$$

Initial shear strength - Table NA.5

$$f_{vko} = 0.3 \text{ N/mm}^2$$

Mortar details - Section 3.2

Mortar type

Thin layer - M12, prescribed mix

Compressive strength of mortar

$$f_m = 12 \text{ N/mm}^2$$

Ultimate limit states - Table NA.1

Class of execution control

$$1$$

Category of manufacture control

$$1$$

Partial factor for direct or flexural compression

$$\gamma_{Mc} = 2.0$$

Partial factor for flexural tension

$$\gamma_{Mt} = 2.3$$

Partial factor for shear

$$\gamma_{Mv} = 2.0$$

Characteristic strengths of concrete infill - Table 3.2

Concrete infill strength class

$$C28/35$$

Characteristic compressive strength

$$f_{ck, \text{infill}} = 25 \text{ N/mm}^2$$

Characteristic shear strength

$$f_{cvk, \text{infill}} = 0.45 \text{ N/mm}^2$$

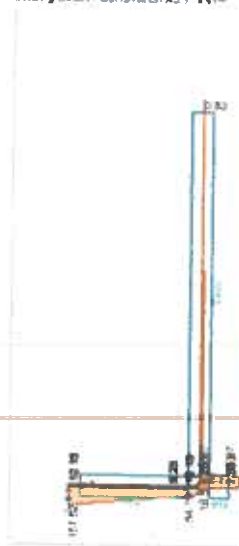
Design shear strength

$$f_{c, \text{d, infl}} = f_{cvk, \text{infill}} / \gamma_{Mv} = 0.225 \text{ N/mm}^2$$

Leading strain: Combination No 1: 1.35

Shear force: Combination No 1: 13.0 kN/m

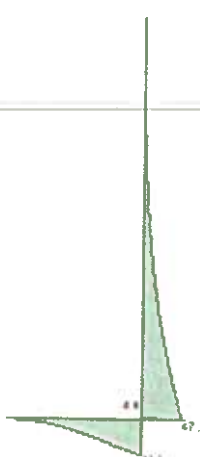
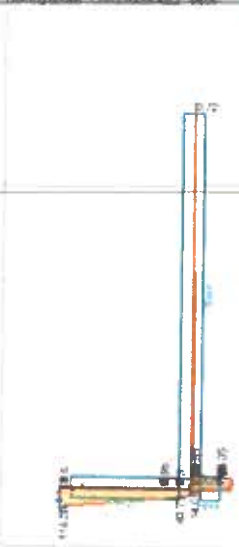
Bending moment: Combination No 1: 13.0 kNm/m



Leading strain: Combination No 2: 1.35

Shear force: Combination No 2: 13.0 kN/m

Bending moment: Combination No 2: 13.0 kNm/m



Check stem design at base of stem

Depth of section

$$t = 400 \text{ mm}$$

Cavity wall details

Front leaf thickness

$$t_f = 100 \text{ mm}$$

Rear leaf thickness

$$t_r = 100 \text{ mm}$$

Masonry characteristics

Compressive strength constants - Table NA.4

$$K = 0.800$$

Characteristic compressive strength - cl.3.6.1.2(1)

$$f_k = K \times f_b^{0.85} \times (1 \text{ N/mm}^2)^{0.15} = 5.856 \text{ N/mm}^2$$

Design compressive strength

$$f_d = \min(f_k, f_{ck, \text{int}}) / \gamma_{Mc} = 2.928 \text{ N/mm}^2$$

Design flexural strength

$$f_{xd} = f_{yk} / \gamma_{Mk} = 0 \text{ N/mm}^2$$

Height of masonry

$$h_{m1} = h_{stem} = 3300 \text{ mm}$$

Compressive axial force combination 0

$$F_x = (\gamma_{G1} \times (\gamma_{stem} \times h_{m1} \times t + P_{G2}) + \gamma_{G2} \times P_{G2}) = 34.9 \text{ kN/m}$$

Moment combination 0

$$M_x = (\gamma_{G1} \times (\gamma_{stem} \times h_{wt} \times t^2 / 2 + P_{G2} \times (p_2 - h_{oe})) + \gamma_{G1} \times P_{G2} \times (p_2 - h_{oe})) = 6.7 \text{ kNm/m}$$

Eccentricity of axial load

$$e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = 20 \text{ mm}$$

Capacity reduction factor - exp.6.4

$$\Phi = 1 - 2 \times e / t = 0.9$$

Design vertical resistance - exp.6.2

$$N_{Rd} = \Phi \times t \times f_d = 1054 \text{ kN/m}$$

Design vertical compressive stress

$$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = 0.087 \text{ N/mm}^2$$

Apparent design flexural strength - exp.6.16

$$f_{xd,app} = f_{xd} + \sigma_d = 0.087 \text{ N/mm}^2$$

Limit of charact. shear strength - exp. 3.1

$$f_{vk,lm} = 0.065 \times f_b = 0.676 \text{ N/mm}^2$$

Characteristic shear strength - exp.3.5

$$f_{vk} = \min(f_{vka} + 0.4 \times \sigma_d, f_{vk,lm}) = 0.335 \text{ N/mm}^2$$

Design shear strength

$$f_{vd} = f_{vk} / \gamma_{Mv} = 0.167 \text{ N/mm}^2$$

Library item: Masonry characteristics output

Reinforced masonry members subjected to bending, bending and axial loading, or axial loading - Section 6.6
Design bending moment combination 1

$$M = 63 \text{ kNm/m}$$

Tension reinforcement provided

$$10 \text{ dia.bars @ } 100 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{sr,prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = 785 \text{ mm}^2/\text{m}$$

Depth to tension reinforcement

$$d = 240 \text{ mm}$$

Minimum area of reinforcement - cl.8.2.3(1)

$$A_{sr,min} = 0.0005 \times d = 120 \text{ mm}^2/\text{m}$$

Lever arm - exp.6.23

$$z = d \times \min(1 - 0.5 \times A_{sr,prov} \times f_{yd} / (d \times f_d), 0.95) = 182 \text{ mm}$$

Moment of resistance - exp.6.22 and exp.6.24a

$$M_{Rd} = \min(A_{sr,prov} \times f_{yd} \times z, 0.4 \times f_d \times d^2) = 62 \text{ kNm/m}$$

$$M / M_{Rd} = 1.016$$

FAIL - Moment of resistance is less than applied design moment

Reinforced masonry members subjected to shear loading - Section 6.7
Design shear force

$$V = 55.929 \text{ kN/m}$$

Design shear resistance - exp.6.40

$$V_{Rd} = \min(f_{vd}, f_{vd,infl}) \times d = 40.19 \text{ kN/m}$$

$$V / V_{Rd} = 1.392$$

Design shear resistance is less than applied design shear force - try concrete shear alone

Determine shear resistance due to concrete infill alone - Clause 6.7.1(3)
Effective depth taking in to account concrete only

$$d = d_{stem} - t_r = 140 \text{ mm}$$

$$C_{Rd,c} = 0.18 / \gamma_c = 0.120$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 2.000$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{sr,prov} / d, 0.02) = 0.006$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck,infl}^{0.5} = 0.495 \text{ N/mm}^2$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck,infl})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = 81 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.690$$

PASS - Design shear resistance exceeds design shear force

Check stem design at 250 mm
Depth of section

$$t = 400 \text{ mm}$$

Cavity wall details
Front leaf thickness

$$t_r = 100 \text{ mm}$$

Rear leaf thickness

$$t_r = 100 \text{ mm}$$

Masonry characteristics
Compressive strength constants - Table NA.4

$$K = 0.800$$

Characteristic compressive strength - cl.3.6.1.2(1)

$$f_k = K \times f_b^{0.85} \times (1 \text{ N/mm}^2)^{0.15} = 5.856 \text{ N/mm}^2$$

Design compressive strength

$$f_d = \min(f_k, f_{ck,infl}) / \gamma_{Mc} = 2.928 \text{ N/mm}^2$$

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Design flexural strength	$f_{xd} = f_{yk} / \gamma_{Mk} = 0 \text{ N/mm}^2$
Height of masonry	$h_{wt} = h_{stem} + 250 \text{ mm} = 3050 \text{ mm}$
Compressive axial force combination 0	$F_x = (\gamma_{Gr} \times (\gamma_{stem} \times h_{wt} \times t + P_{G2}) + \gamma_{Qr} \times P_{Q2}) = 32.4 \text{ kN/m}$
Moment combination 0	$M_x = (\gamma_{Gr} \times (\gamma_{stem} \times h_{wt} \times t^2 / 2 + P_{G2} \times (p_2 - h_{oe})) + \gamma_{Qr} \times P_{Q2} \times (p_2 - h_{oe})) = 6.2 \text{ kNm/m}$
Eccentricity of axial load	$e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = 20 \text{ mm}$
Capacity reduction factor - exp.6.4	$\Phi = 1 - 2 \times e / t = 0.9$
Design vertical resistance - exp.6.2	$N_{Rd} = \Phi \times t \times f_d = 1054 \text{ kN/m}$
Design vertical compressive stress	$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = 0.081 \text{ N/mm}^2$
Apparent design flexural strength - exp.6.16	$f_{xd,app} = f_{xd} + \sigma_d = 0.081 \text{ N/mm}^2$
Limit of charact. shear strength - exp. 3.1	$f_{vk,lm} = 0.065 \times f_b = 0.676 \text{ N/mm}^2$
Characteristic shear strength - exp.3.5	$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lm}) = 0.332 \text{ N/mm}^2$
Design shear strength	$f_{vd} = f_{vk} / \gamma_{Mv} = 0.166 \text{ N/mm}^2$

Library item: Masonry characteristics output

Reinforced masonry members subjected to bending, bending and axial loading, or axial loading - Section 6.6

Design bending moment combination 1	$M = 50.1 \text{ kNm/m}$
Tension reinforcement provided	10 dia.bars @ 100 c/c
Area of tension reinforcement provided	$A_{s1,prov} = \pi \times \phi_{s1}^2 / (4 \times s_{s1}) = 785 \text{ mm}^2/\text{m}$
Depth to tension reinforcement	$d = 240 \text{ mm}$
Minimum area of reinforcement - cl.8.2.3(1)	$A_{s,min} = 0.0005 \times d = 120 \text{ mm}^2/\text{m}$
Lever arm - exp.6.23	$z = d \times \min(1 - 0.5 \times A_{s1,prov} \times f_{yd} / (d \times f_d), 0.95) = 182 \text{ mm}$
Moment of resistance - exp.6.22 and exp.6.24a	$M_{Rd} = \min(A_{s1,prov} \times f_{yd} \times z, 0.4 \times f_d \times d^2) = 62 \text{ kNm/m}$
	$M / M_{Rd} = 0.807$

PASS - Moment of resistance exceeds applied design moment

Reinforced masonry members subjected to shear loading - Section 6.7

Design shear force	$V = 47.969 \text{ kN/m}$
Design shear resistance - exp.6.40	$V_{Rd} = \min(f_{vd}, f_{cvd,infil}) \times d = 39.89 \text{ kN/m}$
	$V / V_{Rd} = 1.203$

Design shear resistance is less than applied design shear force - try concrete shear alone

Determine shear resistance due to concrete infill alone - Clause 6.7.1(3)

Effective depth taking in to account concrete only	$d = d_{stem} - t_r = 140 \text{ mm}$
	$C_{Rd,c} = 0.18 / \gamma_c = 0.120$
	$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 2.000$
Longitudinal reinforcement ratio	$\rho_l = \min(A_{s1,prov} / d, 0.02) = 0.006$
	$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck,infil}^{0.5} = 0.495 \text{ N/mm}^2$
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck,infil})^{1/3}, v_{min}) \times d$
	$V_{Rd,c} = 81 \text{ kN/m}$
	$V / V_{Rd,c} = 0.592$

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem

Minimum area of reinforcement - cl.8.2.3(4)	$A_{s,req} = 0.0005 \times d = 120 \text{ mm}^2/\text{m}$
Transverse reinforcement provided	10 dia.bars @ 200 c/c
Area of transverse reinforcement provided	$A_{s,prov} = \pi \times \phi_{s2}^2 / (4 \times s_{s2}) = 393 \text{ mm}^2/\text{m}$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

 Depth of section $h = 300 \text{ mm}$
Rectangular section in flexure - Section 6.1

 Design bending moment combination 1 $M = 54.9 \text{ kNm/m}$

 Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2 = 220 \text{ mm}$

$$K = M / (d^2 \times f_{ck}) = 0.035$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = 0.207$$

 $K' > K$ - No compression reinforcement is required

 Lever arm $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = 209 \text{ mm}$

 Depth of neutral axis $x = 2.5 \times (d - z) = 28 \text{ mm}$

 Area of tension reinforcement required $A_{bb,req} = M / (f_{yd} \times z) = 604 \text{ mm}^2/\text{m}$

Tension reinforcement provided 10 dia.bars @ 100 c/c

 Area of tension reinforcement provided $A_{bb,prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb}) = 785 \text{ mm}^2/\text{m}$

 Minimum area of reinforcement - exp.9.1N $A_{bb,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 346 \text{ mm}^2/\text{m}$

 Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bb,max} = 0.04 \times h = 12000 \text{ mm}^2/\text{m}$

$$\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = 0.769$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

 Limiting crack width $w_{max} = 0.4 \text{ mm}$

 Variable load factor - EN1990 - Table A1.1 $\psi_2 = 0.6$

 Serviceability bending moment $M_{sb} = 40.8 \text{ kNm/m}$

 Tensile stress in reinforcement $\sigma_s = M_{sb} / (A_{bb,prov} \times z) = 248.3 \text{ N/mm}^2$

Load duration Long term

 Load duration factor $k_1 = 0.4$

 Effective area of concrete in tension $A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$

$$A_{c,eff} = 90833 \text{ mm}^2/\text{m}$$

 Mean value of concrete tensile strength $f_{ct,eff} = f_{ctm} = 3.0 \text{ N/mm}^2$

 Reinforcement ratio $\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = 0.009$

 Modular ratio $\alpha_s = E_s / E_{cm} = 5.998$

 Bond property coefficient $k_1 = 0.8$

 Strain distribution coefficient $k_2 = 0.5$

$$k_3 = 3.4$$

$$k_4 = 0.425$$

 Maximum crack spacing - exp.7.11 $s_{r,max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p,eff} = 452 \text{ mm}$

 Maximum crack width - exp.7.8 $w_k = s_{r,max} \times \max(\sigma_s - k_1 \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_s \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$

$$w_k = 0.336 \text{ mm}$$

$$w_k / w_{max} = 0.841$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

 Design shear force $V = 80.5 \text{ kN/m}$

$$C_{Rd,c} = 0.18 / \gamma_c = 0.120$$

$$k = \min(1 + \sqrt{200 \text{ mm} / d}, 2) = 1.953$$

 Longitudinal reinforcement ratio $\rho_l = \min(A_{bb,prov} / d, 0.02) = 0.004$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ct}^{0.5} = 0.541 \text{ N/mm}^2$$

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Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 N^2/mm^4 \times \rho_1 \times f_{ck})^{1/3}, V_{min}) \times d$$

$$V_{Rd,c} = 118.9 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.677$$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section

$$h = 300 \text{ mm}$$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = 5.9 \text{ kNm/m}$$

Depth to tension reinforcement

$$d = h - C_{bt} - \phi_{bt} / 2 = 245 \text{ mm}$$

$$K = M / (d^2 \times f_{ck}) = 0.003$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = 0.207$$

$K' > K$ - No compression reinforcement is required

Lever arm

$$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = 233 \text{ mm}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = 31 \text{ mm}$$

Area of tension reinforcement required

$$A_{bt,req} = M / (f_{yd} \times z) = 59 \text{ mm}^2/\text{m}$$

Tension reinforcement provided

$$10 \text{ dia. bars @ } 200 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{bt,prov} = n \times \phi_{bt}^2 / (4 \times s_{bt}) = 393 \text{ mm}^2/\text{m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bt,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 385 \text{ mm}^2/\text{m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bt,max} = 0.04 \times h = 12000 \text{ mm}^2/\text{m}$$

$$\max(A_{bt,req}, A_{bt,min}) / A_{bt,prov} = 0.981$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width

$$w_{max} = 0.4 \text{ mm}$$

Variable load factor - EN1990 - Table A1.1

$$\psi_2 = 0.6$$

Serviceability bending moment

$$M_{sls} = 4.4 \text{ kNm/m}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{bt,prov} \times z) = 47.6 \text{ N/mm}^2$$

Load duration

$$\text{Long term}$$

Load duration factor

$$k_t = 0.4$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$$

$$A_{c,eff} = 89792 \text{ mm}^2/\text{m}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = 3.0 \text{ N/mm}^2$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bt,prov} / A_{c,eff} = 0.004$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = 5.998$$

Bond property coefficient

$$k_1 = 0.8$$

Strain distribution coefficient

$$k_2 = 0.5$$

$$k_3 = 3.4$$

$$k_4 = 0.425$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times C_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p,eff} = 559 \text{ mm}$$

Maximum crack width - exp.7.8

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = 0.08 \text{ mm}$$

$$w_k / w_{max} = 0.199$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = 32.7 \text{ kN/m}$$



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Longitudinal reinforcement ratio

$$C_{Rd,c} = 0.18 / \gamma_c = 0.120$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.904$$

$$\rho_l = \min(A_{st,prov} / d, 0.02) = 0.002$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.520 \text{ N/mm}^2$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = 127.4 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.257$$

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

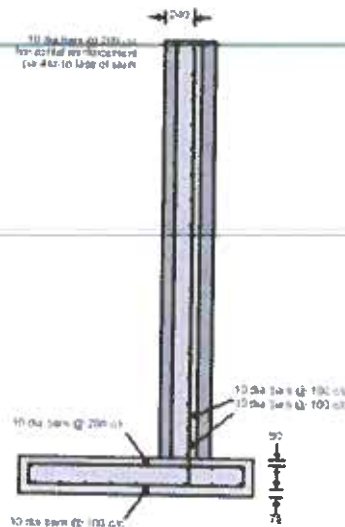
Minimum area of reinforcement - cl.9.3.1.1(2) $A_{bx,req} = 0.2 \times A_{bb,prov} = 157 \text{ mm}^2/\text{m}$

Maximum spacing of reinforcement - cl.9.3.1.1(3) $S_{bx,max} = 450 \text{ mm}$

Transverse reinforcement provided 10 dia.bars @ 200 c/c

Area of transverse reinforcement provided $A_{bx,prov} = \pi \times \phi_{bx}^2 / (4 \times S_{bx}) = 393 \text{ mm}^2/\text{m}$

PASS - Area of reinforcement provided is greater than area of reinforcement required



Reinforcement details