

STRUCTURAL CALCULATIONS

Using
MASTERSERIES POWERPAD

Mipa Paints
Sprinkler Tanks

STRUCTURAL ENGINEERS **R ELLIOTT ASSOCIATES LTD**

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk
Tel: (01590) 683 176 Fax: (01590) 683 533

PROJECT No: 7275

June 2020



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 2 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

INTRODUCTION

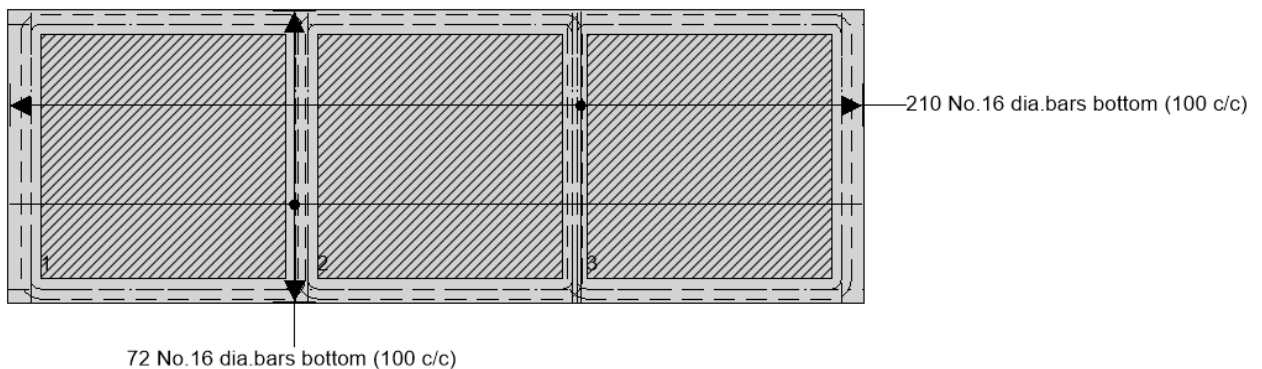
- The **proposed works** include: Foundation design for 3 no water tanks.
- Loadings** have been taken from the table below, unless stated otherwise.
- Codes of Practice used :-**
 - Concrete Design to : BS 8110:Part 1
 - Steel Design to : BS 5950:Part 1

The proposed water tanks, 6.2m in dia. And 5.6m in height are to be utilised within a sprinkler system. It is intended that the tanks will bear onto one foundation sitting 800mm apart from each other. The below calculation outlines that a 300mm tk slab will be required with longitudinal reinforcement (longest length) of H16 @ 100mm c/c and transverse reinforcement (shortest length) of H16 @ 100mm c/c. this will be bottom reinforcement with 40mm cover from the bottom of the slab. Top reinforcement is not required. The foundation should extend past the furthest point of the water tank by 400mm in all directions.

The foundation should be situated onto a heavy duty geotextile onto 200mm well compacted hardcore compacted in 100 mm layers.

The tank with a weight of 100kN will hold 1660kN of water when full. A horizontal loading has been considered acting on the water tanks.

The foundation will be situated onto fill which has provided relatively good CBR values and bearing capacities. However, some settlement of 15 to 20mm should be expected and allowed for when fixing any hose works from the tanks to the sprinkler housing to allow for this movement.



NUMBER OF BARS ARE APPROXIMATE ONLY.



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 3 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

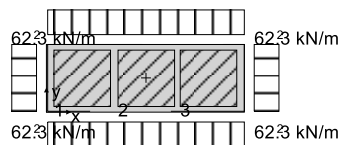
FOUNDATION ANALYSIS (EN1997-1:2004)

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

TEDDS calculation version 3.2.14

Pad foundation details

Length of foundation;	$L_x = 21000 \text{ mm}$
Width of foundation;	$L_y = 7200 \text{ mm}$
Foundation area;	$A = L_x \times L_y = 151.200 \text{ m}^2$
Depth of foundation;	$h = 300 \text{ mm}$
Depth of soil over foundation;	$h_{\text{soil}} = 0 \text{ mm}$
Level of water;	$h_{\text{water}} = 0 \text{ mm}$
Density of water;	$\gamma_{\text{water}} = 9.8 \text{ kN/m}^3$
Density of concrete;	$\gamma_{\text{conc}} = 24.5 \text{ kN/m}^3$



Column no.1 details

Length of column;	$l_{x1} = 6000 \text{ mm}$
Width of column;	$l_{y1} = 6000 \text{ mm}$
position in x-axis;	$x_1 = 3800 \text{ mm}$
position in y-axis;	$y_1 = 3600 \text{ mm}$

Column no.2 details

Length of column;	$l_{x2} = 6000 \text{ mm}$
Width of column;	$l_{y2} = 6000 \text{ mm}$
position in x-axis;	$x_2 = 10600 \text{ mm}$
position in y-axis;	$y_2 = 3600 \text{ mm}$

Column no.3 details

Length of column;	$l_{x3} = 6000 \text{ mm}$
Width of column;	$l_{y3} = 6000 \text{ mm}$
position in x-axis;	$x_3 = 17200 \text{ mm}$
position in y-axis;	$y_3 = 3600 \text{ mm}$

Soil properties

Density of soil;	$\gamma_{\text{soil}} = 18.0 \text{ kN/m}^3$
------------------	--



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 4 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

Characteristic cohesion; $c'_k = 0 \text{ kN/m}^2$
Characteristic effective shear resistance angle; $\phi'_k = 30 \text{ deg}$
Characteristic friction angle; $\delta_k = 20 \text{ deg}$

Foundation loads

Permanent surcharge load; $F_{Gsur} = 2.5 \text{ kN/m}^2$
Variable surcharge load; $F_{Qsur} = 5.0 \text{ kN/m}^2$
Self weight; $F_{swt} = h \times \gamma_{conc} = 7.4 \text{ kN/m}^2$

Column no.1 loads

Permanent load in z; $F_{Gz1} = 100.0 \text{ kN}$
Variable load in y; $F_{Qy1} = 27.0 \text{ kN}$
Variable load in z; $F_{Qz1} = 1660.0 \text{ kN}$
Variable moment in x; $M_{Qx1} = 100.0 \text{ kNm}$
Variable moment in y; $M_{Qy1} = 100.0 \text{ kNm}$

Column no.2 loads

Permanent load in z; $F_{Gz2} = 100.0 \text{ kN}$
Variable load in y; $F_{Qy2} = 27.0 \text{ kN}$
Variable load in z; $F_{Qz2} = 1660.0 \text{ kN}$
Variable moment in x; $M_{Qx2} = 100.0 \text{ kNm}$
Variable moment in y; $M_{Qy2} = 100.0 \text{ kNm}$

Column no.3 loads

Permanent load in z; $F_{Gz3} = 100.0 \text{ kN}$
Variable load in y; $F_{Qy3} = 27.0 \text{ kN}$
Variable load in z; $F_{Qz3} = 1660.0 \text{ kN}$
Variable moment in x; $M_{Qx3} = 100.0 \text{ kNm}$
Variable moment in y; $M_{Qy3} = 100.0 \text{ kNm}$

Partial factors on actions - Combination1

Permanent unfavourable action - Table A.3; $\gamma_G = 1.35$
Permanent favourable action - Table A.3; $\gamma_{Gf} = 1.00$
Variable unfavourable action - Table A.3; $\gamma_Q = 1.50$
Variable favourable action - Table A.3; $\gamma_{Qf} = 0.00$

Partial factors for soil parameters - Combination1

Angle of shearing resistance - Table A.4; $\gamma_{\phi'} = 1.00$
Effective cohesion - Table A.4; $\gamma_{c'} = 1.00$
Weight density - Table A.4; $\gamma_\gamma = 1.00$

Partial factors for spread foundations - Combination1

Bearing - Table A.5; $\gamma_{R,v} = 1.00$
Sliding - Table A.5; $\gamma_{R,h} = 1.00$

Bearing resistance (Section 6.5.2)

Forces on foundation

Force in y-axis; $F_{dy} = \gamma_Q \times (F_{Qy1} + F_{Qy2} + F_{Qy3}) = 121.5 \text{ kN}$
Force in z-axis; $F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{Gsur}) + F_{Gz1} + F_{Gz2} + F_{Gz3}) + \gamma_Q \times (A \times F_{Qsur} + F_{Qz1} + F_{Qz2} + F_{Qz3}) = 11019.6 \text{ kN}$



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 5 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

Moments on foundation

Moment in x-axis;

$$M_{dx} = \gamma_G \times (A \times (F_{swt} + F_{Gsur}) \times L_x / 2 + F_{Gz1} \times X_1 + F_{Gz2} \times X_2 + F_{Gz3} \times X_3) + \gamma_Q \times (A \times F_{Qsur} \times L_x / 2 + F_{Qz1} \times X_1 + F_{Qz2} \times X_2 + F_{Qz3} \times X_3) + \gamma_Q \times (M_{Qx1} + M_{Qx2} + M_{Qx3}) = \mathbf{116418.1 \text{ kNm}}$$

Moment in y-axis;

$$M_{dy} = \gamma_G \times (A \times (F_{swt} + F_{Gsur}) \times L_y / 2 + F_{Gz1} \times y_1 + F_{Gz2} \times y_2 + F_{Gz3} \times y_3) + \gamma_Q \times (A \times F_{Qsur} \times L_y / 2 + F_{Qz1} \times y_1 + F_{Qz2} \times y_2 + F_{Qz3} \times y_3) + \gamma_Q \times (M_{Qy1} + M_{Qy2} + M_{Qy3}) + (\gamma_Q \times (F_{Qy1} + F_{Qy2} + F_{Qy3})) \times h = \mathbf{40156.9 \text{ kNm}}$$

Eccentricity of base reaction

Eccentricity of base reaction in x-axis;

$$e_x = M_{dx} / F_{dz} - L_x / 2 = \mathbf{65 \text{ mm}}$$

Eccentricity of base reaction in y-axis;

$$e_y = M_{dy} / F_{dz} - L_y / 2 = \mathbf{44 \text{ mm}}$$

Effective area of base

Effective length;

$$L'_x = L_x - 2 \times e_x = \mathbf{20871 \text{ mm}}$$

Effective width;

$$L'_y = L_y - 2 \times e_y = \mathbf{7112 \text{ mm}}$$

Effective area;

$$A' = L'_x \times L'_y = \mathbf{148.426 \text{ m}^2}$$

Pad base pressure

Design base pressure;

$$f_{dz} = F_{dz} / A' = \mathbf{74.2 \text{ kN/m}^2}$$

Ultimate bearing capacity under drained conditions (Annex D.4)

Design angle of shearing resistance;

$$\phi'_d = \text{atan}(\tan(\phi'_k) / \gamma_\phi) = \mathbf{30.000 \text{ deg}}$$

Design effective cohesion;

$$c'_d = c'_k / \gamma_c = \mathbf{0.000 \text{ kN/m}^2}$$

Effective overburden pressure;

$$q = (h + h_{soil}) \times \gamma_{soil} - h_{water} \times \gamma_{water} = \mathbf{5.400 \text{ kN/m}^2}$$

Design effective overburden pressure;

$$q' = q / \gamma_\gamma = \mathbf{5.400 \text{ kN/m}^2}$$

Bearing resistance factors;

$$N_q = \text{Exp}(\pi \times \tan(\phi'_d)) \times (\tan(45 \text{ deg} + \phi'_d / 2))^2 = \mathbf{18.401}$$

$$N_c = (N_q - 1) \times \cot(\phi'_d) = \mathbf{30.140}$$

$$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_d) = \mathbf{20.093}$$

Foundation shape factors;

$$s_q = 1 + (L'_y / L'_x) \times \sin(\phi'_d) = \mathbf{1.170}$$

$$s_\gamma = 1 - 0.3 \times (L'_y / L'_x) = \mathbf{0.898}$$

$$s_c = (s_q \times N_q - 1) / (N_q - 1) = \mathbf{1.180}$$

Load inclination factors;

$$H = \text{abs}(F_{dy}) = \mathbf{121.5 \text{ kN}}$$

$$m_y = [2 + (L'_y / L'_x)] / [1 + (L'_y / L'_x)] = \mathbf{1.746}$$

$$m_x = [2 + (L'_x / L'_y)] / [1 + (L'_x / L'_y)] = \mathbf{1.254}$$

$$m = m_y = \mathbf{1.746}$$

$$i_q = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^m = \mathbf{0.981}$$

$$i_\gamma = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^{m+1} = \mathbf{0.970}$$

$$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_d)) = \mathbf{0.980}$$

Ultimate bearing capacity;

$$n_f = c'_d \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{soil} \times L'_y \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{1234.0 \text{ kN/m}^2}$$

PASS - Ultimate bearing capacity exceeds design base pressure

Sliding resistance (Section 6.5.3)

Forces on foundation

Force in y-axis;

$$F_{dy} = \gamma_Q \times (F_{Qy1} + F_{Qy2} + F_{Qy3}) = \mathbf{121.5 \text{ kN}}$$

Force in z-axis;

$$F_{dz} = \gamma_{Gf} \times (A \times (F_{swt} + F_{Gsur}) + F_{Gz1} + F_{Gz2} + F_{Gz3}) + \gamma_{Qf} \times (A \times F_{Qsur} + F_{Qz1} + F_{Qz2} + F_{Qz3}) = \mathbf{1789.3 \text{ kN}}$$



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 6 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

Sliding resistance verification (Section 6.5.3)

Horizontal force on foundation;

$$H = \text{abs}(F_{dy}) = 121.5 \text{ kN}$$

Sliding resistance (exp.6.3a);

$$R_{H,d} = F_{dz} \times \tan(\delta_k / \gamma_\phi) = 651.3 \text{ kN}$$

$$H / R_{H,d} = 0.187$$

PASS - Foundation is not subject to failure by sliding

Partial factors on actions - Combination2

Permanent unfavourable action - Table A.3;

$$\gamma_G = 1.00$$

Permanent favourable action - Table A.3;

$$\gamma_{Gf} = 1.00$$

Variable unfavourable action - Table A.3;

$$\gamma_Q = 1.30$$

Variable favourable action - Table A.3;

$$\gamma_{Qf} = 0.00$$

Partial factors for soil parameters - Combination2

Angle of shearing resistance - Table A.4;

$$\gamma_\phi = 1.25$$

Effective cohesion - Table A.4;

$$\gamma_{c'} = 1.25$$

Weight density - Table A.4;

$$\gamma_\gamma = 1.00$$

Partial factors for spread foundations - Combination2

Bearing - Table A.5;

$$\gamma_{R,v} = 1.00$$

Sliding - Table A.5;

$$\gamma_{R,h} = 1.00$$

Bearing resistance (Section 6.5.2)

Forces on foundation

Force in y-axis;

$$F_{dy} = \gamma_Q \times (F_{Qy1} + F_{Qy2} + F_{Qy3}) = 105.3 \text{ kN}$$

Force in z-axis;

$$F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{Gsur}) + F_{Gz1} + F_{Gz2} + F_{Gz3}) + \gamma_Q \times (A \times F_{Qsur} + F_{Qz1} + F_{Qz2} + F_{Qz3}) = 9246.1 \text{ kN}$$

Moments on foundation

Moment in x-axis;

$$M_{dx} = \gamma_G \times (A \times (F_{swt} + F_{Gsur}) \times L_x / 2 + F_{Gz1} \times x_1 + F_{Gz2} \times x_2 + F_{Gz3} \times x_3) + \gamma_Q \times (A \times F_{Qsur} \times L_x / 2 + F_{Qz1} \times x_1 + F_{Qz2} \times x_2 + F_{Qz3} \times x_3) + \gamma_Q \times (M_{Qx1} + M_{Qx2} + M_{Qx3}) = 97700.1 \text{ kNm}$$

Moment in y-axis;

$$M_{dy} = \gamma_G \times (A \times (F_{swt} + F_{Gsur}) \times L_y / 2 + F_{Gz1} \times y_1 + F_{Gz2} \times y_2 + F_{Gz3} \times y_3) + \gamma_Q \times (A \times F_{Qsur} \times L_y / 2 + F_{Qz1} \times y_1 + F_{Qz2} \times y_2 + F_{Qz3} \times y_3) + \gamma_Q \times (M_{Qy1} + M_{Qy2} + M_{Qy3}) + (\gamma_Q \times (F_{Qy1} + F_{Qy2} + F_{Qy3})) \times h = 33707.6 \text{ kNm}$$

Eccentricity of base reaction

Eccentricity of base reaction in x-axis;

$$e_x = M_{dx} / F_{dz} - L_x / 2 = 67 \text{ mm}$$

Eccentricity of base reaction in y-axis;

$$e_y = M_{dy} / F_{dz} - L_y / 2 = 46 \text{ mm}$$

Effective area of base

Effective length;

$$L'_x = L_x - 2 \times e_x = 20867 \text{ mm}$$

Effective width;

$$L'_y = L_y - 2 \times e_y = 7109 \text{ mm}$$

Effective area;

$$A' = L'_x \times L'_y = 148.338 \text{ m}^2$$

Pad base pressure

Design base pressure;

$$f_{dz} = F_{dz} / A' = 62.3 \text{ kN/m}^2$$

Ultimate bearing capacity under drained conditions (Annex D.4)

Design angle of shearing resistance;

$$\phi'_d = \text{atan}(\tan(\phi'_k) / \gamma_\phi) = 24.791 \text{ deg}$$

Design effective cohesion;

$$c'_d = c'_k / \gamma_{c'} = 0.000 \text{ kN/m}^2$$

Effective overburden pressure;

$$q = (h + h_{soil}) \times \gamma_{soil} - h_{water} \times \gamma_{water} = 5.400 \text{ kN/m}^2$$

Design effective overburden pressure;

$$q' = q / \gamma_\gamma = 5.400 \text{ kN/m}^2$$



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 7 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

Bearing resistance factors;

$$N_q = \text{Exp}(\pi \times \tan(\phi'_d)) \times (\tan(45 \text{ deg} + \phi'_d / 2))^2 = \mathbf{10.431}$$

$$N_c = (N_q - 1) \times \cot(\phi'_d) = \mathbf{20.418}$$

$$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_d) = \mathbf{8.712}$$

Foundation shape factors;

$$s_q = 1 + (L'_y / L'_x) \times \sin(\phi'_d) = \mathbf{1.143}$$

$$s_\gamma = 1 - 0.3 \times (L'_y / L'_x) = \mathbf{0.898}$$

$$s_c = (s_q \times N_q - 1) / (N_q - 1) = \mathbf{1.158}$$

Load inclination factors;

$$H = \text{abs}(F_{dy}) = \mathbf{105.3 \text{ kN}}$$

$$m_y = [2 + (L'_y / L'_x)] / [1 + (L'_y / L'_x)] = \mathbf{1.746}$$

$$m_x = [2 + (L'_x / L'_y)] / [1 + (L'_x / L'_y)] = \mathbf{1.254}$$

$$m = m_y = \mathbf{1.746}$$

$$i_q = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^m = \mathbf{0.980}$$

$$i_\gamma = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^{m+1} = \mathbf{0.969}$$

$$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_d)) = \mathbf{0.978}$$

Ultimate bearing capacity;

$$n_f = c'_d \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{\text{soil}} \times L'_y \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{548.0 \text{ kN/m}^2}$$

PASS - Ultimate bearing capacity exceeds design base pressure

Sliding resistance (Section 6.5.3)

Forces on foundation

Force in y-axis;

$$F_{dy} = \gamma_Q \times (F_{Qy1} + F_{Qy2} + F_{Qy3}) = \mathbf{105.3 \text{ kN}}$$

Force in z-axis;

$$F_{dz} = \gamma_{Gf} \times (A \times (F_{swt} + F_{Gsur}) + F_{Gz1} + F_{Gz2} + F_{Gz3}) + \gamma_{Qf} \times (A \times F_{Qsur} + F_{Qz1} + F_{Qz2} + F_{Qz3}) = \mathbf{1789.3 \text{ kN}}$$

Sliding resistance verification (Section 6.5.3)

Horizontal force on foundation;

$$H = \text{abs}(F_{dy}) = \mathbf{105.3 \text{ kN}}$$

Sliding resistance (exp.6.3a);

$$R_{H,d} = F_{dz} \times \tan(\delta_k / \gamma_\phi) = \mathbf{513.1 \text{ kN}}$$

$$H / R_{H,d} = \mathbf{0.205}$$

PASS - Foundation is not subject to failure by sliding

FOUNDATION DESIGN (EN1992-1-1:2004)

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

TEDDS calculation version 3.2.14

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

Concrete strength class;

C30/37

Characteristic compressive cylinder strength;

$$f_{ck} = \mathbf{30 \text{ N/mm}^2}$$

Characteristic compressive cube strength;

$$f_{ck,cube} = \mathbf{37 \text{ N/mm}^2}$$

Mean value of compressive cylinder strength;

$$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = \mathbf{38 \text{ N/mm}^2}$$

Mean value of axial tensile strength;

$$f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = \mathbf{2.9 \text{ N/mm}^2}$$

5% fractile of axial tensile strength;

$$f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.0 \text{ N/mm}^2}$$

Secant modulus of elasticity of concrete;

$$E_{cm} = 22 \text{ kN/mm}^2 \times [f_{cm} / 10 \text{ N/mm}^2]^{0.3} = \mathbf{32837 \text{ N/mm}^2}$$

Partial factor for concrete (Table 2.1N);

$$\gamma_C = \mathbf{1.50}$$

Compressive strength coefficient (cl.3.1.6(1));

$$\alpha_{cc} = \mathbf{0.85}$$

Design compressive concrete strength (exp.3.15);

$$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{17.0 \text{ N/mm}^2}$$

Tens.strength coeff.for plain concrete (cl.12.3.1(1));

$$\alpha_{ct,pl} = \mathbf{0.80}$$

Des.tens.strength for plain concrete (exp.12.1);

$$f_{ctd,pl} = \alpha_{ct,pl} \times f_{ctk,0.05} / \gamma_C = \mathbf{1.1 \text{ N/mm}^2}$$

Maximum aggregate size;

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



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

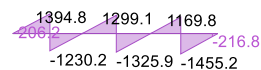
Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 8 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

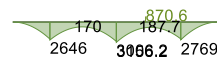
Reinforcement details

Characteristic yield strength of reinforcement; $f_{yk} = 500 \text{ N/mm}^2$
Modulus of elasticity of reinforcement; $E_s = 210000 \text{ N/mm}^2$
Partial factor for reinforcing steel (Table 2.1N); $\gamma_s = 1.15$
Design yield strength of reinforcement; $f_{yd} = f_{yk} / \gamma_s = 435 \text{ N/mm}^2$
Nominal cover to reinforcement; $C_{nom} = 40 \text{ mm}$

Shear diagram, x axis (kN)



Moment diagram, x axis (kNm)



Rectangular section in flexure (Section 6.1)

Design bending moment; $M_{Ed.x.max} = 870.6 \text{ kNm}$
Depth to tension reinforcement; $d = h - C_{nom} - \phi_{x.bot} / 2 = 252 \text{ mm}$
 $K = M_{Ed.x.max} / (L_y \times d^2 \times f_{ck}) = 0.063$
 $K' = 0.207$

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

Lever arm; $z = \min((d / 2) \times [1 + (1 - 3.53 \times K)^{0.5}], 0.95 \times d) = 237 \text{ mm}$
Depth of neutral axis; $x = 2.5 \times (d - z) = 38 \text{ mm}$
Area of tension reinforcement required; $A_{sx.bot.req} = M_{Ed.x.max} / (f_{yd} \times z) = 8449 \text{ mm}^2$
Tension reinforcement provided; 72 No.16 dia.bars bottom (100 c/c)
Area of tension reinforcement provided; $A_{sx.bot.prov} = 14476 \text{ mm}^2$
Minimum area of reinforcement (exp.9.1N); $A_{s.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times L_y \times d = 2733 \text{ mm}^2$
Maximum area of reinforcement (cl.9.2.1.1(3)); $A_{s.max} = 0.04 \times L_y \times d = 72576 \text{ mm}^2$

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

Crack control (Section 7.3)

Limiting crack width; $w_{max} = 0.3 \text{ mm}$
Variable load factor (EN1990 – Table A1.1); $\psi_2 = 0.3$
Serviceability bending moment; $M_{sls.x.max} = 198.9 \text{ kNm}$
Tensile stress in reinforcement; $\sigma_s = M_{sls.x.max} / (A_{sx.bot.prov} \times z) = 58 \text{ N/mm}^2$
Load duration factor; $k_t = 0.4$
Effective depth of concrete in tension; $h_{c.ef} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = 87 \text{ mm}$
Effective area of concrete in tension; $A_{c.ef} = h_{c.ef} \times L_y = 629951 \text{ mm}^2$
Mean value of concrete tensile strength; $f_{ct,eff} = f_{ctm} = 2.9 \text{ N/mm}^2$
Reinforcement ratio; $\rho_{p,eff} = A_{sx.bot.prov} / A_{c.ef} = 0.023$
Modular ratio; $\alpha_e = E_s / E_{cm} = 6.395$
Bond property coefficient; $k_1 = 0.8$
Strain distribution coefficient; $k_2 = 0.5$



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 9 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

Maximum crack spacing (exp.7.11);

Maximum crack width (exp.7.8);

$$k_3 = 3.4$$

$$k_4 = 0.425$$

$$s_{r,max} = k_3 \times c_{nom} + k_1 \times k_2 \times k_4 \times \phi_{x,bot} / \rho_{p,eff} = 254 \text{ mm}$$

$$w_k = s_{r,max} \times \max([\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff})] / E_s, 0.6 \times \sigma_s / E_s) = 0.042 \text{ mm}$$

PASS - Maximum crack width is less than limiting crack width Rectangular section in shear (Section 6.2)

Design shear force;

$$\text{abs}(V_{Ed,x,min}) = 216.8 \text{ kN}$$

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

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.921$$

Longitudinal reinforcement ratio;

$$\rho_l = \min(A_{sx,bot,prov} / (L_y \times d), 0.02) = 0.009$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.510 \text{ N/mm}^2$$

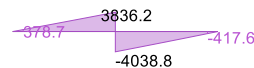
Design shear resistance (exp.6.2a & 6.2b);

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

$$V_{Rd,c} = 1153.6 \text{ kN}$$

PASS - Design shear resistance exceeds design shear force

Shear diagram, y axis (kN)



Moment diagram, y axis (kNm)



Rectangular section in flexure (Section 6.1)

Design bending moment;

$$M_{Ed,y,max} = 206.4 \text{ kNm}$$

Depth to tension reinforcement;

$$d = h - c_{nom} - \phi_{x,bot} - \phi_{y,bot} / 2 = 236 \text{ mm}$$

$$K = M_{Ed,y,max} / (L_x \times d^2 \times f_{ck}) = 0.006$$

$$K' = 0.207$$

K' > K - No compression reinforcement is required

Lever arm;

$$z = \min((d / 2) \times [1 + (1 - 3.53 \times K)^{0.5}], 0.95 \times d) = 224 \text{ mm}$$

Depth of neutral axis;

$$x = 2.5 \times (d - z) = 30 \text{ mm}$$

Area of tension reinforcement required;

$$A_{sy,bot,req} = M_{Ed,y,max} / (f_{yd} \times z) = 2118 \text{ mm}^2$$

Tension reinforcement provided;

210 No.16 dia.bars bottom (100 c/c)

Area of tension reinforcement provided;

$$A_{sy,bot,prov} = 42223 \text{ mm}^2$$

Minimum area of reinforcement (exp.9.1N);

$$A_{s,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times L_x \times d = 7465 \text{ mm}^2$$

Maximum area of reinforcement (cl.9.2.1.1(3));

$$A_{s,max} = 0.04 \times L_x \times d = 198240 \text{ mm}^2$$

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

Crack control (Section 7.3)

Limiting crack width;

$$w_{max} = 0.3 \text{ mm}$$

Variable load factor (EN1990 – Table A1.1);

$$\psi_2 = 0.3$$

Serviceability bending moment;

$$M_{sls,y,max} = 46.8 \text{ kNm}$$

Tensile stress in reinforcement;

$$\sigma_s = M_{sls,y,max} / (A_{sy,bot,prov} \times z) = 4.9 \text{ N/mm}^2$$

Load duration factor;

$$k_t = 0.4$$



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 10 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

Effective depth of concrete in tension;

$$h_{c,ef} = \min(2.5 \times (h - d), (h - x) / 3, h / 2) = \mathbf{90 \text{ mm}}$$

Effective area of concrete in tension;

$$A_{c,eff} = h_{c,ef} \times L_x = \mathbf{1893500 \text{ mm}^2}$$

Mean value of concrete tensile strength;

$$f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$$

Reinforcement ratio;

$$\rho_{p,eff} = A_{sy,bot,prov} / A_{c,eff} = \mathbf{0.022}$$

Modular ratio;

$$\alpha_e = E_s / E_{cm} = \mathbf{6.395}$$

Bond property coefficient;

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient;

$$k_2 = \mathbf{0.5}$$

$$k_3 = \mathbf{3.4}$$

$$k_4 = \mathbf{0.425}$$

Maximum crack spacing (exp.7.11);

$$s_{r,max} = k_3 \times (c_{nom} + \phi_{x,bot}) + k_1 \times k_2 \times k_4 \times \phi_{y,bot} / \rho_{p,eff} = \mathbf{312 \text{ mm}}$$

Maximum crack width (exp.7.8);

$$w_k = s_{r,max} \times \max([\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff})] / E_s, 0.6 \times \sigma_s / E_s) = \mathbf{0.004 \text{ mm}}$$

PASS - Maximum crack width is less than limiting crack width Rectangular section in shear (Section 6.2)

Design shear force;

$$\text{abs}(V_{Ed,y,min}) = \mathbf{417.6 \text{ kN}}$$

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

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.921}$$

Longitudinal reinforcement ratio;

$$\rho_l = \min(A_{sy,bot,prov} / (L_x \times d), 0.02) = \mathbf{0.009}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.510 \text{ N/mm}^2}$$

Design shear resistance (exp.6.2a & 6.2b);

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

$$V_{Rd,c} = \mathbf{3364.5 \text{ kN}}$$

PASS - Design shear resistance exceeds design shear force

Punching shear (Section 6.4)

Strength reduction factor (exp.6.6N);

$$v = 0.6 \times [1 - f_{ck} / 250 \text{ N/mm}^2] = \mathbf{0.528}$$

Average depth to reinforcement;

$$d = \mathbf{244 \text{ mm}}$$

Maximum punching shear resistance (cl.6.4.5(3));

$$V_{Rd,max} = 0.5 \times v \times f_{cd} = \mathbf{4.488 \text{ N/mm}^2}$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.905}$$

Longitudinal reinforcement ratio (cl.6.4.4(1));

$$\rho_{lx} = A_{sx,bot,prov} / (L_y \times d) = \mathbf{0.008}$$

$$\rho_{ly} = A_{sy,bot,prov} / (L_x \times d) = \mathbf{0.008}$$

$$\rho_l = \min(\sqrt{\rho_{lx} \times \rho_{ly}}, 0.02) = \mathbf{0.008}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.504 \text{ N/mm}^2}$$

Design punching shear resistance (exp.6.47);
N/mm²

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) = \mathbf{0.666}$$

Design punching shear resistance at 1d (exp. 6.50); $v_{Rd,c1} = (2 \times d / d) \times v_{Rd,c} = \mathbf{1.332 \text{ N/mm}^2}$

Column No.1 - Punching shear perimeter at column face

Punching shear perimeter;

$$u_0 = \mathbf{24000 \text{ mm}}$$

Area within punching shear perimeter;

$$A_0 = \mathbf{36.000 \text{ m}^2}$$

Maximum punching shear force;

$$V_{Ed,max} = \mathbf{701 \text{ kN}}$$

Punching shear stress factor (fig 6.21N);

$$\beta = \mathbf{1.500}$$

Maximum punching shear stress (exp 6.38);

$$V_{Ed,max} = \beta \times V_{Ed,max} / (u_0 \times d) = \mathbf{0.180 \text{ N/mm}^2}$$

PASS - Maximum punching shear resistance exceeds maximum punching shear stress

Column No.1 - Punching shear perimeter at 1d from column face

Punching shear perimeter;

$$u_1 = \mathbf{25533 \text{ mm}}$$

Area within punching shear perimeter;

$$A_1 = \mathbf{42.043 \text{ m}^2}$$

Design punching shear force;

$$V_{Ed,1} = \mathbf{378 \text{ kN}}$$

Punching shear stress factor (fig 6.21N);

$$\beta = \mathbf{1.500}$$

Design punching shear stress (exp 6.38);

$$V_{Ed,1} = \beta \times V_{Ed,1} / (u_1 \times d) = \mathbf{0.091 \text{ N/mm}^2}$$



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 11 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

PASS - Design punching shear resistance exceeds increased design punching shear stress

Column No.1 - Punching shear perimeter at 2d from column face

Punching shear perimeter; $u_2 = 27066$ mm
Area within punching shear perimeter; $A_2 = 48.460$ m²
Design punching shear force; $V_{Ed,2} = 35$ kN
Punching shear stress factor (fig 6.21N); $\beta = 1.500$
Design punching shear stress (exp 6.38); $V_{Ed,2} = \beta \times V_{Ed,2} / (u_2 \times d) = 0.008$ N/mm²

PASS - Design punching shear resistance exceeds design punching shear stress

Column No.2 - Punching shear perimeter at column face

Punching shear perimeter; $u_0 = 24000$ mm
Area within punching shear perimeter; $A_0 = 36.000$ m²
Maximum punching shear force; $V_{Ed,max} = 701$ kN
Punching shear stress factor (fig 6.21N); $\beta = 1.500$
Maximum punching shear stress (exp 6.38); $V_{Ed,max} = \beta \times V_{Ed,max} / (u_0 \times d) = 0.180$ N/mm²

PASS - Maximum punching shear resistance exceeds maximum punching shear stress

Column No.2 - Punching shear perimeter at 1d from column face

Punching shear perimeter; $u_1 = 25533$ mm
Area within punching shear perimeter; $A_1 = 42.043$ m²
Design punching shear force; $V_{Ed,1} = 378$ kN
Punching shear stress factor (fig 6.21N); $\beta = 1.500$
Design punching shear stress (exp 6.38); $V_{Ed,1} = \beta \times V_{Ed,1} / (u_1 \times d) = 0.091$ N/mm²

PASS - Design punching shear resistance exceeds increased design punching shear stress

Column No.2 - Punching shear perimeter at 2d from column face

Punching shear perimeter; $u_2 = 27066$ mm
Area within punching shear perimeter; $A_2 = 48.460$ m²
Design punching shear force; $V_{Ed,2} = 35$ kN
Punching shear stress factor (fig 6.21N); $\beta = 1.500$
Design punching shear stress (exp 6.38); $V_{Ed,2} = \beta \times V_{Ed,2} / (u_2 \times d) = 0.008$ N/mm²

PASS - Design punching shear resistance exceeds design punching shear stress

Column No.3 - Punching shear perimeter at column face

Punching shear perimeter; $u_0 = 24000$ mm
Area within punching shear perimeter; $A_0 = 36.000$ m²
Maximum punching shear force; $V_{Ed,max} = 701$ kN
Punching shear stress factor (fig 6.21N); $\beta = 1.500$
Maximum punching shear stress (exp 6.38); $V_{Ed,max} = \beta \times V_{Ed,max} / (u_0 \times d) = 0.180$ N/mm²

PASS - Maximum punching shear resistance exceeds maximum punching shear stress

Column No.3 - Punching shear perimeter at 1d from column face

Punching shear perimeter; $u_1 = 25533$ mm
Area within punching shear perimeter; $A_1 = 42.043$ m²
Design punching shear force; $V_{Ed,1} = 378$ kN
Punching shear stress factor (fig 6.21N); $\beta = 1.500$
Design punching shear stress (exp 6.38); $V_{Ed,1} = \beta \times V_{Ed,1} / (u_1 \times d) = 0.091$ N/mm²

PASS - Design punching shear resistance exceeds increased design punching shear stress

Column No.3 - Punching shear perimeter at 2d from column face

Punching shear perimeter; $u_2 = 27066$ mm



R Elliott Associates Ltd

Dennett House, Brighton Road, Sway
Lymington, Hampshire SO41 6EB
E-mail: info@rea-ltd.co.uk

Tel: (01590) 683 176

Fax: (01590) 683 533

Job ref : 7275
Sheet : Sheet Ref / 12 -
Made By : PF
Date : 11 Jun 2020/ Version 2015.04
Checked :
Approved :

Area within punching shear perimeter;

$$A_2 = 48.460 \text{ m}^2$$

Design punching shear force;

$$V_{Ed,2} = 35 \text{ kN}$$

Punching shear stress factor (fig 6.21N);

$$\beta = 1.500$$

Design punching shear stress (exp 6.38);

$$v_{Ed,2} = \beta \times V_{Ed,2} / (u_2 \times d) = 0.008 \text{ N/mm}^2$$

PASS - Design punching shear resistance exceeds design punching shear stress