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Land at the Rear of
54 Tonacliffe Rd.
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Structural Design For Garden Retaining Wall

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Project:	54 Tonacliffe Rd	23-23033	

Subject:	Introduction	Sheet	2	Of	20

Issue	1	Date	2	Date	3	Date	4	Date	5	Date
Made/ Revised by	DG	05.23								
Checked by										
Approved -										

INTRODUCTION

The following document is associated with the construction work to take place at the above mentioned address and contains design calculations for structural elements, as well as approximate schematic arrangements of those elements.

DEFINITIONS

The "Engineer" is STRUCTURAL DESIGN & DRAUGHTING
The "Client" is the individual or organisation that has instructed the engineer to carry out structural engineering consultancy work.
The "Architect" is the individual or organisation that has provided the information upon which these calculations are based.
The "Builder" is the contractor who has been engaged to undertake the construction work to which this document relates.

IMPORTANT GUIDANCE ON THE USE OF THIS DOCUMENT
(TO BE READ BY ALL PARTIES)

This document is intended to be accompanied by all relevant architects' and engineer's drawings, and all relevant documentation should be considered prior to commencement of the work. Engineer's drawings relating to this document will be explicitly outlined herein.

This document should be reviewed in its entirety (along with any other relevant documentation) by the builder, architect (if applicable) and client, prior to commencement of the work.
Any layouts, instructions or recommendations should be considered. Any deviations from the proposals outlined herein are to be approved by the Engineer prior to the work being undertaken. Any deviations from the proposals made without the Engineer's consent are beyond the scope of this document and the Engineer cannot be held liable for any adverse consequences of such deviations.
The calculations within this document have been carried out in good faith based on the data provided by the client and/or builder/architect.

Where applicable extracts of the information provided will be included within this document for reference. It is the responsibility of the architect (where applicable) or client to notify the engineer when changes are made to the information. This will enable the design to be reviewed and, where necessary, changes made.

Approval of these calculations and drawings by the Local Authority Building Control or similar approved body should be obtained prior to any ordering of material or fabrication. No liability is accepted for any changes that may be required as a result of work having commenced prior to such an approval.

Where information about the existing arrangements of buildings is not available (e.g. floor / roof span orientations or load-bearing wall arrangements) the Engineer will use their judgement to make assumptions. These (generally conservative) assumptions will be clearly outlined within the document, and should be confirmed by a suitably qualified individual on site. The engineer is then to be notified of any discrepancies prior to commencement of the work as design changes may be necessary.

IF IN DOUBT: ASK!!

It should be noted that until the existing structure has been exposed it is not always possible to foresee what the existing structural arrangement will be. This may include floor and roof span directions, construction materials and existing beam locations among other aspects. It is therefore advised to remove finishes from areas being modified as early as possible to avoid any delays on site that the untimely discovery of such (previously unknown) information can lead to.

In addition, it is advised to carry out some form of ground investigation as early as possible to avoid any unexpected below ground construction requirements which may cause delays on site e.g. piled foundations, raft foundations etc.
Wherever there is any uncertainty we will make every effort to highlight where this lies, however suitable project planning / management by the contractor / client are essential to the smooth execution of any construction project.

CONSTRUCTION NOTES

GENERAL NOTES

- **Any SPAN / HEIGHT DIMENSIONS shown in this document are for CALCULATION PURPOSES ONLY and are not to be used as a final dimension for the fabrication / machining of structural elements.**
- **All dimensions are to be checked on site by the builder / contractor / fabricator prior to commencement of fabrication / machining / construction.**

Any discrepancies between the information outlined herein and the dimensions on site are to be reported to the engineer.

- **Temporary works are the sole responsibility of the builder / contractor. Temporary works method statements are to be provided to the Engineer by the builder / contractor prior to commencement of the work.**
- **All parties are assumed to be aware of their responsibilities under the Construction Design and Management (CDM) Regulations 2015.**

If you are unsure of this please contact the Engineer.

- **STRUCTURAL DESIGN & DRAUGHTING take no responsibility for any elements outside of the scope of these calculations. For structural elements not covered by this document it is assumed that a design is being prepared / provided by others, if additional calculations / drawings / specifications are required then please contact STRUCTURAL DESIGN & DRAUGHTING and we can provide a fee for their design.**
- **All structural work has to be carried out by a competent builder in accordance with the requirements of The Building Regulations Part A and the recommendations set out in BS8103 Parts 1-3.**
- **This document is to be read in conjunction with the architectural drawings / details, and any discrepancies reported to the engineer immediately. Final steel levels and dimensions are to be confirmed by the architectural consultant.**
- **If STRUCTURAL DESIGN & DRAUGHTING are not contracted to visit site we take no responsibility for the quality of construction nor its compliance with this document. It is the contractor's responsibility to ensure that all works comply with the drawings, notes and assumptions made within these calculations.**
- **The client / contractor should be aware of beam, frame and column deflections and their impact on existing or adjacent elements, for example beam deflection on bi-fold doors. Typical beam deflections will be span/250 total (Dead+Live) for beams and height/300 (Wind) for columns.**

The following calculations provide anticipated deflections within the relevant sections.

- **The client should be aware that where beams are installed within existing masonry structures it is likely that minor cracking will occur within the masonry above due to the load redistribution. It is recommended that the contractor allows to make suitable repairs within their contract.**
- **All proprietary (i.e. off-the-shelf) items specified within this document are to be installed in strict accordance with the manufacturer's recommendations. This includes, but is not limited to restraint straps, lintels, chemical / resin anchors and fixing brackets.**
- **For structural elements not considered within the scope of this document it is assumed that a suitable specification is to be made by others. If additional calculations, specifications or drawings are required then please contact STRUCTURAL DESIGN & DRAUGHTING and we can provide a fee for their design.**
- **At locations where beam bearing information is provided on the layout this will be in a position where loadbearing masonry (with foundations / support) has been assumed. It should be confirmed by a suitably qualified individual that these walls are load-bearing, and the masonry is to be inspected for suitability prior to commencement of the work.**

DESIGN PHILOSOPHY

All structural members are designed to be capable of withstanding applied loads during construction, operation and maintenance of the building without any distress, failure, loss of function, damage or durability problems. They are to support the most onerous combinations of dead, imposed and (where applicable) wind loads tending to produce either maximum ultimate stresses or deflection.

STABILITY STATEMENT

For this project the stability is to be provided by the following structural systems or a combination thereof: Global Lateral Stability: moment-transmitting frames / masonry piers or shear walls with dead load restoring moment / floors or ceilings to provide diaphragm (boarded & strapped where critical)
Wall Panel Local Lateral Stability: steel or timber posts / masonry piers or walls / floors, ceilings or rafters (boarded & strapped where critical) / timber stud walls.
Vertical Loads: masonry walls, piers or columns with padstones for concentrated loads where necessary / steel posts / strip footings / pad foundations
Internal walls are to be removed. If required sway frames will be introduced

DESIGN PHILOSOPHY

The calculations shall be read in conjunction with drawings 23-23033 - 001

GROUND BEARING PRESSURES

150kN/m^2

Notes:

British Standards and Codes of Practice

BS 648	Schedule of Weights of Building Material
BS 6399	Loading for Buildings
BS EN 1993	Structural Use of Steelwork
BS EN 1995	Structural Use of Unreinforced Masonry

Design has been carried out in accordance with accepted international practice and utilising the above standards and industry best practice.

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 2.9.19

Retaining wall details

Stem type;	Cantilever
Stem height;	h_{stem} = **3200** mm
Stem thickness;	t_{stem} = **400** mm
Angle to rear face of stem;	α = **90** deg
Stem density;	γ_{stem} = **25** kN/m^3
Toe length;	l_{toe} = **1200** mm
Heel length;	l_{heel} = **500** mm
Base thickness;	t_{base} = **350** mm
Base density;	γ_{base} = **25** kN/m^3
Height of retained soil;	**h_{ret} =** 2600 **mm**
Angle of soil surface;	**β =** 10 **deg**
Depth of cover;	**d_{cover} =** 600 **mm**
Depth of excavation;	d_{exc} = **200** mm

Retained soil properties

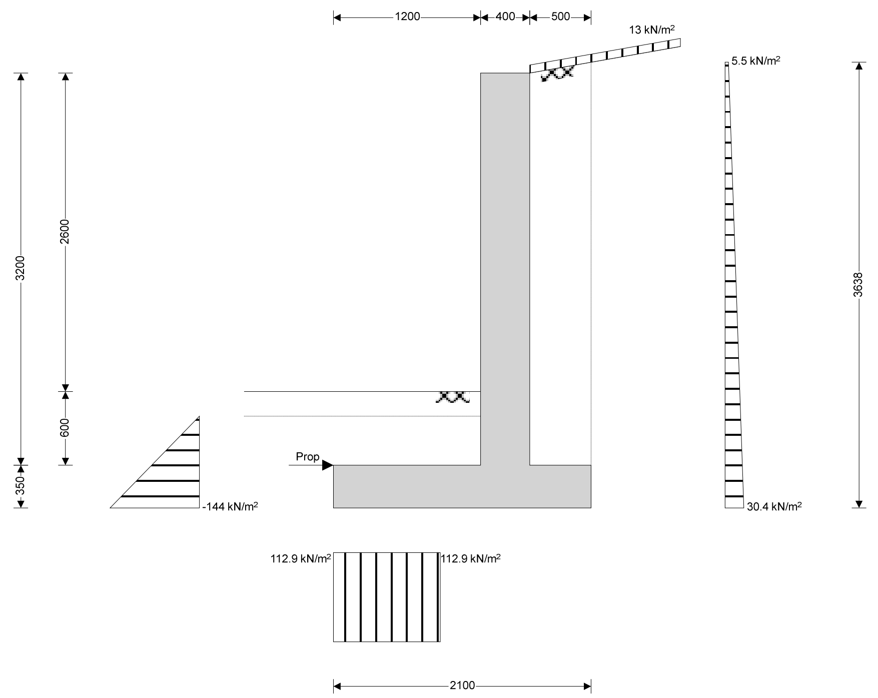
Soil type;	Medium dense rock fill
Moist density;	γ_{mr} = **16.3** kN/m^3
Saturated density;	γ_{sr} = **20.3** kN/m^3
Characteristic effective shear resistance angle;	$\phi'_{r.k}$ = **30** deg
Characteristic wall friction angle;	$\delta_{r.k}$ = **15** deg

Base soil properties

Soil type;	Very dense well graded sand and gravel
Soil density;	γ_b = **21** kN/m^3
Characteristic cohesion;	**$c'_{b.k}$ =** 0 **kN/m^2**
Characteristic effective shear resistance angle;	$\phi'_{b.k}$ = **42** deg
Characteristic wall friction angle;	$\delta_{b.k}$ = **21** deg
Characteristic base friction angle;	$\delta_{bb.k}$ = **28** deg

Loading details

Variable surcharge load;	**$Surcharge_Q$ =** 10 **kN/m^2**



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length;	$l_{base} = l_{toe} + t_{stem} + l_{heel} = \mathbf{2100}$ mm
Moist soil height;	$h_{moist} = h_{soil} = \mathbf{3200}$ mm
Length of surcharge load;	$l_{sur} = l_{heel} = \mathbf{500}$ mm
- Distance to vertical component;	$x_{sur\_v} = l_{base} - l_{heel} / 2 = \mathbf{1850}$ mm
Effective height of wall;	$h_{eff} = h_{base} + d_{cover} + h_{ret} + l_{sur} \times \tan(\beta) = \mathbf{3638}$ mm
- Distance to horizontal component;	$x_{sur\_h} = h_{eff} / 2 = \mathbf{1819}$ mm
Area of wall stem;	$A_{stem} = h_{stem} \times t_{stem} = \mathbf{1.28}$ m^2
- Distance to vertical component;	$x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{1400}$ mm
Area of wall base;	$A_{base} = l_{base} \times t_{base} = \mathbf{0.735}$ m^2
- Distance to vertical component;	$x_{base} = l_{base} / 2 = \mathbf{1050}$ mm
Area of moist soil;	$A_{moist} = h_{moist} \times l_{heel} + \tan(\beta) \times l_{heel}^2 / 2 = \mathbf{1.622}$ m^2

- Distance to vertical component;	$x_{moist\_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2 + \tan(\beta) \times l_{heel}^3 / 6) / A_{moist} =$ **1851** mm
- Distance to horizontal component;	$x_{moist\_h} = h_{eff} / 3 =$ **1213** mm
Area of base soil;	$A_{pass} = d_{cover} \times l_{toe} =$ **0.72** m^2
- Distance to vertical component;	$x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} =$ **600** mm
- Distance to horizontal component;	$x_{pass\_h} = (d_{cover} + h_{base}) / 3 =$ **317** mm
Area of excavated base soil;	$A_{exc} = h_{pass} \times l_{toe} =$ **0.48** m^2
- Distance to vertical component;	$x_{exc\_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc} =$ **600** mm
- Distance to horizontal component;	$x_{exc\_h} = (h_{pass} + h_{base}) / 3 =$ **250** 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;	$\gamma_Q =$ 1.500
Variable favourable action;	$\gamma_{Qf} =$ 0.000

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

Soil parameter set;	**M1**
Angle of shearing resistance;	$\gamma_{\phi'} =$ 1.00
Effective cohesion;	$\gamma_{c'} =$ 1.00
Weight density;	$\gamma_\gamma =$ 1.00

Retained soil properties

Design moist density;	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma =$ **16.3** kN/m^3
Design saturated density;	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma =$ **20.3** kN/m^3
Design effective shear resistance angle;	$\phi'_{r.d} = \mathrm{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **30** deg
Design wall friction angle;	$\delta_{r.d} = \mathrm{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) =$ **15** deg

Base soil properties

Design soil density;	$\gamma_b' = \gamma_b / \gamma_\gamma =$ **21** kN/m^3
Design effective shear resistance angle;	$\phi'_{b.d} = \mathrm{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) =$ **42** deg
Design wall friction angle;	$\delta_{b.d} = \mathrm{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) =$ **21** deg
Design base friction angle;	$\delta_{bb.d} = \mathrm{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **28** deg
Design effective cohesion;	$c'_{b.d} = c'_{b.k} / \gamma_{c'} =$ 0 **kN/m^2**

Using Coulomb theory

Active pressure coefficient;	$K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[}\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2) =$ **0.343**

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2)$ = **14.662**

Overturning check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **32** kN/m

Wall base; $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **18.4** kN/m

Moist retained soil; $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **26.4** kN/m

Base soil; $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b'$ = **10.1** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{moist\_v} + F_{exc\_v}$ = **86.8** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **18.1** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **48.1** kN/m

Base soil; $F_{exc\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h}))$ = **-66.2** kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h}$ = **0** kN/m

Overturning moments on wall

Surcharge load; $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h}$ = **32.9** kNm/m

Moist retained soil; $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **58.4** kNm/m

Total; $M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT}$ = **91.3** kNm/m

Restoring moments on wall

Wall stem; $M_{stem\_R} = F_{stem} \times x_{stem}$ = **44.8** kNm/m

Wall base; $M_{base\_R} = F_{base} \times x_{base}$ = **19.3** kNm/m

Moist retained soil; $M_{moist\_R} = F_{moist\_v} \times x_{moist\_v}$ = **48.8** kNm/m

Base soil; $M_{exc\_R} = F_{exc\_v} \times x_{exc\_v}$ = **6** kNm/m

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{moist\_R} + M_{exc\_R}$ = **118.9** kNm/m

Check stability against overturning

Factor of safety; $\mathbf{FoS_{ot} = M_{total\_R} / M_{total\_OT}}$ = 1.303

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **43.2** kN/m

Wall base; $F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **24.8** kN/m

Surcharge load; $F_{sur\_v} = \gamma_Q \times Surcharge_Q \times l_{heel}$ = **7.5** kN/m

Moist retained soil;	$F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = \mathbf{35.6}$ kN/m
Base soil;	$F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b' = \mathbf{20.4}$ kN/m
Total;	$F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{moist\_v} + F_{pass\_v} = \mathbf{131.5}$ kN/m
Horizontal forces on wall	
Surcharge load;	$F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{18.1}$ kN/m
Moist retained soil;	$F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{48.1}$ kN/m
Base soil;	$F_{pass\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h})) = \mathbf{-66.2}$ kN/m
Total;	$F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} = \mathbf{0}$ kN/m
Moments on wall	
Wall stem;	$M_{stem} = F_{stem} \times x_{stem} = \mathbf{60.5}$ kNm/m
Wall base;	$M_{base} = F_{base} \times x_{base} = \mathbf{26}$ kNm/m
Surcharge load;	$M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h} = \mathbf{-19}$ kNm/m
Moist retained soil;	$M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h} = \mathbf{7.5}$ kNm/m
Base soil;	$M_{pass} = F_{pass\_v} \times x_{pass\_v} = \mathbf{12.2}$ kNm/m
Total;	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{87.3}$ kNm/m
Check bearing pressure	
Propping force;	$F_{prop\_base} = F_{total\_h} = \mathbf{0}$ kN/m
Distance to reaction;	$\bar{x} = M_{total} / F_{total\_v} =$ 664 **mm**
Eccentricity of reaction;	$e = \bar{x} - l_{base} / 2 =$ -386 **mm**
Loaded length of base;	$l_{load} = 2 \times \bar{x} =$ 1327 **mm**
Bearing pressure at toe;	$q_{toe} = F_{total\_v} / l_{load} =$ 99.1 **kN/m²**
Bearing pressure at heel;	$q_{heel} =$ 0 **kN/m²**
Effective overburden pressure;	$q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{20}$ kN/m²
Design effective overburden pressure;	$q' = q / \gamma_\gamma = \mathbf{20}$ kN/m²
Bearing resistance factors;	$N_q = \text{Exp}(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 = \mathbf{85.374}$
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{93.706}$
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{151.941}$
Foundation shape factors;	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors;	$H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{prop\_base} = \mathbf{0}$ kN/m
	$V = F_{total\_v} = \mathbf{131.5}$ kN/m
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{1}$
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} = \mathbf{1}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{1}$

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{3820.3}$ kN/m^2

Factor of safety; **$FoS_{bp} = n_f / max(q_{toe}, q_{heel})$ =** 38.552

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; **γ_G =** 1.000

Permanent favourable action; **γ_{Gf} =** 1.000

Variable unfavourable action; **γ_Q =** 1.300

Variable favourable action; **γ_{Qf} =** 0.000

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

Soil parameter set; **M2**

Angle of shearing resistance; **$\gamma_{\phi'}$ =** 1.25

Effective cohesion; **$\gamma_{c'}$ =** 1.25

Weight density; **γ_γ =** 1.00

Retained soil properties

Design moist density; $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma = \mathbf{16.3}$ kN/m^3

Design saturated density; $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma = \mathbf{20.3}$ kN/m^3

Design effective shear resistance angle; $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) = \mathbf{24.8}$ deg

Design wall friction angle; $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) = \mathbf{12.1}$ deg

Base soil properties

Design soil density; $\gamma_b' = \gamma_b / \gamma_\gamma = \mathbf{21}$ kN/m^3

Design effective shear resistance angle; $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) = \mathbf{35.8}$ deg

Design wall friction angle; $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) = \mathbf{17.1}$ deg

Design base friction angle; $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) = \mathbf{23}$ deg

Design effective cohesion; $\mathbf{c'_{b.d} = c'_{b.k} / \gamma_{c'}} = 0$ **kN/m^2**

Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[}\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2) = \mathbf{0.431}$

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[}\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2) = \mathbf{7.553}$

Overturning check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **32** kN/m

Wall base; $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **18.4** kN/m

Moist retained soil; $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **26.4** kN/m

Base soil; $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_{b}'$ = **10.1** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{moist\_v} + F_{exc\_v}$ = **86.8** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **19.9** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **45.3** kN/m

Base soil; $F_{exc\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h}))$ = **-42.6** kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h}$ = **22.6** kN/m

Overturning moments on wall

Surcharge load; $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h}$ = **36.2** kNm/m

Moist retained soil; $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **54.9** kNm/m

Total; $M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT}$ = **91.2** kNm/m

Restoring moments on wall

Wall stem; $M_{stem\_R} = F_{stem} \times x_{stem}$ = **44.8** kNm/m

Wall base; $M_{base\_R} = F_{base} \times x_{base}$ = **19.3** kNm/m

Moist retained soil; $M_{moist\_R} = F_{moist\_v} \times x_{moist\_v}$ = **48.8** kNm/m

Base soil; $M_{exc\_R} = F_{exc\_v} \times x_{exc\_v}$ = **6** kNm/m

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{moist\_R} + M_{exc\_R}$ = **118.9** kNm/m

Check stability against overturning

Factor of safety; $\mathbf{FoS_{ot} = M_{total\_R} / M_{total\_OT}}$ = 1.305

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **32** kN/m

Wall base; $F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **18.4** kN/m

Surcharge load; $F_{sur\_v} = \gamma_Q \times Surcharge_Q \times l_{heel}$ = **6.5** kN/m

Moist retained soil; $F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}'$ = **26.4** kN/m

Base soil; $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b'$ = **15.1** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{moist\_v} + F_{pass\_v}$ = **98.4** kN/m

Horizontal forces on wall

Surcharge load;	$F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **19.9** kN/m
Moist retained soil;	$F_{moist\_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **45.3** kN/m
Base soil;	$F_{pass\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h}))$ = **-65.2** kN/m
Total;	$F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{pass\_h}$ = **0** kN/m
Moments on wall	
Wall stem;	$M_{stem} = F_{stem} \times x_{stem}$ = **44.8** kNm/m
Wall base;	$M_{base} = F_{base} \times x_{base}$ = **19.3** kNm/m
Surcharge load;	$M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h}$ = **-24.2** kNm/m
Moist retained soil;	$M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h}$ = **-6.1** kNm/m
Base soil;	$M_{pass} = F_{pass\_v} \times x_{pass\_v}$ = **9.1** kNm/m
Total;	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass}$ = **42.8** kNm/m
Check bearing pressure	
Propping force;	$F_{prop\_base} = F_{total\_h}$ = **0** kN/m
Distance to reaction;	$\bar{x} = M_{total} / F_{total\_v}$ = 435 **mm**
Eccentricity of reaction;	$e = \bar{x} - l_{base} / 2$ = -615 **mm**
Loaded length of base;	$l_{load} = 2 \times \bar{x}$ = 871 **mm**
Bearing pressure at toe;	$q_{toe} = F_{total\_v} / l_{load}$ = 112.9 **kN/m²**
Bearing pressure at heel;	q_{heel} = 0 **kN/m²**
Effective overburden pressure;	$q = (t_{base} + d_{cover}) \times \gamma_b'$ = **20** kN/m²
Design effective overburden pressure;	$q' = q / \gamma_\gamma$ = **20** kN/m²
Bearing resistance factors;	$N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 deg + \phi'_{b.d} / 2))^2$ = **36.651**
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d})$ = **49.493**
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d})$ = **51.36**
Foundation shape factors;	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors;	$H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{prop\_base}$ = **0** kN/m
	$V = F_{total\_v}$ = **98.4** kN/m
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m$ = **1**
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)}$ = **1**
	$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d}))$ = **1**

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma$ = **1200.8** kN/m²

Factor of safety;	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel})$ = 10.632

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 2.9.19

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

Concrete strength class; **C28/35**

Characteristic compressive cylinder strength; f_{ck} = 28 N/mm^2

Characteristic compressive cube strength; $f_{ck,cube}$ = 35 N/mm^2

Mean value of compressive cylinder strength; $f_{cm} = f_{ck} + 8$ N/mm^2 = 36 N/mm^2

Mean value of axial tensile strength; $f_{ctm} = 0.3$ N/mm$^2 \times (f_{ck} / 1$ N/mm$^2)^{2/3}$ = 2.8 N/mm^2

5% fractile of axial tensile strength; $f_{ctk,0.05} = 0.7 \times f_{ctm}$ = 1.9 N/mm^2

Secant modulus of elasticity of concrete; $E_{cm} = 22$ kN/mm$^2 \times (f_{cm} / 10$ N/mm$^2)^{0.3}$ = 32308 N/mm^2

Partial factor for concrete - Table 2.1N; γ_C = 1.50

Compressive strength coefficient - cl.3.1.6(1); α_{cc} = 0.85

Design compressive concrete strength - exp.3.15; $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C$ = 15.9 N/mm^2

Maximum aggregate size; h_{agg} = 20 mm

Ultimate strain - Table 3.1; ε_{cu2} = 0.0035

Shortening strain - Table 3.1; ε_{cu3} = 0.0035

Effective compression zone height factor; λ = 0.80

Effective strength factor; η = 1.00

Bending coefficient k1; K_1 = 0.40

Bending coefficient k2; $K_2 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2})$ = 1.00

Bending coefficient k3; K_3 =0.40

Bending coefficient k4; $K_4 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2})$ =1.00

Reinforcement details

Characteristic yield strength of reinforcement; f_{yk} = 500 N/mm^2

Modulus of elasticity of reinforcement; E_s = 200000 N/mm^2

Partial factor for reinforcing steel - Table 2.1N; γ_S = 1.15

Design yield strength of reinforcement; $f_{yd} = f_{yk} / \gamma_S$ = 435 N/mm^2

Cover to reinforcement

Top face of base; c_{bt} = **40** mm

Bottom face of base; c_{bb} = **40** mm

Structural Design & Draughting 159. Newmarket Rd. Ashton-under-Lyne 0161 330 3714						Project No.	Document/ Item Reference			
Project:	54 Tonacliffe Rd					23-23033				
Subject:	Introduction						Sheet	14	Of	20
Issue	1	Date	2	Date	3	Date	4	Date	5	Date
Made/ Revised by	DG	05.23								
Checked by										
Approved -										

Masonry details - Section 3.1

Masonry type;	**Aggregate concrete - Group 1**
Normalised mean compressive strength;	f_b = 7.3 N/mm^2
Characteristic flexural strength - cl.6.3.4(1);	f_{xk} = 0 N/mm^2
Initial shear strength - Table NA.5;	f_{vko} = 0.15 N/mm^2

Mortar details - Section 3.2

Mortar type;	**General purpose - M6, prescribed mix**
Compressive strength of mortar;	f_m = 6 N/mm^2

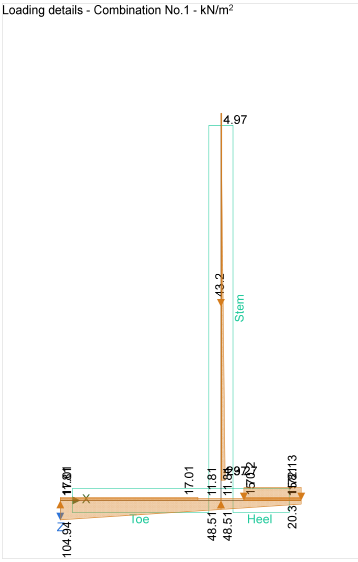
Ultimate limit states - Table NA.1

Class of execution control;	**1**
Category of manufacture control;	**1**
Partial factor for direct or flexural compression;	γ_{Mc} = 2.0
Partial factor for flexural tension;	γ_{Mt} = 2.3
Partial factor for shear;	γ_{Mv} = 2.0

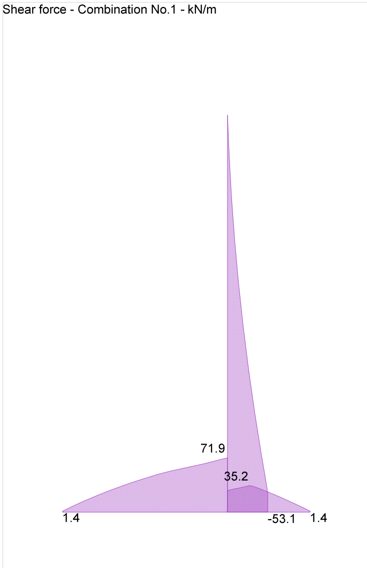
Characteristic strengths of concrete infill - Table 3.2

Concrete infill strength class;	**C28/35**
Characteristic compressive strength;	$f_{ck,infill}$ = 25 N/mm^2
Characteristic shear strength;	$f_{cvk,infill}$ = 0.45 N/mm^2
Design shear strength;	$f_{cvd,infill} = f_{cvk,infill} / \gamma_{Mv}$ = 0.225 N/mm^2

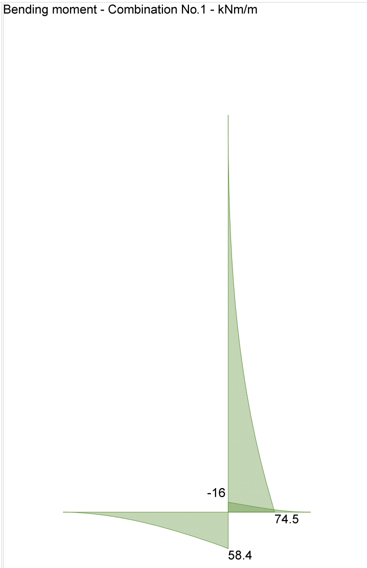
Loading details - Combination No.1 - kN/m^2

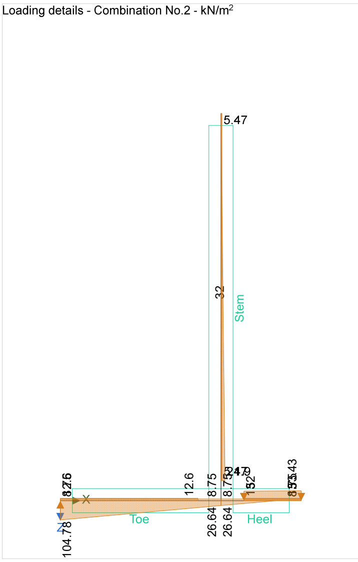


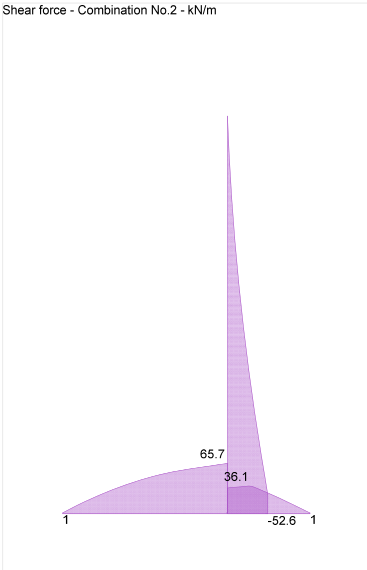
Shear force - Combination No.1 - kN/m

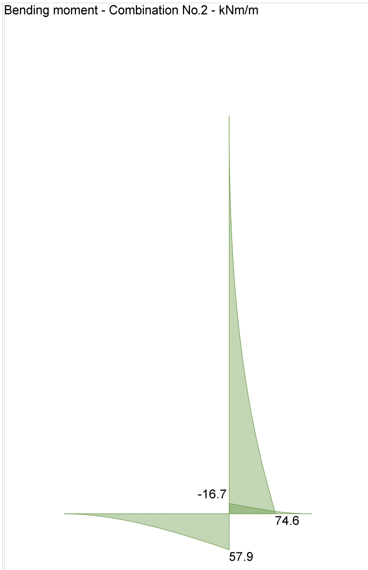


Bending moment - Combination No.1 - kNm/m









Check stem design at base of stem

Depth of section; t = **400** mm

Cavity wall details

Front leaf thickness; t_f = 100 **mm**

Rear leaf thickness; t_r = 100 **mm**

Masonry characteristics

Compressive strength constants - Table NA.4 **K = 0.750**

Characteristic compressive strength - cl.3.6.1.2(1) $f_k = K \times f_b^{0.7} \times f_m^{0.3}$ = 5.162 **N/mm²**

Design compressive strength $f_d = \min(f_k, f_{ck,infill}) / \gamma_{Mc}$ = 2.581 **N/mm²**

Design flexural strength $f_{xd} = f_{xk} / \gamma_{Mt}$ = 0 **N/mm²**

Height of masonry $h_{wt} = h_{stem}$ = 3200 **mm**

Compressive axial force combination 0 $F_x = \gamma_{Gf} \times \gamma_{stem} \times h_{wt} \times t$ = **32** kN/m

Moment combination 0 $M_x = \gamma_{Gf} \times \gamma_{stem} \times h_{wt} \times t^2 / 2$ = **6.4** kNm/m

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

Capacity reduction factor - exp.6.4 $\Phi = 1 - 2 \times e / t$ = **0.9**

Design vertical resistance - exp.6.2 $N_{Rd} = \Phi \times t \times f_d$ = 929.2 **kN/m**

Design vertical compressive stress $\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t)$ = 0.08 **N/mm²**

Apparent design flexural strength - exp.6.16 $f_{xd,app} = f_{xd} + \sigma_d$ = 0.08 **N/mm²**

Limit of charact. shear strength - exp. 3.1; $f_{vk,lim}$ **= 0.065** × f_b **=** 0.475 **N/mm²**

Characteristic shear strength - exp.3.5 f_{vk} **= min(**f_{vko} **+ 0.4** × σ_d**,** $f_{vk,lim}$**) =** 0.182 **N/mm²**

Design shear strength $f_{vd} = f_{vk} / \gamma_{Mv}$ = 0.091 **N/mm²**

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 2; **M =** 65.4 **kNm/m**

Tension reinforcement provided; **16 dia.bars @ 200 c/c**

Area of tension reinforcement provided; $A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr})$ = 1005 **mm²/m**

Depth to tension reinforcement; **d =** 260 **mm**

Minimum area of reinforcement - cl.8.2.3(1); $A_{sr.min} = 0.0005 \times d$ = 130 **mm²/m**

Lever arm - exp.6.23; $z = d \times \min(1 - 0.5 \times A_{sr.prov} \times f_{yd} / (d \times f_d), 0.95)$ = 175 **mm**

Moment of resistance - exp.6.22 and exp.6.24a; $M_{Rd} = \min(A_{sr.prov} \times f_{yd} \times z, 0.4 \times f_d \times d^2)$ = **69.8** kNm/m

M / M_{Rd} = 0.937

PASS - Moment of resistance exceeds applied design moment

Reinforced masonry members subjected to shear loading - Section 6.7

Design shear force **V =** 53.141 **kN/m**

Longitudinal reinforcement ratio - exp.J.2; $\rho_{enh} = A_{sr.prov} / d$ = **0.004**

Enhanced shear strength - exp.J.1; $f_{vd,enh1} = \min((0.35\ N/mm^2 + 17.5\ N/mm^2 \times \rho_{enh}), 0.7\ N/mm^2) / \gamma_{Mv}$ = **0.209** N/mm²

Shear span; $a_{v,enh} = M / V$ = **1231** mm

Enhancement factor; $\chi = 2.5 - \min(0.25 \times a_{v,enh} / d, 1.5)$ = **1.32**

Enhanced shear strength - exp.J.3; $f_{vd,enh2} = \min(\chi \times f_{vd,enh1}, 1.75N/mm^2 / \gamma_{Mv})$ = **0.275** N/mm²

Design shear resistance - exp.6.40; $V_{Rd} = \min(f_{vd,enh2}, f_{cvd,infill}) \times d$ = 58.5 **kN/m**

V / V_{Rd} = 0.908

PASS - Design shear resistance exceeds applied design shear force

Horizontal reinforcement parallel to face of stem

Minimum area of reinforcement - cl.8.2.3(4); $A_{sx.req} = 0.0005 \times d$ = 130 **mm²/m**

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

Area of transverse reinforcement provided; $A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx})$ = 393 **mm²/m**

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

Check base design at toe

Depth of section; h = **350** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2; **M =** 45.2 **kNm/m**

Depth to tension reinforcement; $d = h - c_{bb} - \phi_{bb} / 2$ = 306 **mm**

$K = M / (d^2 \times f_{ck})$ = 0.017

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

$K' = 0.207$

K' > K - No compression reinforcement is required

Lever arm; $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d =$ 291 **mm**

Depth of neutral axis; $x = 2.5 \times (d - z) =$ 38 **mm**

Area of tension reinforcement required; $A_{bb.req} = M / (f_{yd} \times z) =$ 358 **mm²/m**

Tension reinforcement provided; **Mesh B503 - 8 dia.bars @ 100 c/c**

Area of tension reinforcement provided; $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb}) =$ 503 **mm²/m**

Minimum area of reinforcement - exp.9.1N; $A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ 440 **mm²/m**

Maximum area of reinforcement - cl.9.2.1.1(3); $A_{bb.max} = 0.04 \times h =$ 14000 **mm²/m**

$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov} = 0.876$

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; $w_{max} = 0.3$ **mm**

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

Serviceability bending moment; $M_{sls} = 27.8$ **kNm/m**

Tensile stress in reinforcement; $\sigma_s = M_{sls} / (A_{bb.prov} \times z) = 190$ **N/mm²**

Load duration; **Long term**

Load duration factor; $k_t = 0.4$

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

$A_{c.eff} = 103917$ **mm²/m**

Mean value of concrete tensile strength; $f_{ct.eff} = f_{ctm} = 2.8$ **N/mm²**

Reinforcement ratio; $\rho_{p.eff} = A_{bb.prov} / A_{c.eff} = 0.005$

Modular ratio; $\alpha_e = E_s / E_{cm} = 6.19$

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; $s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff} = 417$ **mm**

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

$w_k =$ **0.238** mm

$w_k / w_{max} =$ **0.793**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force; $V = 63.7$ kN/m

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.808$

Longitudinal reinforcement ratio; $\rho_l = \min(A_{bb.prov} / d, 0.02) = 0.002$

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.450 \text{ N/mm}^2$

Design shear resistance - exp.6.2a & 6.2b; $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c} = 137.8$ kN/m

$V / V_{Rd.c} = 0.462$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section; h = **350** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2; $M = 9.7$ kNm/m

Depth to tension reinforcement; $d = h - c_{bt} - \phi_{bt} / 2 = 306$ mm

$K = M / (d^2 \times f_{ck}) = 0.004$

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

$K' = 0.207$

K' > K - No compression reinforcement is required

Lever arm; $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d = 291$ mm

Depth of neutral axis; $x = 2.5 \times (d - z) = 38$ mm

Area of tension reinforcement required; $A_{bt.req} = M / (f_{yd} \times z) = 76 \text{ mm}^2/\text{m}$

Tension reinforcement provided; **Mesh B503 - 8 dia.bars @ 100 c/c**

Area of tension reinforcement provided; $A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = 503 \text{ mm}^2/\text{m}$

Minimum area of reinforcement - exp.9.1N; $A_{bt.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 440 \text{ mm}^2/\text{m}$

Maximum area of reinforcement - cl.9.2.1.1(3); $A_{bt.max} = 0.04 \times h = 14000 \text{ mm}^2/\text{m}$

$\max(A_{bt.req}, A_{bt.min}) / A_{bt.prov} = 0.876$

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; $w_{max} = 0.3$ mm

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

Serviceability bending moment; $M_{sls} = 5.5$ kNm/m

Tensile stress in reinforcement; $\sigma_s = M_{sls} / (A_{bt.prov} \times z) = 37.9 \text{ N/mm}^2$

Load duration; **Long term**

Load duration factor; $k_t = 0.4$

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

$A_{c.eff} = 103917\ mm^2/m$

Mean value of concrete tensile strength; $f_{ct.eff} = f_{ctm} = 2.8\ N/mm^2$

Reinforcement ratio; $\rho_{p.eff} = A_{bt.prov} / A_{c.eff} = 0.005$

Modular ratio; $\alpha_e = E_s / E_{cm} = 6.19$

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; $s_{r.max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p.eff} = 417\ mm$

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

$w_k = \mathbf{0.047}$ mm

$w_k / w_{max} = \mathbf{0.158}$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force; $V = 36.1\ kN/m$

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

$k = \min(1 + \sqrt{(200\ mm / d)}, 2) = 1.808$

Longitudinal reinforcement ratio; $\rho_l = \min(A_{bt.prov} / d, 0.02) = 0.002$

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} = 0.450\ N/mm^2$

Design shear resistance - exp.6.2a & 6.2b; $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c} = 137.8\ kN/m$

$V / V_{Rd.c} = 0.262$

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); $A_{bx.req} = 0.2 \times A_{bb.prov} = 101\ mm^2/m$

Maximum spacing of reinforcement – cl.9.3.1.1(3); $s_{bx\_max} = 450\ mm$

Transverse reinforcement provided; **Mesh - 8 dia.bars @ 200 c/c**

Area of transverse reinforcement provided; $A_{bx.prov} = \pi \times \phi_{bxt}^2 / (4 \times s_{bxt}) = 251\ mm^2/m$

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

Secondary transverse reinforcement to base - Section 9.3

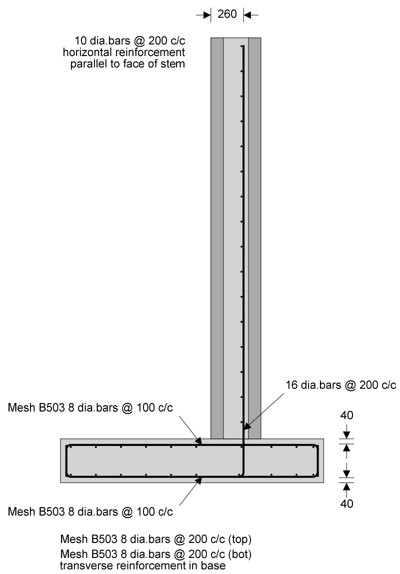
Minimum area of reinforcement – cl.9.3.1.1(2); $A_{bx.req} = 0.2 \times A_{bb.prov} = 101\ mm^2/m$

Maximum spacing of reinforcement – cl.9.3.1.1(3); $s_{bx\_max} = 450\ mm$

Transverse reinforcement provided; **Mesh - 8 dia.bars @ 200 c/c**

Area of transverse reinforcement provided; $A_{bx.prov} = \pi \times \phi_{bxb}^2 / (4 \times s_{bxb}) = 251\ mm^2/m$

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



Reinforcement details