Mr R. Marland
Land at the Rear of
54 Tonacliffe Rd.
Whitworth
Rochdale

Structural Design For Garden Retaining Wall, Surface Water & Foul Drainage And Slope Stability

Structural Design & Draughting

D.Garforth
Structural Design & Draughting
159. Newmarket Rd.
Ashton-under-Lyne
Lancs

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.

<table>
<tr><td colspan="2">Structural Design & Draughting
159. Newmarket Rd.
Ashton-under-Lyne
0161 330 3714</td><td colspan="3">Projec
t No.</td><td colspan="5">Document/ Item Reference</td></tr>
<tr><td>Project:</td><td colspan="3">54 Tonacliffe Rd</td><td colspan="6">23-23033</td></tr>
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Issue	1	Date	2	Date	3	Date	4	Date	5	Date
Made/ Revised by	DG	05.23								
Checked by										
Approved -										

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

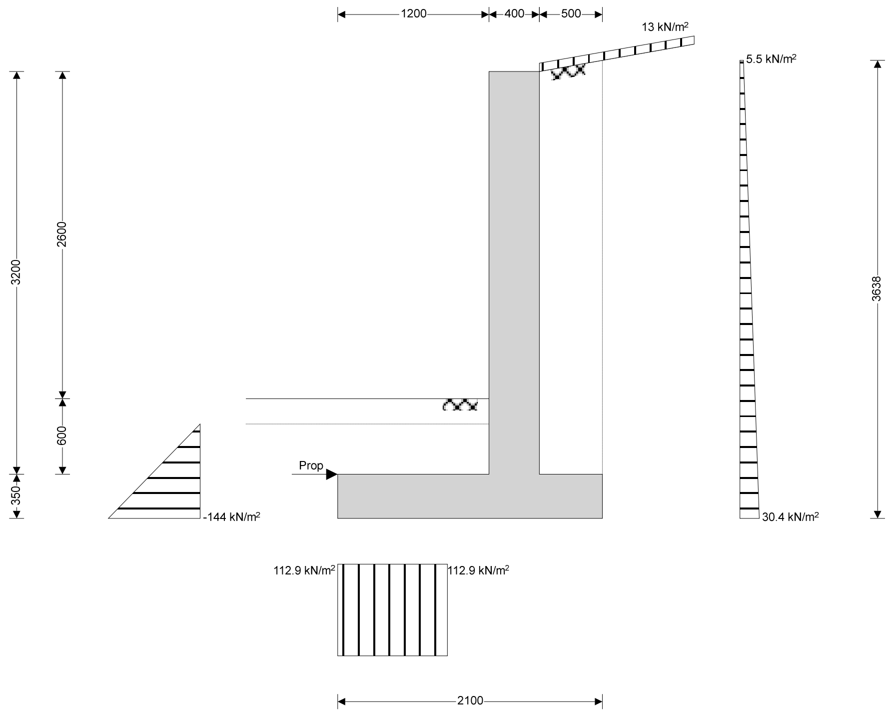
Soil type;	Medium dense rock fill
Moist density;	γ_{mr} = **16.3** kN/m^3
Saturated density;	γ_{sr} = **20.3** kN/m^3
Characteristic effective shear resistance angle;	$\phi'_{r.k}$ = **30** deg
Characteristic wall friction angle;	$\delta_{r.k}$ = **15** deg

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;	$x_{moist\_h} = h_{eff} / 3 = \mathbf{1213}$ mm
Area of base soil;	$A_{pass} = d_{cover} \times l_{toe} = \mathbf{0.72}$ 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; γ_G **= 1.350**

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

Variable unfavourable action; γ_Q **= 1.500**

Variable favourable action; γ_{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; γ_{γ} **= 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; $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **30** deg

Design wall friction angle; $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **15** deg

Base soil properties

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

Design effective shear resistance angle; $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **42** deg

Design wall friction angle; $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **21** deg

Design base friction angle; $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **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; $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **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; $F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}'$ = **35.6** kN/m

Base soil; $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b'$ = **20.4** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{moist\_v} + F_{pass\_v}$ = **131.5** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **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; $F_{pass\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h})) = \mathbf{-66.2}$ 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; $\bar{x} = M_{total} / F_{total\_v} = \mathbf{664\ mm}$

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2 = \mathbf{-386\ mm}$

Loaded length of base; $l_{load} = 2 \times \bar{x} = \mathbf{1327\ mm}$

Bearing pressure at toe; $q_{toe} = F_{total\_v} / l_{load} = \mathbf{99.1\ kN/m^2}$

Bearing pressure at heel; $q_{heel} = \mathbf{0\ kN/m^2}$

Effective overburden pressure; $q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{20}$ kN/m^2

Design effective overburden pressure; $q' = q / \gamma_\gamma = \mathbf{20}$ kN/m^2

Bearing resistance factors; $N_q = \mathrm{Exp}(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\ \mathrm{deg} + \phi'_{b.d} / 2))^2 = \mathbf{85.374}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{93.706}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{151.941}$

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; $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{38.552}$

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; $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **16.3** kN/m^3

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

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

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

Base soil properties

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

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

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

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

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

Using Coulomb theory

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

Passive pressure coefficient; $K_P = sin(90 - \phi'_{b.d})^2 / (sin(90 + \delta_{b.d}) \times [1 - \sqrt{[}sin(\phi'_{b.d} + \delta_{b.d}) \times sin(\phi'_{b.d}) / (sin(90 + \delta_{b.d}))]]^2)$ = **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; **$FoS_{ot} = M_{total\_R} / M_{total\_OT} = 1.305$**

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; $M_{pass} = F_{pass\_v} \times x_{pass\_v} = \mathbf{9.1}$ kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{42.8}$ kNm/m

Check bearing pressure

Propping force; $F_{prop\_base} = F_{total\_h} = \mathbf{0}$ kN/m

Distance to reaction; $\bar{x} = M_{total} / F_{total\_v} = 435$ **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; $q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{20}$ kN/m²

Design effective overburden pressure; $q' = q / \gamma_\gamma = \mathbf{20}$ kN/m²

Bearing resistance factors; $N_q = Exp(\pi \times tan(\phi'_{b.d})) \times (tan(45 deg + \phi'_{b.d} / 2))^2 = \mathbf{36.651}$

$N_c = (N_q - 1) \times cot(\phi'_{b.d}) = \mathbf{49.493}$

$N_\gamma = 2 \times (N_q - 1) \times tan(\phi'_{b.d}) = \mathbf{51.36}$

Foundation shape factors; $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors; $H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{prop\_base} = \mathbf{0}$ kN/m

$V = F_{total\_v} = \mathbf{98.4}$ 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

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{1200.8}$ 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/mm²**

Characteristic compressive cube strength; $f_{ck,cube} = 35$ **N/mm²**

Mean value of compressive cylinder strength; $f_{cm} = f_{ck} + 8$ **N/mm² = 36 N/mm²**

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

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

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

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; $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C =$ **15.9 N/mm²**

Maximum aggregate size; $h_{agg} = 20$ mm

Ultimate strain - Table 3.1; $\varepsilon_{cu2} = 0.0035$

Shortening strain - Table 3.1; $\varepsilon_{cu3} = 0.0035$

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

Bending coefficient k_3; $K_3 = 0.40$

Bending coefficient k_4; $K_4 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2}) = 1.00$

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; $c_{bt} = \textbf{40}$ mm

Bottom face of base; $c_{bb} = \textbf{40}$ mm

Masonry details - Section 3.1

Masonry type; **Aggregate concrete - Group 1**

Normalised mean compressive strength; $f_b = 7.3 \text{ N/mm}^2$

Characteristic flexural strength - cl.6.3.4(1); $f_{xk} = 0 \text{ N/mm}^2$

Initial shear strength - Table NA.5; $f_{vko} = 0.15 \text{ N/mm}^2$

Mortar details - Section 3.2

Mortar type; **General purpose - M6, prescribed mix**

Compressive strength of mortar; $f_m = 6 \text{ N/mm}^2$

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

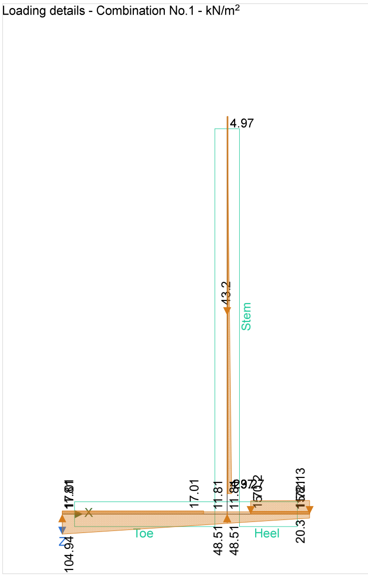
Concrete infill strength class; **C28/35**

Characteristic compressive strength; $f_{ck,infill} = 25\ N/mm^2$

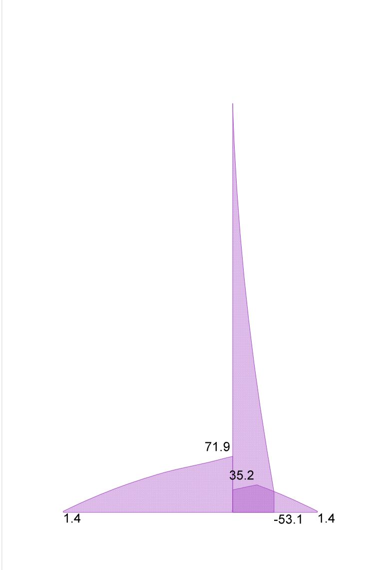
Characteristic shear strength; $f_{cvk,infill} = 0.45\ N/mm^2$

Design shear strength; $f_{cvd,infill} = f_{cvk,infill} / \gamma_{Mv} = 0.225\ N/mm^2$

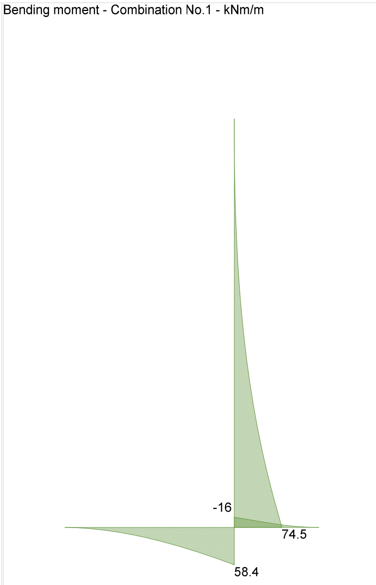
Loading details - Combination No.1 - kN/m²



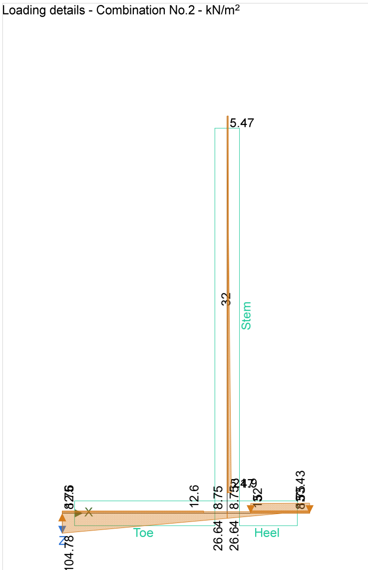
Shear force - Combination No.1 - kN/m



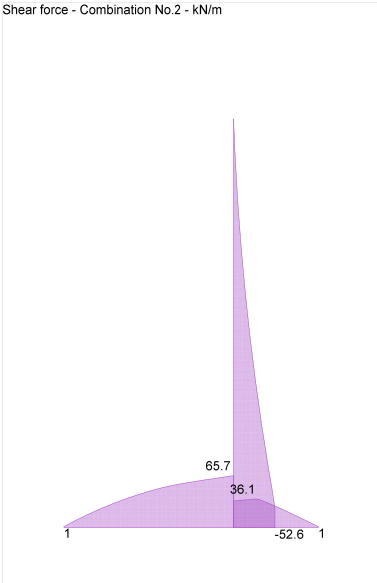
Bending moment - Combination No.1 - kNm/m



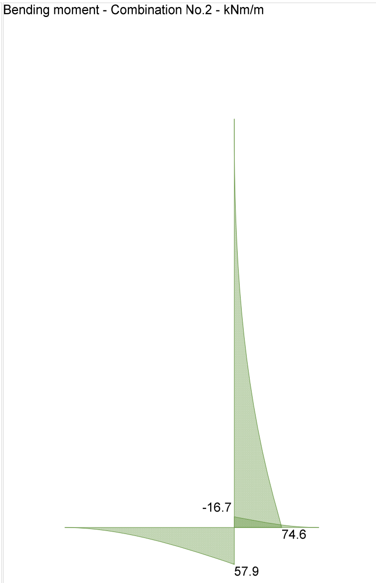
Loading details - Combination No.2 - kN/m²



Shear force - Combination No.2 - kN/m



Bending moment - Combination No.2 - 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/mm^2**

Design compressive strength **$f_d = \min(f_k, f_{ck,infill}) / \gamma_{Mc}$ = 2.581 N/mm^2**

Design flexural strength **$f_{xd} = f_{xk} / \gamma_{Mt}$ = 0 N/mm^2**

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(abs(t / 2 - M_x / F_x), 0.05 × 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/mm^2**

Apparent design flexural strength - exp.6.16 **$f_{xd,app} = f_{xd} + \sigma_d$ = 0.08 N/mm^2**

Limit of charact. shear strength - exp. 3.1; **$f_{vk,lim} = 0.065 \times f_b$ = 0.475 N/mm^2**

Characteristic shear strength - exp.3.5 **$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim})$ = 0.182 N/mm^2**

Design shear strength **$f_{vd} = f_{vk} / \gamma_{Mv}$ = 0.091 N/mm^2**

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 mm^2/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 mm^2/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; $f_{vd,enh1} = \min((0.35 \text{ N/mm}^2 + 17.5 \text{ N/mm}^2 \times \rho_{enh}), 0.7 \text{ N/mm}^2) / \gamma_{Mv}$ = **0.209** N/mm^2

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

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

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

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); $A_{sx.req} = 0.0005 \times d = 130$ **mm^2/m**

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

Area of transverse reinforcement provided; $A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx}) = 393$ **mm^2/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; $A_{bb.req} = M / (f_{yd} \times z) = 358$ **mm^2/m**

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

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

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

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

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

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

$v_{min} = 0.035$ 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; $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c} = 137.8$ 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; $A_{bt.req} = M / (f_{yd} \times z) = 76$ mm^2/m

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

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

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

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

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

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

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

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

$w_k = 0.047$ mm

$w_k / w_{max} = 0.158$

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

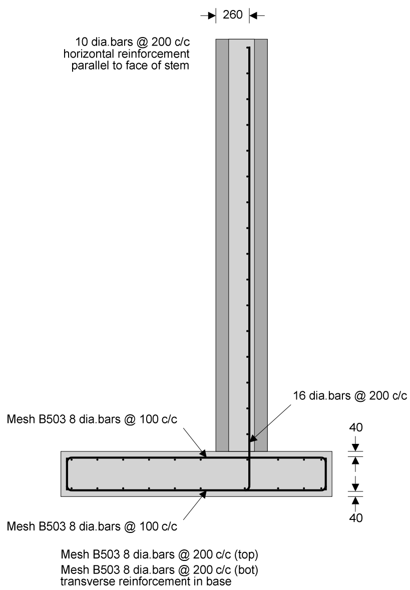
Minimum area of reinforcement – cl.9.3.1.1(2); **$A_{bx.req} = 0.2 \times A_{bb.prov} = 101$ mm^2/m**

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

Calculation for the surface water and foul drainage for the proposed property on land at the rear of 54. Tnnacliffe Rd. Whitworth.

British Standards and Codes of Practice

BS EN 12056-3:2000 Design Rainfall and Drainage of an Area

Chezy Formulas)
)
Escritt Formulas) Formulae for the sizing and flow rates of gutters and drain runs
)
Colebrook White Formulas)

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

In accordance with the National Planning Practice Guidance, the proposed drainage scheme for the plot on land at the rear of 54 Tonnacliffe Rd. has been made after consideration of the required drainage hierarchy as follows: -

Infiltration
Two trial holes were excavated on the site. These trial holes both showed a layer of topsoil (200mm approx.). This top soil overlay sandy gravel of unknown depth. The hole in the area of the house hit rock at 200mm approx. Percolation tests were carried out at both trial pits. These tests showed that the fall in water level was significant with the holes fully draining within 90 seconds.
Infiltration drainage was therefore discounted. Location plan and photographs of the trial holes are attached.

Drainage to a local water course
There are no water courses within a reasonable distance and without passing through other properties and a major road.

Connection to a surface water sewer, highways drain, or another drainage system
There are no surface water or highways drains within the site proximity.

Connection to a combined sewer
The drainage system at the rear of 54 Tonnacliffe Road is a public combined sewer system which runs on the far side of the access road and serves the 2 properties on Oakenshaw Avenue. This system culminates in a 225mm diameter combined sewer running generally North South along the A671 Market Street.

Percolation Test Results

Trial Pit 1

As specified, the trial pit was dug 500x500x500 then 300x300x1.0m giving a total depth of 1.5m and the surrounding soaked. The hole was then filled to a pre marked level. Within 90 seconds the hole had drained. This was repeated 3 times and the longest recorded time was 90 seconds.

Test 1				
Water Level Full	**420.0mm**			
Water Level	**0.0mm**	**VP =**	**85 / 420 =**	**0.2**
Test 2				
Water Level Full	**420.0mm**			
Water Level	**0.0mm**	**VP =**	**88 / 420 =**	**0.2**
Test 3				
Water Level Full	**420.0mm**			
Water Level	**0.0mm**	**VP =**	**90 / 420 =**	**0.2**

Trial Pit 2

Trial pit 2 hit rock at 200mm. Additional positions were tried within the area of the proposed property foundation with rock being found at a similar depth in all 3 locations. This trial pit was therefore abandoned.

As the water drained freely in all cases with an average VP of 0.2, it is considered that the soil in this site is unsuitable for infiltration drainage to be considered viable. A VP lower than 5 is considered to indicate that the speed of infiltration is likely to wash fines and cause settlement of the surrounding ground.

Gutters

Area to be drained = 8.6 x 6.9 / 2 = 29.7m² / Gutter

DESIGN RAINFALL

In accordance with the Wallingford Procedure

Tedds calculation version 2.0.02

Design rainfall intensity

Location of catchment area; **Manchester**

Storm duration; **D = 30 min**

Return period; **Period = 30 yr**

Ratio 60 min to 2 day rainfall of 5 yr return period; **r = 0.360**

5-year return period rainfall of 60 minutes duration; **M5_60min = 18.0 mm**

Increase of rainfall intensity due to global warming; **$p_{climate}$ = 0 %**

Factor Z1 (Wallingford procedure); Z1 = **0.79**

Rainfall for 30min storm with 5 year return period; $M5\_30min_i = Z1 \times M5\_60min$ = **14.2** mm

Factor Z2 (Wallingford procedure); Z2 = **1.52**

Rainfall for 30min storm with 30 year return period; $M30\_30min = Z2 \times M5\_30min_i$ = **21.6** mm

Design rainfall intensity; $I_{max} = M30\_30min / D$ = **43.3** mm/hr

Maximum surface water runoff

Catchment area; **$A_{catch} = 60\ m^2$**

Percentage of area that is impermeable; **p = 100 %**

Maximum surface water runoff; **$Q_{max} = A_{catch} \times p \times I_{max} = 0.7$ l/s**

DESIGN RAINFALL

In accordance with the Wallingford Procedure

Tedds calculation version 2.0.02

Design rainfall intensity

Location of catchment area; **Manchester**

Storm duration; **D = 30 min**

Return period; **Period = 100 yr**

Ratio 60 min to 2 day rainfall of 5 yr return period; **r = 0.360**

5-year return period rainfall of 60 minutes duration; **M5_60min = 18.0 mm**

Increase of rainfall intensity due to global warming; **$p_{climate}$ = 40 %**

Factor Z1 (Wallingford procedure); Z1 = **0.79**

Rainfall for 30min storm with 5 year return period; $M5\_30min_i = Z1 \times M5\_60min \times (1 + p_{climate})$ = **19.9** mm

Factor Z2 (Wallingford procedure); Z2 = **2.03**

Rainfall for 30min storm with 100 year return period; $M100\_30min = Z2 \times M5\_30min_i$ = **40.4** mm

Design rainfall intensity; $I_{max} = M100\_30min / D$ = **80.8** mm/hr

Maximum surface water runoff

Catchment area; **$A_{catch} = 60\ m^2$**

Percentage of area that is impermeable; p = 100 %

Maximum surface water runoff; $Q_{max} = A_{catch} \times p \times I_{max}$ = 1.3 l/s

Roof drainage gutters - to BS EN 12056-3:2000 (with Amd. No. 17041)

Effective area of roof - Clause 4.3
Width of roof from gutter to ridge Br=3.45 m
Length of roof to be drained Lr=8.60 m
No allowance will be made for wind.
Effective roof area A=Lr*Br=8.6*3.45=29.67 m¬2
Rainfall intensity r=0.021 l/(s.m2)
The runoff coefficient C=1
Rate of flow of water (Clause 4.1) Q=r*A*C=0.021*29.67*1
=0.62 l/s

Capacity of gutter - Clause 5.1
Nominal half round eaves gutter; of width 100 mm
Full cross-sectional area of gutter Ae=3926 mm¬2
Nominal capacity of the gutter Qn=2.78*1.0E-5*Ae^1.25
=2.78*1.0E-5*3926^1.25 = 0.86 l/s
Depth of water below designed water line W=50 mm
Capacity of gutter Ql=0.9*Qn=0.9*0.86394 = 0.78 l/s

Long gutters
Length of gutter L=8.6 m
Ratio of length to maximum depth L'W=L*1000/W=8.6*1000/50 = 172
As the drainage length of the gutter exceeds 50 times the design water depth, W, the gutter will be considered to be "long".
The capacity of the gutter will be multiplied by the appropriate capacity factor, Fl, from Table 6.
Gradient of gutter Ggrad=3 mm/m
The gutter is referred to as "normally level" as the gradient is not more than 3 mm/m.
Reduction factor Fl=0.8336
Capacity of gutter Ql=Ql*Fl=0.77754*0.8336 = 0.65 l/s
Since Q <= Ql (0.62307 <= 0.65) capacity of gutter is sufficient.

The outlet is not fitted with a strainer or grating.
Outlet coefficient Ko=1.0
Outlet head factor (Figure 10) Fh=0.65
Gutter critical depth of flow yc=Fh*W=0.65*50=32.5 mm
Gutter discharge to outlet Q=Q=0.62307 L/s

Gutter discharges into a circular downpipe.

Outlet sizing - Clause 5.3
Diameter of circular downpipe D=65 mm
Note: A non-circular rainwater pipe could be used provided it has the same cross sectional area as a circular downpipe of internal diameter 65 mm i.e. Area required = 3316.6 mm^2

From Table 8, assuming a filling degree of 0.33 and a pipe roughness of 0.25 mm the capacity of the rainwater pipe in l/s is given by the following expression:

Qrwp=(2.5*10^-4*0.25^-0.167*D^2.667*0.33^1.667)*Ko
=(2.5*10^-4*0.25^-0.167*65^2.667*0.33^1.667)*1 = 3.4 l/s

As Qrwp > Q (3.3954 > 0.62307) the gutter will discharge freely and the size of the outlet is satisfactory.

DESIGN SUMMARY Gutter is a nominal half round (segmental) gutter

Width of gutter	100 mm
Capacity of gutter is	0.65 l/s
Rate of flow of water	0.62 l/s
Diameter of outlet pipe	65 mm

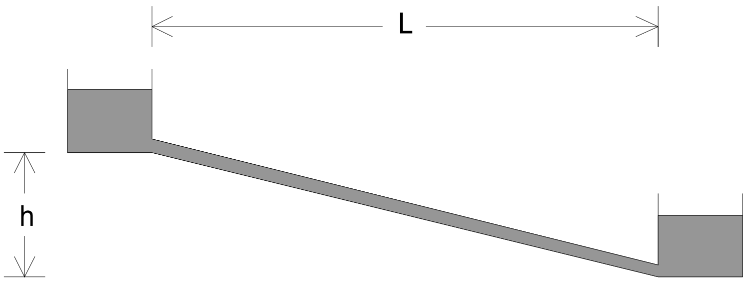
Surface Water Drain RWP to IC 3

Length = **7.92m**

Minimum Fall = **1 in 100**

DESIGN OF A SURFACE WATER DRAIN

TEDDS calculation version 1.0.04



Drain design details

Design flow rate; **Q_{design} = 5.00×10^{-3} m^3/s**

Length of the drain; **L = 7.9 m**

Fall along length of drain; **h = 0.080 m**

Gradient of drain; **i = h / L = 0.010; (1 in 99)**

Minimum flow velocity; **V_{min} = 0.750 m/s**

Minimum pipe diameter; **D_{min} = 100 mm**

Surface roughness; **k_s = 0.6 mm**

Mean hydraulic depth factor; **m = 0.25**

Kinematic viscosity of fluid; **ν = 1.31×10^{-6} m^2/s**

Using the Chezy equation

Constant; **c = 56**

Diameter of pipe required; **$D = ((Q_{design}^2 \times 16) / (\pi^2 \times m \times c^2 \times i \times 1m/s^2))^{0.2}$ = 87 mm**

Nearest pipe diameter; **D_{chezy} = 100 mm**

Flow velocity using Chezy; **$V_{chezy} = c \times \sqrt{(m \times D_{chezy} \times i \times 1m/s^2)}$ = 0.890 m/s**

Using the Escritt equation

Diameter of pipe required; **$D = (Q_{design} \times 1000 \times \sqrt{(1 / i)} / 0.00035\ m^3/s)^{0.382} \times 1mm$ = 93 mm**

Nearest pipe diameter; **$D_{escritt}$ = 100 mm**

Flow velocity using Escritt; **$V_{escritt} = 26.738 \times (D_{escritt} / 1mm)^{0.62} \times 1\ m/s / (\sqrt{(1 / i)} \times 60)$ = 0.778 m/s**

Using the Colebrook-White Equation for pipe running full and partially full

Design pipe diameter; **$D_{design} = max(D_{chezy}, D_{escritt}, D_{min})$ = 100 mm**

Constant; **$Z = \sqrt{(2 \times (g_{acc} / 1m/s^2) \times (D_{design} / 1000mm) \times i)}$ = 0.141**

Flow velocity; **$V_{full} = -2 \times Z \times log((k_s/(3.7 \times D_{design}))+((2.51 \times \nu)/(D_{design} \times Z \times 1m/s))) \times 1m/s$**

V_{full} = 0.769 m/s

Flow rate running full; **$Q_{full} = V_{full} \times \pi \times D_{design}^2 / 4 = 6.04\times10^{-3}$ m³/s**

PASS - Maximum flow rate is greater than design flow rate

From Hydraulics Research Tables 35 and 36

Depth as proportion of D; **x = 0.696**

Flow velocity at design flow rate; **V_{design} = 0.858 m/s**

PASS - Design velocity is greater than 0.750 m/s

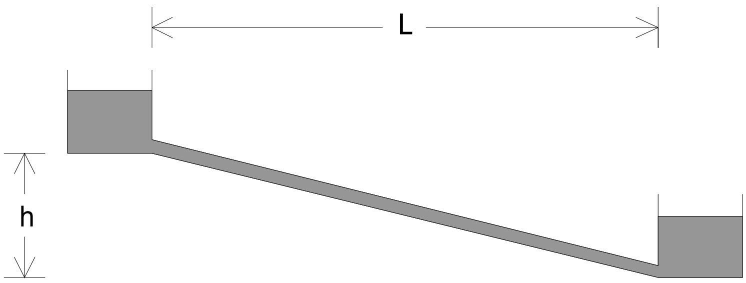
Foul Drain

Length = **22.4m**

Minimum Fall = **1 in 80**

DESIGN OF A FOUL SEWER

TEDDS calculation version 1.0.04



Design pipe flow limited to 0.75 times full depth

Sewer design details

Design flow rate;	$Q_{design} = 5.00\times10^{-3}$ m^3/s
Length of the sewer;	L = 22.4 m
Fall along length of sewer;	h = 0.280 m
Gradient of sewer;	i = h / L = 0.013; (1 in 80)
Minimum flow velocity;	V_{min} = 0.750 m/s
Minimum pipe diameter;	D_{min} = 100 mm
Surface roughness;	k_s = 1.5 mm
Mean hydraulic depth factor;	m = 0.30
Kinematic viscosity of fluid;	$\nu = 1.31\times10^{-6}$ m^2/s

Using the Chezy equation

Constant;	c = 56
Diameter of pipe required;	$D = ((Q_{design}^2 \times 16) / (\pi^2 \times m \times c^2 \times i \times 1m/s^2))^{0.2} = 81$ mm
Nearest pipe diameter;	D_{chezy} = 100 mm
Flow velocity using Chezy;	$V_{chezy} = c \times \sqrt{(m \times D_{chezy} \times i \times 1m/s^2)} = 1.084$ m/s

Using the Escritt equation

Diameter of pipe required; $D = (Q_{design} \times 1000 \times \sqrt{(1 / i)} / 0.00035\ m^3/s)^{0.382} \times 1mm =$ **89 mm**

Nearest pipe diameter; $D_{escritt}$ = 100 mm

Flow velocity using Escritt; $V_{escritt} = 26.738 \times (D_{escritt} / 1mm)^{0.62} \times 1\ m/s / (\sqrt{(1 / i)} \times 60) =$ **0.866 m/s**

Using the Colebrook-White Equation for pipe running full and partially full

Design pipe diameter;	$D_{design} = \max(D_{chezy}, D_{escritt}, D_{min}) = 100$ mm
Constant;	$Z = \sqrt{(2 \times (g_{acc} / 1m/s^2) \times (D_{design} / 1000mm) \times i)} = 0.157$

Flow velocity; $V_{full} = -2 \times Z \times \log((k_s/(3.7 \times D_{design})) + ((2.51 \times \nu)/(D_{design} \times Z \times 1m/s))) \times 1m/s$

$V_{full} = 0.742$ m/s

Flow rate running full; $Q_{full} = V_{full} \times \pi \times D_{design}^2 / 4 = 5.83 \times 10^{-3}$ m^3/s

PASS - Maximum flow rate is greater than design flow rate

From Hydraulics Research Tables 35 and 36

Depth as proportion of D; $x = 0.715$

PASS - Design pipe flow less than 0.75 times full depth

Flow velocity at design flow rate; $V_{design} = 0.832$ m/s

PASS - Design velocity is greater than 0.750 m/s

Structural Design & Draughting	Structural Design & Draughting 159. Newmarket Rd. Ashton-under-Lyne 0161 330 3714	Project No.	Document/ Item Reference

Project:	54 Tonacliffe Rd	23-23033			
Subject:	Slope Stability	Sheet	30	Of	40

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

SLOPE STABILITY - SLIP CIRCLE ANALYSIS

Tedds calculation version 1.0.02

Slope geometry

Angle of slope; β = 33.69 **deg**

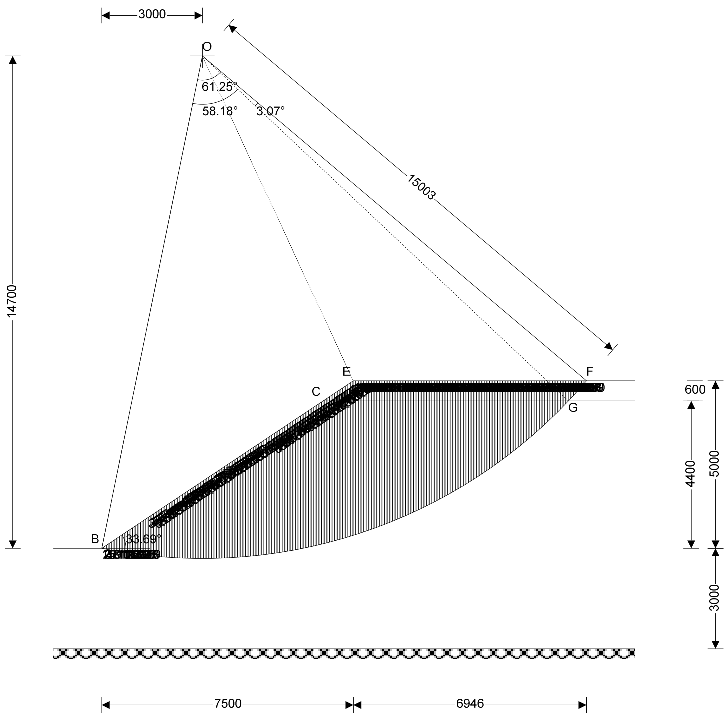
Height of slope; **H =** 5000 **mm**

Horizontal length of slope; **L = H / Tan(β) =** 7500 **mm**

Depth of upper soil layer; H_A = 600 **mm**

Depth of lower soil layer; H_B = 4400 **mm**

Depth of hard layer; H_L = 3000 **mm**



Soil properties

Bulk unit weight of upper soil; γ_A = 19 **kN/m³**

Bulk unit weight of lower soil; γ_B = 18 **kN/m³**

Drained shear strength of upper soil; c'_A = 10 **kN/m²**

Drained shear strength of lower soil; c'_B = 10 **kN/m²**

Shear resistance of upper soil; ϕ'_A = 35 **deg**

Shear resistance of lower soil; ϕ'_B = 35 **deg**

Pore pressure ratio; r_u = 0.3

Drained stability - Bishop's simplified method effective stress analysis

Slice No.	Area (m²)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
1	0.0	0.0	-2968	-11.4	0.5	0.0
2	0.0	0.1	-2928	-11.3	0.6	0.0

Slice No.	Area (m^2)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
3	0.0	0.1	-2880	-11.1	0.6	0.0
4	0.0	0.1	-2831	-10.9	0.6	0.0
5	0.0	0.2	-2783	-10.7	0.6	0.0
6	0.0	0.2	-2735	-10.5	0.6	0.0
7	0.0	0.2	-2687	-10.3	0.6	0.0
8	0.0	0.3	-2639	-10.1	0.7	0.0
9	0.0	0.3	-2591	-9.9	0.7	-0.1
10	0.0	0.3	-2543	-9.8	0.7	-0.1
11	0.0	0.4	-2494	-9.6	0.7	-0.1
12	0.0	0.4	-2446	-9.4	0.7	-0.1
13	0.0	0.4	-2398	-9.2	0.7	-0.1
14	0.0	0.5	-2350	-9.0	0.8	-0.1
15	0.0	0.5	-2302	-8.8	0.8	-0.1
16	0.0	0.5	-2254	-8.6	0.8	-0.1
17	0.0	0.6	-2205	-8.5	0.8	-0.1
18	0.0	0.6	-2157	-8.3	0.8	-0.1
19	0.0	0.6	-2109	-8.1	0.8	-0.1
20	0.0	0.7	-2061	-7.9	0.9	-0.1
21	0.0	0.7	-2013	-7.7	0.9	-0.1
22	0.0	0.7	-1965	-7.5	0.9	-0.1
23	0.0	0.8	-1917	-7.3	0.9	-0.1
24	0.0	0.8	-1868	-7.2	0.9	-0.1
25	0.0	0.8	-1820	-7.0	0.9	-0.1
26	0.0	0.9	-1772	-6.8	1.0	-0.1
27	0.1	0.9	-1724	-6.6	1.0	-0.1
28	0.1	0.9	-1676	-6.4	1.0	-0.1
29	0.1	1.0	-1628	-6.2	1.0	-0.1
30	0.1	1.0	-1580	-6.0	1.0	-0.1
31	0.1	1.0	-1531	-5.9	1.0	-0.1
32	0.1	1.1	-1483	-5.7	1.0	-0.1
33	0.1	1.1	-1435	-5.5	1.1	-0.1
34	0.1	1.1	-1387	-5.3	1.1	-0.1
35	0.1	1.2	-1339	-5.1	1.1	-0.1
36	0.1	1.2	-1291	-4.9	1.1	-0.1

Slice No.	Area (m^2)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
37	0.1	1.2	-1242	-4.8	1.1	-0.1
38	0.1	1.3	-1194	-4.6	1.1	-0.1
39	0.1	1.3	-1146	-4.4	1.1	-0.1
40	0.1	1.3	-1098	-4.2	1.2	-0.1
41	0.1	1.4	-1050	-4.0	1.2	-0.1
42	0.1	1.4	-1002	-3.8	1.2	-0.1
43	0.1	1.4	-954	-3.6	1.2	-0.1
44	0.1	1.4	-905	-3.5	1.2	-0.1
45	0.1	1.5	-857	-3.3	1.2	-0.1
46	0.1	1.5	-809	-3.1	1.2	-0.1
47	0.1	1.5	-761	-2.9	1.3	-0.1
48	0.1	1.6	-713	-2.7	1.3	-0.1
49	0.1	1.6	-665	-2.5	1.3	-0.1
50	0.1	1.6	-616	-2.4	1.3	-0.1
51	0.1	1.7	-568	-2.2	1.3	-0.1
52	0.1	1.7	-520	-2.0	1.3	-0.1
53	0.1	1.7	-472	-1.8	1.3	-0.1
54	0.1	1.7	-424	-1.6	1.3	0.0
55	0.1	1.8	-376	-1.4	1.4	0.0
56	0.1	1.8	-328	-1.3	1.4	0.0
57	0.1	1.8	-279	-1.1	1.4	0.0
58	0.1	1.9	-231	-0.9	1.4	0.0
59	0.1	1.9	-183	-0.7	1.4	0.0
60	0.1	1.9	-135	-0.5	1.4	0.0
61	0.1	1.9	-87	-0.3	1.4	0.0
62	0.1	2.0	-39	-0.1	1.5	0.0
63	0.1	2.0	9	0.0	1.5	0.0
64	0.1	2.0	58	0.2	1.5	0.0
65	0.1	2.1	106	0.4	1.5	0.0
66	0.1	2.1	154	0.6	1.5	0.0
67	0.1	2.1	202	0.8	1.5	0.0
68	0.1	2.1	250	1.0	1.5	0.0
69	0.1	2.2	298	1.1	1.5	0.0
70	0.1	2.2	347	1.3	1.5	0.1

Slice No.	Area (m^2)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
71	0.1	2.2	395	1.5	1.6	0.1
72	0.1	2.2	443	1.7	1.6	0.1
73	0.1	2.3	491	1.9	1.6	0.1
74	0.1	2.3	539	2.1	1.6	0.1
75	0.1	2.3	587	2.2	1.6	0.1
76	0.1	2.4	635	2.4	1.6	0.1
77	0.1	2.4	684	2.6	1.6	0.1
78	0.1	2.4	732	2.8	1.6	0.1
79	0.1	2.4	780	3.0	1.6	0.1
80	0.1	2.5	828	3.2	1.7	0.1
81	0.1	2.5	876	3.3	1.7	0.1
82	0.1	2.5	924	3.5	1.7	0.2
83	0.1	2.5	973	3.7	1.7	0.2
84	0.1	2.6	1021	3.9	1.7	0.2
85	0.1	2.6	1069	4.1	1.7	0.2
86	0.1	2.6	1117	4.3	1.7	0.2
87	0.1	2.6	1165	4.5	1.7	0.2
88	0.1	2.7	1213	4.6	1.7	0.2
89	0.1	2.7	1261	4.8	1.8	0.2
90	0.2	2.7	1310	5.0	1.8	0.2
91	0.2	2.7	1358	5.2	1.8	0.2
92	0.2	2.8	1406	5.4	1.8	0.3
93	0.2	2.8	1454	5.6	1.8	0.3
94	0.2	2.8	1502	5.7	1.8	0.3
95	0.2	2.8	1550	5.9	1.8	0.3
96	0.2	2.8	1598	6.1	1.8	0.3
97	0.2	2.9	1647	6.3	1.8	0.3
98	0.2	2.9	1695	6.5	1.8	0.3
99	0.2	2.9	1743	6.7	1.9	0.3
100	0.2	2.9	1791	6.9	1.9	0.4
101	0.2	3.0	1839	7.0	1.9	0.4
102	0.2	3.0	1887	7.2	1.9	0.4
103	0.2	3.0	1936	7.4	1.9	0.4
104	0.2	3.0	1984	7.6	1.9	0.4

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

Slice No.	Area (m^2)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
105	0.2	3.1	2032	7.8	1.9	0.4
106	0.2	3.1	2080	8.0	1.9	0.4
107	0.2	3.1	2128	8.2	1.9	0.4
108	0.2	3.1	2176	8.3	1.9	0.5
109	0.2	3.1	2224	8.5	2.0	0.5
110	0.2	3.2	2273	8.7	2.0	0.5
111	0.2	3.2	2321	8.9	2.0	0.5
112	0.2	3.2	2369	9.1	2.0	0.5
113	0.2	3.2	2417	9.3	2.0	0.5
114	0.2	3.2	2465	9.5	2.0	0.5
115	0.2	3.3	2513	9.6	2.0	0.5
116	0.2	3.3	2562	9.8	2.0	0.6
117	0.2	3.3	2610	10.0	2.0	0.6
118	0.2	3.3	2658	10.2	2.0	0.6
119	0.2	3.3	2706	10.4	2.0	0.6
120	0.2	3.4	2754	10.6	2.1	0.6
121	0.2	3.4	2802	10.8	2.1	0.6
122	0.2	3.4	2850	11.0	2.1	0.6
123	0.2	3.4	2899	11.1	2.1	0.7
124	0.2	3.4	2947	11.3	2.1	0.7
125	0.2	3.5	2995	11.5	2.1	0.7
126	0.2	3.5	3043	11.7	2.1	0.7
127	0.2	3.5	3091	11.9	2.1	0.7
128	0.2	3.5	3139	12.1	2.1	0.7
129	0.2	3.5	3187	12.3	2.1	0.8
130	0.2	3.6	3236	12.5	2.1	0.8
131	0.2	3.6	3284	12.6	2.1	0.8
132	0.2	3.6	3332	12.8	2.2	0.8
133	0.2	3.6	3380	13.0	2.2	0.8
134	0.2	3.6	3428	13.2	2.2	0.8
135	0.2	3.7	3476	13.4	2.2	0.8
136	0.2	3.7	3525	13.6	2.2	0.9
137	0.2	3.7	3573	13.8	2.2	0.9
138	0.2	3.7	3621	14.0	2.2	0.9

Slice No.	Area (m^2)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
139	0.2	3.7	3669	14.2	2.2	0.9
140	0.2	3.7	3717	14.3	2.2	0.9
141	0.2	3.8	3765	14.5	2.2	0.9
142	0.2	3.8	3813	14.7	2.2	1.0
143	0.2	3.8	3862	14.9	2.2	1.0
144	0.2	3.8	3910	15.1	2.3	1.0
145	0.2	3.8	3958	15.3	2.3	1.0
146	0.2	3.9	4006	15.5	2.3	1.0
147	0.2	3.9	4054	15.7	2.3	1.0
148	0.2	3.9	4102	15.9	2.3	1.1
149	0.2	3.9	4151	16.1	2.3	1.1
150	0.2	3.9	4199	16.3	2.3	1.1
151	0.2	3.9	4247	16.4	2.3	1.1
152	0.2	4.0	4295	16.6	2.3	1.1
153	0.2	4.0	4343	16.8	2.3	1.2
154	0.2	4.0	4391	17.0	2.3	1.2
155	0.2	4.0	4439	17.2	2.3	1.2
156	0.2	4.0	4488	17.4	2.3	1.2
157	0.2	4.0	4536	17.6	2.3	1.2
158	0.2	4.0	4584	17.8	2.3	1.2
159	0.2	4.0	4632	18.0	2.3	1.2
160	0.2	4.0	4680	18.2	2.3	1.2
161	0.2	4.0	4728	18.4	2.3	1.2
162	0.2	3.9	4777	18.6	2.3	1.3
163	0.2	3.9	4825	18.8	2.3	1.3
164	0.2	3.9	4873	19.0	2.3	1.3
165	0.2	3.9	4921	19.1	2.3	1.3
166	0.2	3.9	4969	19.3	2.3	1.3
167	0.2	3.9	5017	19.5	2.3	1.3
168	0.2	3.9	5065	19.7	2.3	1.3
169	0.2	3.8	5114	19.9	2.3	1.3
170	0.2	3.8	5162	20.1	2.3	1.3
171	0.2	3.8	5210	20.3	2.3	1.3
172	0.2	3.8	5258	20.5	2.2	1.3

Slice No.	Area (m^2)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
173	0.2	3.8	5306	20.7	2.2	1.3
174	0.2	3.8	5354	20.9	2.2	1.3
175	0.2	3.8	5402	21.1	2.2	1.4
176	0.2	3.7	5451	21.3	2.2	1.4
177	0.2	3.7	5499	21.5	2.2	1.4
178	0.2	3.7	5547	21.7	2.2	1.4
179	0.2	3.7	5595	21.9	2.2	1.4
180	0.2	3.7	5643	22.1	2.2	1.4
181	0.2	3.7	5691	22.3	2.2	1.4
182	0.2	3.6	5740	22.5	2.2	1.4
183	0.2	3.6	5788	22.7	2.2	1.4
184	0.2	3.6	5836	22.9	2.2	1.4
185	0.2	3.6	5884	23.1	2.2	1.4
186	0.2	3.6	5932	23.3	2.1	1.4
187	0.2	3.5	5980	23.5	2.1	1.4
188	0.2	3.5	6028	23.7	2.1	1.4
189	0.2	3.5	6077	23.9	2.1	1.4
190	0.2	3.5	6125	24.1	2.1	1.4
191	0.2	3.5	6173	24.3	2.1	1.4
192	0.2	3.5	6221	24.5	2.1	1.4
193	0.2	3.4	6269	24.7	2.1	1.4
194	0.2	3.4	6317	24.9	2.1	1.4
195	0.2	3.4	6366	25.1	2.1	1.4
196	0.2	3.4	6414	25.3	2.1	1.4
197	0.2	3.4	6462	25.5	2.1	1.4
198	0.2	3.3	6510	25.7	2.1	1.4
199	0.2	3.3	6558	25.9	2.0	1.4
200	0.2	3.3	6606	26.1	2.0	1.5
201	0.2	3.3	6654	26.3	2.0	1.5
202	0.2	3.3	6703	26.5	2.0	1.5
203	0.2	3.2	6751	26.7	2.0	1.5
204	0.2	3.2	6799	26.9	2.0	1.5
205	0.2	3.2	6847	27.2	2.0	1.5
206	0.2	3.2	6895	27.4	2.0	1.5

Slice No.	Area (m^2)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
207	0.2	3.1	6943	27.6	2.0	1.5
208	0.2	3.1	6991	27.8	2.0	1.5
209	0.2	3.1	7040	28.0	2.0	1.5
210	0.2	3.1	7088	28.2	1.9	1.5
211	0.2	3.1	7136	28.4	1.9	1.5
212	0.2	3.0	7184	28.6	1.9	1.5
213	0.2	3.0	7232	28.8	1.9	1.5
214	0.2	3.0	7280	29.0	1.9	1.5
215	0.2	3.0	7329	29.2	1.9	1.4
216	0.2	2.9	7377	29.5	1.9	1.4
217	0.2	2.9	7425	29.7	1.9	1.4
218	0.2	2.9	7473	29.9	1.9	1.4
219	0.2	2.9	7521	30.1	1.9	1.4
220	0.2	2.8	7569	30.3	1.8	1.4
221	0.2	2.8	7617	30.5	1.8	1.4
222	0.2	2.8	7666	30.7	1.8	1.4
223	0.2	2.8	7714	30.9	1.8	1.4
224	0.2	2.7	7762	31.2	1.8	1.4
225	0.1	2.7	7810	31.4	1.8	1.4
226	0.1	2.7	7858	31.6	1.8	1.4
227	0.1	2.7	7906	31.8	1.8	1.4
228	0.1	2.6	7955	32.0	1.8	1.4
229	0.1	2.6	8003	32.2	1.8	1.4
230	0.1	2.6	8051	32.5	1.7	1.4
231	0.1	2.6	8099	32.7	1.7	1.4
232	0.1	2.5	8147	32.9	1.7	1.4
233	0.1	2.5	8195	33.1	1.7	1.4
234	0.1	2.5	8243	33.3	1.7	1.4
235	0.1	2.5	8292	33.5	1.7	1.4
236	0.1	2.4	8340	33.8	1.7	1.4
237	0.1	2.4	8388	34.0	1.7	1.3
238	0.1	2.4	8436	34.2	1.7	1.3
239	0.1	2.3	8484	34.4	1.6	1.3
240	0.1	2.3	8532	34.7	1.6	1.3

Slice No.	Area (m^2)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
241	0.1	2.3	8580	34.9	1.6	1.3
242	0.1	2.3	8629	35.1	1.6	1.3
243	0.1	2.2	8677	35.3	1.6	1.3
244	0.1	2.2	8725	35.6	1.6	1.3
245	0.1	2.2	8773	35.8	1.6	1.3
246	0.1	2.1	8821	36.0	1.6	1.3
247	0.1	2.1	8869	36.2	1.5	1.2
248	0.1	2.1	8918	36.5	1.5	1.2
249	0.1	2.0	8966	36.7	1.5	1.2
250	0.1	2.0	9014	36.9	1.5	1.2
251	0.1	2.0	9062	37.2	1.5	1.2
252	0.1	2.0	9110	37.4	1.5	1.2
253	0.1	1.9	9158	37.6	1.5	1.2
254	0.1	1.9	9206	37.9	1.4	1.2
255	0.1	1.9	9255	38.1	1.4	1.1
256	0.1	1.8	9303	38.3	1.4	1.1
257	0.1	1.8	9351	38.6	1.4	1.1
258	0.1	1.8	9399	38.8	1.4	1.1
259	0.1	1.7	9447	39.0	1.4	1.1
260	0.1	1.7	9495	39.3	1.4	1.1
261	0.1	1.7	9544	39.5	1.3	1.1
262	0.1	1.6	9592	39.7	1.3	1.0
263	0.1	1.6	9640	40.0	1.3	1.0
264	0.1	1.6	9688	40.2	1.3	1.0
265	0.1	1.5	9736	40.5	1.3	1.0
266	0.1	1.5	9784	40.7	1.3	1.0
267	0.1	1.4	9832	40.9	1.2	0.9
268	0.1	1.4	9881	41.2	1.2	0.9
269	0.1	1.4	9929	41.4	1.2	0.9
270	0.1	1.3	9977	41.7	1.2	0.9
271	0.1	1.3	10025	41.9	1.2	0.9
272	0.1	1.3	10073	42.2	1.2	0.8
273	0.1	1.2	10121	42.4	1.1	0.8
274	0.1	1.2	10170	42.7	1.1	0.8

Slice No.	Area (m^2)	W (kN/m)	x (mm)	α (deg)	B (kN/m)	T (kN/m)
275	0.1	1.1	10218	42.9	1.1	0.8
276	0.1	1.1	10266	43.2	1.1	0.8
277	0.1	1.1	10314	43.4	1.1	0.7
278	0.1	1.0	10362	43.7	1.1	0.7
279	0.1	1.0	10410	43.9	1.0	0.7
280	0.1	0.9	10458	44.2	1.0	0.7
281	0.0	0.9	10507	44.5	1.0	0.6
282	0.0	0.9	10555	44.7	1.0	0.6
283	0.0	0.8	10603	45.0	1.0	0.6
284	0.0	0.8	10651	45.2	0.9	0.6
285	0.0	0.7	10699	45.5	0.9	0.5
286	0.0	0.7	10747	45.8	0.9	0.5
287	0.0	0.7	10795	46.0	0.9	0.5
288	0.0	0.6	10844	46.3	0.9	0.4
289	0.0	0.6	10892	46.5	0.8	0.4
290	0.0	0.5	10940	46.8	0.8	0.4
291	0.0	0.5	10988	47.1	0.8	0.3
292	0.0	0.4	11036	47.4	0.8	0.3
293	0.0	0.4	11084	47.6	0.7	0.3
294	0.0	0.3	11133	47.9	0.7	0.2
295	0.0	0.3	11181	48.2	0.7	0.2
296	0.0	0.2	11229	48.5	0.7	0.2
297	0.0	0.2	11277	48.7	0.6	0.1
298	0.0	0.1	11325	49.0	0.6	0.1
299	0.0	0.1	11373	49.3	0.6	0.1
300	0.0	0.0	11413	49.5	0.6	0.0
Σ					485.4	208.9

Origin co-ordinates;	x = 3000 mm
	y = 14700 mm
Radius of circle;	R = 15003 mm
Sector angle;	θ = 61.254 deg
Number of slices;	N = 300
Width of each slice;	b = (AB + L + EF) / N = 48 mm
For each slice, angle;	$\alpha_N = \mathrm{asin}(x_N / R)$
Slice weight;	$W_N = b \times h_N \times \gamma$

Pore pressure; $u_N = r_u \times \gamma \times h_N$

$B_N = [c' \times b + (W_N - u_N \times b) \times \tan(\phi')] \times \sec(\alpha_N) / (1 + \tan(\alpha_N) \times \tan(\phi') / F)$

Shearing force induced along base; $T_N = W_N \times \sin(\alpha_N)$

ΣB = 485.368 kN/m

Sum of shearing forces induced along base; ΣT = 208.878 kN/m

Factor of safety using Fellenius' method; $F = \Sigma B / \Sigma T$ = 2.324

Required factor of safety; F_{req} = 2

PASS - Actual factor of safety exceeds required factor of safety