Vale Consultancy
Consulting Civil & Structural Engineers

Title: Retaining Wall Calculations.

Project: Ty Twyn, Mill Road, Dinas Powys,
           Vale of Glamorgan, CF64 4BT.

Client: Mr T Woodward.

SCOPE & DESIGN

- THE EXISTING FRONT GARDEN WALL TO TY TWYN MILL ROAD DINAS POWYS, VALE OF GLAMORGAN CF64 4BT, FRONTED ONTO THE ADOPTED HIGHWAY, MILL ROAD BETWEEN THE WALL AND CARRIAGEWAY IS A NARROW TARMAC FINISHED VERGE & STANDARD KERB DETAIL. MIDWAY ALONG THE FRONTAGE IS A TIMBER POLE SUPPORTING WESTERN POWER DISTRIBUTION CABLES. IN ADDITION THERE ARE ALSO BURIED SERVICES WITHIN THE VERGE.

- THE EXISTING WALL HAD FAILED AND WAS FULLY REMOVED DUE TO THE REMAINING RISK OF FURTHER COLLAPSE ONTO THE PUBLIC HIGHWAY. THE ORIGINAL WALL APPEARED TO BE PREDOMINANTLY A DRY STONE CONSTRUCTION, AND HAD CONSIDERABLE ESTABLISHED IVY AND TREE GROWTH FROM WITHIN THE FACE AND TOP OF THE WALL.

- THE REMOVAL OF THE WALL EXPOSED A STEPPED ROCK FACE, WHICH IS PARTIALLY TERRACED. THE BASE OF THE ROCK OUTCROP IS ABOVE THE HIGHWAY VERGE WHICH CONTAINS SERVICES

- V&G HIGHWAYS DEPT COMMENTED ON A PREVIOUS SCHEME THAT WAS SUBMITTED, WHICH WAS APPROVED. THIS CURRENT SCHEME IS BASED ON THE SAME PRINCIPALS WITH SOME VARIATIONS TO SUIT SITE CONDITIONS & CONSTRAINTS. NAMELY THE ALIGNMENT OF THE ROCK FACE, THE ELEVATION OF THE ROCK OUTCROP ABOVE THE HIGHWAY VERGE AND PRESENCE OF EXISTING SERVICES IN THE HIGHWAY VERGE.

- TO CONSTRAIN THE WALL HEIGHT, THE WALLS WILL BE TERRACED, WITH TWO WALLS TO LIMIT THE HEIGHT OF EACH WALL. PRACTICALLY & TO PROVIDE STABILITY THE WALLS WILL BE CONSTRUCTED OFF THE TOP FACE OF THE ROCK OUTCROP, OTHERWISE THE WALLS WOULD HAVE TO BE CONSTRUCTED OFF COMPACTED FILL, WHICH DUE TO THE LOCATION & CONSTRUCTIVE SITE CONDITIONS WOULD NOT BE ACHIEVABLE.

- A TOPOGRAPHIC SURVEY OF THE SITE HAS BEEN USED TO ESTABLISH THE ALIGNMENT AND FORMATION LEVEL OF EACH WALL. AS SHOWN IN THE CALCULATIONS & DRAWINGS THE

SCOPE & DESIGN (CONT)

- RETAINED HEIGHT ABOVE THE WALL BASE FOR THE BOTTOM & TOP WALLS ARE 1.85m & 1.0m RESPECTIVELY. AS PER V&G HIGHWAYS COMMENTS ON THE PREVIOUS SCHEME A 2.5KN/m² SURCHARGE HAS BEEN APPLIED TO BOTH WALLS TO ALLOW FOR PARKING ON THE DRIVEWAY ABOVE THE UPPER WALL & CONSTRUCTION LOADS ON BOTH WALLS.

- THE WALL CONSTRUCTION CONSISTS OF A MASONRY CAVITY BLOCKWORK WALL WITH REINFORCED CONCRETE CORE, & REINFORCED CONCRETE BASE. THE WALL IS IN A CONSERVATION AREA, AND AS SUCH WILL BE CLAD IN NON STRUCTURAL BONDED STONE FACING. AS THE LOWER LEVEL WALL FOUNDATION WILL BE ABOVE THE ROAD VERGE LEVEL, THE STONE FACING WILL BE SUPPORTED ON A STAINLESS STEEL ANGLE SUPPORT SYSTEM (CAST INTO THE FOUNDATION FACE) TO MASK THE FOUNDATION.

- DUE TO THE ELEVATED POSITION OF THE LOWER WALL AN EFFECTIVE DRAINAGE SYSTEM IS NOT FEASIBLE. IT IS PROPOSED TO TO PROVIDE A FLUTED CHANNEL TO THE WALL BASE TO PREVENT GROUND WATER RUNOFF FROM THE WALL/ROCK FACE TRACKING ACROSS THE HIGHWAY VERGE. THERE WILL ALSO BE FLUTED CHANNELS CROSSING THE VERGE TO CHANNEL WATER INTO THE NEARBY HIGHWAY GULLEY.

- THE FINAL ALIGNMENT OF BOTH WALLS WILL BE DETERMINED WHEN ALL LOOSE MATERIAL HAS BEEN REMOVED FROM THE FACE OF THEIR ROCK OUTCROP.

- A GROUND BEARING PRESSURE OF 250KN/m² ONTO THE UPPER FACE OF THE ROCK HAS BEEN ADOPTED IN THE DESIGN. THE LOWER WALL WILL ALSO HAVE RESIN ANCHORED DOWELS INTO THE ROCK FACE AT THE REAR OF THE FOUNDATION FOR FURTHER STABILITY.

- THE WALLS WORK AS FREESTANDING ELEMENTS, HOWEVER DOWELS INTO THE ROCK FACE BEHIND THE LOWER WALLS HAVE BEEN INDICATED ON DRAWING 6157-02 TO PROVIDE ADDITIONAL REDUNDANCY DUE TO ITS POSITION.

LOADING.

BACK FILL & RETAINED MATERIAL CALCULATED IN
TERMS SOFTWARE FOR BOTH LOWER & UPPER WALL.

LOWER WALL

BONDED STONE FACE CLADDING

THICKNESS - 100mm   HEIGHT - 2.15m.

$\text{LOAD}/m = 22 kN/m^3 \times 0.1 \times 2.15 = 4.75 \ kN/m$ } — APPLIED AT FACE OF WALL *

SURCHARGE $= 2.5 \ kN/m^2$
ONLY PRACTICALLY APPLIED DURING CONSTRUCTION
& BACKFILLING. NOT APPLIED LONG TERM WITH CLADDING.

DESIGN WITH 'AT REST' PRESSURE

DESIGN WITH ALLOWANCE FOR 300mm
PLANNED EXCAVATION IN FRONT OF TOE TO
REMOVE PASSIVE PRESSURE RESISTANCE

UPPER WALL

BONDED STONE FACE CLADDING

THICKNESS - 100mm   HEIGHT - 1.3m.

$\text{LOAD}/m = 22 kN/m^3 \times 0.1 \times 1.3 = 2.9 \ kN/m$ } — APPLIED AT 50mm FROM FACE OF WALL

SURCHARGE $= 2.5 \ kN/m^2$

DESIGN WITH 'AT REST' PRESSURE

DESIGN WITH ALLOWANCE FOR 300mm PLANNED
EXCAVATION IN FRONT OF TOE TO REMOVE
PASSIVE PRESSURE RESISTANCE.

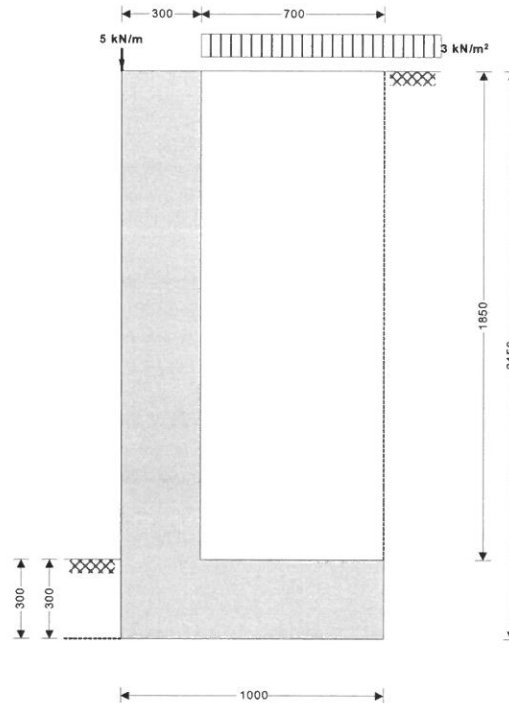*   NOMINAL MOMENT FROM ECCENTRIC CLADDING LOAD
     $4.75 \ kN/m \times 0.06m = 0.3 \ kNm/m$

     FROM TERMS OUTPUT - LOAD APPLIED AT WALL FACE
     OVERTURNING MOMENT = 9.7 kNm/m RESISTANCE : 19.9 kNm/m ∴ OK OF
     ADDITIONAL
     NOMINAL MOMENT

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RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Wall details

Retaining wall type	**Unpropped cantilever**
Height of retaining wall stem	h_{stem} = **1850** mm
Thickness of wall stem	t_{wall} = **300** mm
Length of toe	l_{toe} = **0** mm
Length of heel	l_{heel} = **700** mm
Overall length of base	l_{base} = l_{toe} + l_{heel} + t_{wall} = **1000** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **450** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	h_{wall} = h_{stem} + t_{base} + d_{ds} = **2150** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **300** mm
Height of ground water behind wall	h_{water} = **0** mm
Height of saturated fill above base	h_{sat} = max(h_{water} - t_{base} - d_{ds}, 0 mm) = **0** mm
Density of wall construction	γ_{wall} = **20.0** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	h_{eff} = h_{wall} + l_{heel} × tan(β) = **2150** mm

Retained material details

Mobilisation factor	M = **1.2**
Moist density of retained material	γ_m = **17.5** kN/m^3

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Saturated density of retained material $\gamma_s = $ **21.0 kN/m³**

Design shear strength $\phi' = $ **29.3 deg**

Angle of wall friction $\delta = $ **22.8 deg**

Base material details

Moist density $\gamma_{mb} = $ **18.0 kN/m³**

Design shear strength $\phi'_b = $ **27.5 deg**

Design base friction $\delta_b = $ **21.3 deg**

Allowable bearing pressure $P_{bearing} = $ **200 kN/m²**

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.304}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{5.571}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi') = $ **0.511**

Loading details

Surcharge load on plan $Surcharge = $ **2.5 kN/m²**

Applied vertical dead load on wall $W_{dead} = $ **4.7 kN/m**

Applied vertical live load on wall $W_{live} = $ **0.0 kN/m**

Position of applied vertical load on wall $l_{load} = $ **0 mm**

Applied horizontal dead load on wall $F_{dead} = $ **0.0 kN/m**

Applied horizontal live load on wall $F_{live} = $ **0.0 kN/m**

Height of applied horizontal load on wall $h_{load} = $ **0 mm**
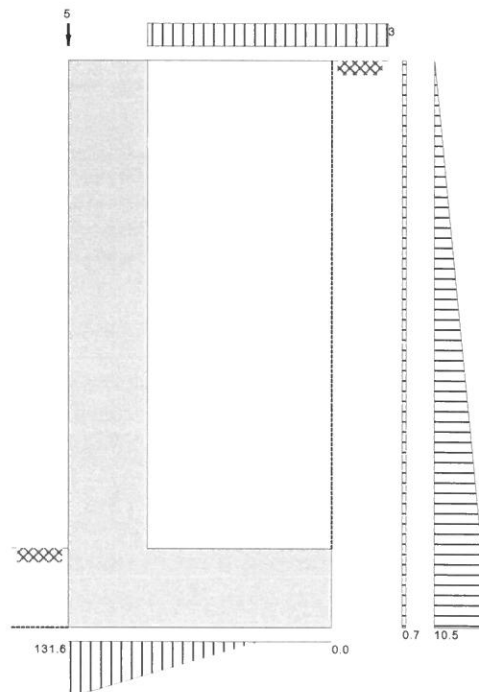
Loads shown in kN/m, pressures shown in kN/m²

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = $ **11.1 kN/m**

![Vale Consultancy Logo] VALE CONSULTANCY CONSULTING CIVIL & STRUCTURAL ENGINEERS 29 Bocam Park, Old Field Road Pencoed, Bridgend CF35 5LJ	Project Ty Twyn, Mill Road, Dinas Powys, Vale of Glamorgan			Job no. 6154	
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Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base} =$ **7.1 kN/m**	
Surcharge	$w_{sur} = Surcharge \times l_{heel} =$ **1.8 kN/m**	
Moist backfill to top of wall	$w_{m\_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m =$ **22.7 kN/m**	
Applied vertical load	$W_v = W_{dead} + W_{live} =$ **4.7 kN/m**	
Total vertical load	$W_{total} = w_{wall} + w_{base} + w_{sur} + w_{m\_w} + W_v =$ **47.3 kN/m**	

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff} =$ **1.5 kN/m**
Moist backfill above water table	$F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 =$ **11.3 kN/m**
Total horizontal load	$F_{total} = F_{sur} + F_{m\_a} =$ **12.8 kN/m**

Calculate stability against sliding

Resistance to sliding $F_{res} = (W_{total} - w_{sur}) \times \tan(\delta_b) =$ **17.8 kN/m**

PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 =$ **1.6 kNm/m**
Moist backfill above water table	$M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 =$ **8.1 kNm/m**
Total overturning moment	$M_{ot} = M_{sur} + M_{m\_a} =$ **9.7 kNm/m**

Restoring moments

Wall stem	$M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) =$ **1.7 kNm/m**
Wall base	$M_{base} = w_{base} \times l_{base} / 2 =$ **3.5 kNm/m**
Moist backfill	$M_{m\_r} = (w_{m\_w} \times (l_{base} - l_{heel} / 2) + w_{m\_s} \times (l_{base} - l_{heel} / 3)) =$ **14.7 kNm/m**
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{m\_r} =$ **19.9 kNm/m**

Check stability against overturning

Total overturning moment $M_{ot} =$ **9.7 kNm/m**

Total restoring moment $M_{rest} =$ **19.9 kNm/m**

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge	$M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2) =$ **1.1 kNm/m**
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur\_r} =$ **11.3 kNm/m**
Total vertical reaction	$R = W_{total} =$ **47.3 kN/m**
Distance to reaction	$x_{bar} = M_{total} / R =$ **240 mm**
Eccentricity of reaction	$e = abs((l_{base} / 2) - x_{bar}) =$ **260 mm**

Reaction acts outside middle third of base

Bearing pressure at toe	$p_{toe} = R / (1.5 \times x_{bar}) =$ **131.6 kN/m²**
Bearing pressure at heel	$p_{heel} = 0$ kN/m² = **0 kN/m²**

PASS - Maximum bearing pressure is less than allowable bearing pressure

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RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor $\qquad \gamma_{f\_d} = \mathbf{1.4}$

Live load factor $\qquad \gamma_{f\_l} = \mathbf{1.6}$

Earth and water pressure factor $\qquad \gamma_{f\_e} = \mathbf{1.4}$

Factored vertical forces on wall

Wall stem $\qquad w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = \mathbf{15.5}$ kN/m

Wall base $\qquad w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base} = \mathbf{9.9}$ kN/m

Surcharge $\qquad w_{sur\_f} = \gamma_{f\_l} \times$ Surcharge $\times l_{heel} = \mathbf{2.8}$ kN/m

Moist backfill to top of wall $\qquad w_{m\_w\_f} = \gamma_{f\_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = \mathbf{31.7}$ kN/m

Applied vertical load $\qquad W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live} = \mathbf{6.6}$ kN/m

Total vertical load $\qquad W_{total\_f} = w_{wall\_f} + w_{base\_f} + w_{sur\_f} + w_{m\_w\_f} + W_{v\_f} = \mathbf{66.6}$ kN/m

Factored horizontal at-rest forces on wall

Surcharge $\qquad F_{sur\_f} = \gamma_{f\_l} \times K_0 \times$ Surcharge $\times h_{eff} = \mathbf{4.4}$ kN/m

Moist backfill above water table $\qquad F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = \mathbf{28.9}$ kN/m

Total horizontal load $\qquad F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} = \mathbf{33.3}$ kN/m

Factored overturning moments

Surcharge $\qquad M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = \mathbf{4.7}$ kNm/m

Moist backfill above water table $\qquad M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = \mathbf{20.7}$ kNm/m

Total overturning moment $\qquad M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} = \mathbf{25.4}$ kNm/m

Restoring moments

Wall stem $\qquad M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2) = \mathbf{2.3}$ kNm/m

Wall base $\qquad M_{base\_f} = w_{base\_f} \times l_{base} / 2 = \mathbf{5}$ kNm/m

Surcharge $\qquad M_{sur\_r\_f} = w_{sur\_f} \times (l_{base} - l_{heel} / 2) = \mathbf{1.8}$ kNm/m

Moist backfill $\qquad M_{m\_r\_f} = (w_{m\_w\_f} \times (l_{base} - l_{heel} / 2) + w_{m\_s\_f} \times (l_{base} - l_{heel} / 3)) = \mathbf{20.6}$ kNm/m

Total restoring moment $\qquad M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{m\_r\_f} = \mathbf{29.7}$ kNm/m

Factored bearing pressure

Total moment for bearing $\qquad M_{total\_f} = M_{rest\_f} - M_{ot\_f} = \mathbf{4.3}$ kNm/m

Total vertical reaction $\qquad R_f = W_{total\_f} = \mathbf{66.6}$ kN/m

Distance to reaction $\qquad x_{bar\_f} = M_{total\_f} / R_f = \mathbf{64}$ mm

Eccentricity of reaction $\qquad e_f = abs((l_{base} / 2) - x_{bar\_f}) = \mathbf{436}$ mm

Reaction acts outside middle third of base

Bearing pressure at toe $\qquad p_{toe\_f} = R_f / (1.5 \times x_{bar\_f}) = \mathbf{688.9}$ kN/m^2

Bearing pressure at heel $\qquad p_{heel\_f} = 0$ kN/m$^2 = \mathbf{0}$ kN/m^2

Rate of change of base reaction $\qquad rate = p_{toe\_f} / (3 \times x_{bar\_f}) = \mathbf{3564.61}$ kN/m^2/m

Bearing pressure at stem / toe $\qquad p_{stem\_toe\_f} = max(p_{toe\_f} - (rate \times l_{toe}), 0$ kN/m$^2) = \mathbf{688.9}$ kN/m^2

Bearing pressure at mid stem $\qquad p_{stem\_mid\_f} = max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0$ kN/m$^2) = \mathbf{154.2}$ kN/m^2

Bearing pressure at stem / heel $\qquad p_{stem\_heel\_f} = max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0$ kN/m$^2) = \mathbf{0}$ kN/m^2

Design of reinforced concrete retaining wall heel (BS 8002:1994)

Material properties

Characteristic strength of concrete $\qquad f_{cu} = \mathbf{35}$ N/mm^2

Characteristic strength of reinforcement $\qquad f_y = \mathbf{500}$ N/mm^2

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Base details

Minimum area of reinforcement $k = 0.13$ %

Cover to reinforcement in heel $C_{heel} = 35$ mm

Calculate shear for heel design

Shear from weight of base $V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base} = 6.9$ kN/m

Shear from weight of moist backfill $V_{heel\_wt\_m} = w_{m\_w\_f} = 31.7$ kN/m

Shear from surcharge $V_{heel\_sur} = w_{sur\_f} = 2.8$ kN/m

Total shear for heel design $V_{heel} = V_{heel\_wt\_base} + V_{heel\_wt\_m} + V_{heel\_sur} = 41.5$ kN/m

Calculate moment for heel design

Moment from weight of base $M_{heel\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 3.6$ kNm/m

Moment from weight of moist backfill $M_{heel\_wt\_m} = w_{m\_w\_f} \times (l_{heel} + t_{wall}) / 2 = 15.9$ kNm/m

Moment from surcharge $M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2 = 1.4$ kNm/m

Total moment for heel design $M_{heel} = M_{heel\_wt\_base} + M_{heel\_wt\_m} + M_{heel\_sur} = 20.8$ kNm/m
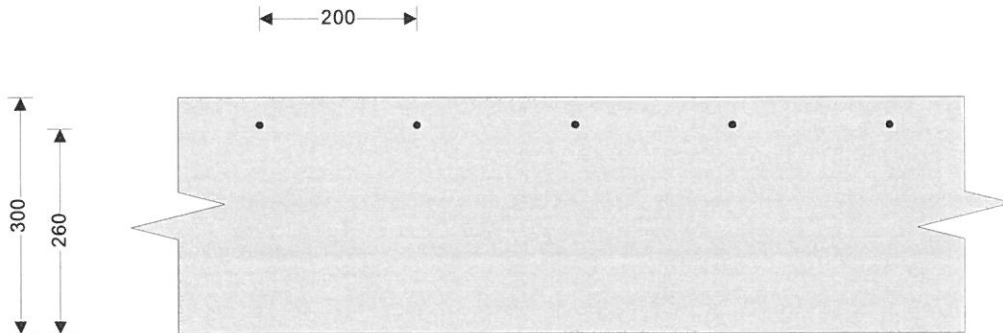
Check heel in bending

Width of heel $b = 1000$ mm/m

Depth of reinforcement $d_{heel} = t_{base} - C_{heel} - (\phi_{heel} / 2) = 260.0$ mm

Constant $K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = 0.009$

Compression reinforcement is not required

Lever arm $z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))}, 0.95) \times d_{heel}$

$z_{heel} = 247$ mm

Area of tension reinforcement required $A_{s\_heel\_des} = M_{heel} / (0.87 \times f_y \times z_{heel}) = 194$ mm²/m

Minimum area of tension reinforcement $A_{s\_heel\_min} = k \times b \times t_{base} = 390$ mm²/m

Area of tension reinforcement required $A_{s\_heel\_req} = \max(A_{s\_heel\_des}, A_{s\_heel\_min}) = 390$ mm²/m

Reinforcement provided **A393 mesh**

Area of reinforcement provided $A_{s\_heel\_prov} = 393$ mm²/m

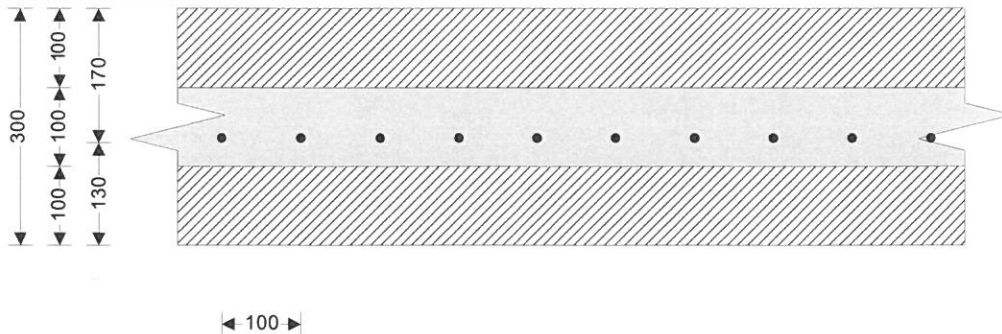**PASS - Reinforcement provided at the retaining wall heel is adequate**

Check shear resistance at heel

Design shear stress $v_{heel} = V_{heel} / (b \times d_{heel}) = 0.159$ N/mm²

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 = 4.733$ N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_heel} = 0.419$ N/mm²

$v_{heel} < v_{c\_heel}$ - **No shear reinforcement required**

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Design of cavity reinforced masonry retaining wall stem - BS5628-2:2000

Wall details

Thickness of outer leaf of wall $\qquad$ $t_{outer} = \mathbf{100}$ mm

Thickness of inner leaf of wall $\qquad$ $t_{inner} = \mathbf{100}$ mm

Thickness of reinforced cavity $\qquad$ $t_{cavity} = t_{wall} - t_{outer} - t_{inner} = \mathbf{100}$ mm

Depth of stem reinforcement $\qquad$ $d_{stem} = \mathbf{170}$ mm

Masonry details

Masonry type $\qquad$ **Aggregate concrete blocks no voids**

Compressive strength of units $\qquad$ $p_{unit} = \mathbf{7.3}$ N/mm^2

Mortar designation $\qquad$ **(ii)**

Category of manufactoring control of units $\qquad$ **Category I**

Partial safety factor for material strength $\qquad$ $\gamma_{mm} = \mathbf{2.0}$

Characteristic compressive strength of masonry

Least horizontal dimension of masonry units $\qquad$ $b_{unit} = \mathbf{100.0}$ mm

Height of masonry units $\qquad$ $h_{unit} = \mathbf{215.0}$ mm

Ratio of height to least horizontal dimension $\qquad$ $ratio = h_{unit} / b_{unit} = \mathbf{2.2}$

From BS5628:2 Table 3d, mortar ii

Characteristic compressive strength $\qquad$ $f_k = \mathbf{6.4}$ N/mm^2

Factored horizontal at-rest forces on stem

Surcharge $\qquad$ $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds}) = \mathbf{3.8}$ kN/m

Moist backfill above water table $\qquad$ $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = \mathbf{21.4}$ kN/m

Calculate shear for stem design

Shear at base of stem $\qquad$ $V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} = \mathbf{25.2}$ kN/m

Calculate moment for stem design

Surcharge $\qquad$ $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2 = \mathbf{4.1}$ kNm/m

Moist backfill above water table $\qquad$ $M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = \mathbf{16.4}$ kNm/m

Total moment for stem design $\qquad$ $M_{stem} = M_{s\_sur} + M_{s\_m\_a} = \mathbf{20.5}$ kNm/m

Check maximum design moment for wall stem

Width of wall $\qquad$ $b = \mathbf{1000}$ mm/m

Maximum design moment $\qquad$ $M_{d\_stem} = 0.4 \times f_k \times b \times d_{stem}^2 / \gamma_{mm} = \mathbf{37.0}$ kNm/m

PASS - Applied moment is less than maximum design moment

Check wall stem in bending

Moment of resistance factor $\qquad$ $Q = M_{stem} / d_{stem}^2 = \mathbf{0.708}$ N/mm^2

$\qquad$ $Q = 2 \times c \times (1 - c) \times f_k / \gamma_{mm}$

Lever arm factor $\qquad$ $c = \mathbf{0.873}$

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Lever arm
$z_{stem} = min(0.95, c) \times d_{stem} = \textbf{148.4 mm}$

Area of tension reinforcement required
$A_{s\_stem\_des} = M_{stem} \times \gamma_{ms} / (f_y \times z_{stem}) = \textbf{317 mm}^2\textbf{/m}$

Minimum area of tension reinforcement
$A_{s\_stem\_min} = k \times b \times t_{wall} = \textbf{390 mm}^2\textbf{/m}$

Area of tension reinforcement required
$A_{s\_stem\_req} = Max(A_{s\_stem\_des}, A_{s\_stem\_min}) = \textbf{390 mm}^2\textbf{/m}$

Reinforcement provided
12 mm dia.bars @ 100 mm centres

Area of reinforcement provided
$A_{s\_stem\_prov} = \pi \times \phi_{stem}^2 / (4 \times s_{stem}) = \textbf{1131 mm}^2\textbf{/m}$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress
$v_{stem} = V_{stem} / (b \times d_{stem}) = \textbf{0.148 N/mm}^2$

Basic characteristic shear strength of masonry
$f_{vbas} = min[0.35 + (17.5 \times A_{s\_stem\_prov} / (b \times d_{stem})), 0.7] \times 1 \text{ N/mm}^2$
$f_{vbas} = \textbf{0.466 N/mm}^2$

Shear span
$a = M_{stem} / V_{stem} = \textbf{812.9 mm}$

Characteristic shear strength of masonry
$f_v = Min(f_{vbas} \times max(2.5 - 0.25 \times (a / d_{stem}), 1), 1.75 \text{ N/mm}^2)$
$f_v = \textbf{0.608 N/mm}^2$

Allowable shear stress
$v_{adm} = f_v / \gamma_{mv} = \textbf{0.304 N/mm}^2$

PASS - Design shear stress is less than maximum shear stress

Check limiting dimensions

Limiting span/effective depth ratio
$ratio_{max} = \textbf{18.00}$

Actual span/effective depth ratio
$ratio_{act} = (h_{stem} + d_{stem} / 2) / d_{stem} = \textbf{11.38}$

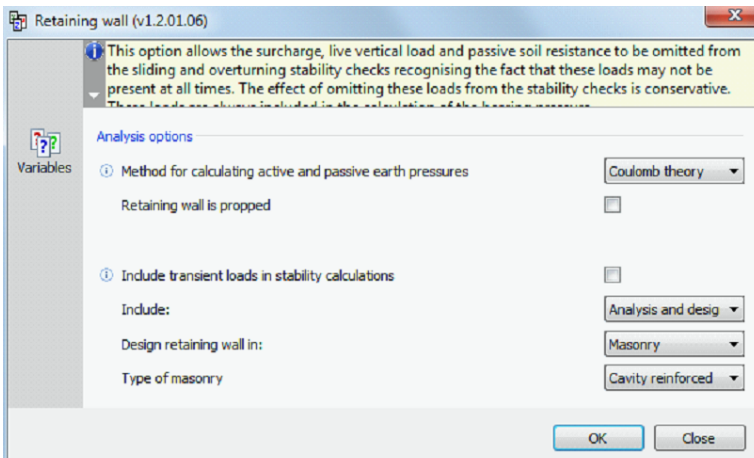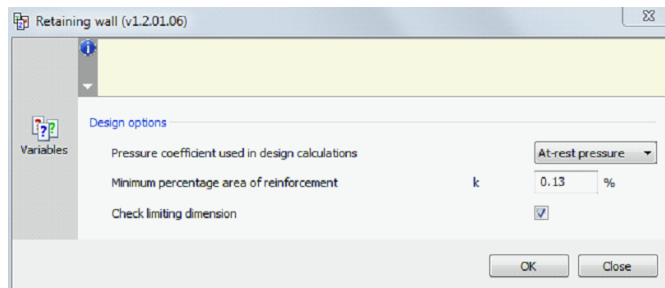*PASS - Span to depth ratio is acceptable*

Axial load check

Factored axial load on wall
$N_{wall} = ([t_{wall} \times h_{stem} \times \gamma_{wall} + W_{dead}] \times \gamma_{f\_d}) + (W_{live} \times \gamma_{f\_l}) = \textbf{22.1 kN/m}$

Limiting axial load
$N_{limit} = 0.1 \times f_k \times t_{wall} = \textbf{192.0 kN/m}$
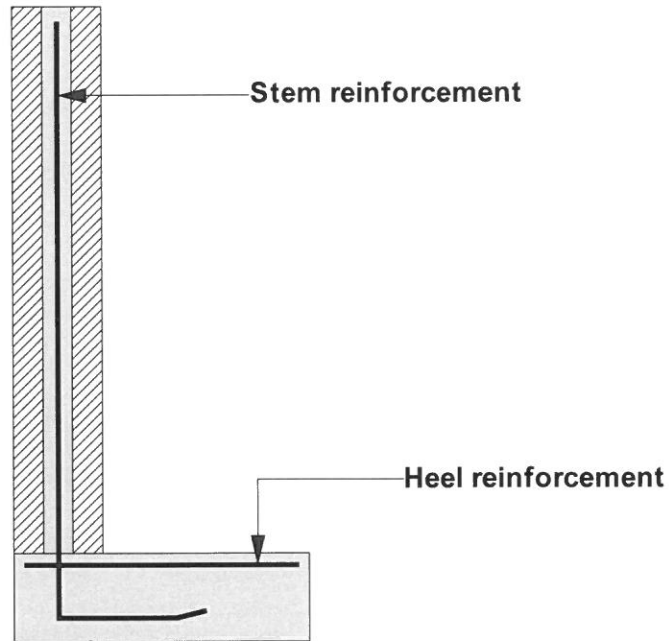
Applied axial load may be ignored - calculations valid

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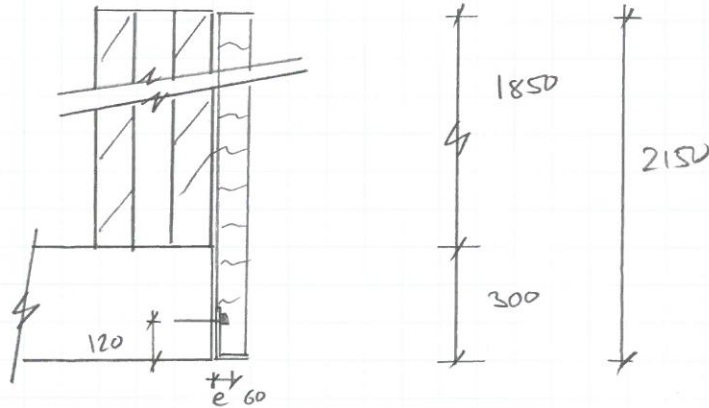**Indicative retaining wall reinforcement diagram**

Heel mesh - A393 - (393 mm^2/m)

Stem bars - 12 mm dia.@ 100 mm centres - (1131 mm^2/m)

LOWER WALL - STONE CLADDING SUPPORT ANGLE

BONDED STONE FACE CLADDING = $22 \, kN/m^3$

THICKNESS = 100mm $\gamma_f = 1.4$

HEIGHT = 2.15m

VERTICAL LOAD ON ANGLE = $22 \, kN/m^3 \times 0.1m \times 2.15m \times 1.4 = 6.6 \, kN/m$

SEE HILTI CAST IN ANCHOR CHANNEL OUTPUT
FOR CHANNEL CAPACITY / DESIGN. TYPICAL 1m LENGTH.

PROVIDE HILTI HAC-50F CHANNEL HBC-C 50R BOLTS.

ANGLE CHECK.

STONE CLADDING UDL_{ULT} = 6.6 kN/m.

ECCENTRICITY 'e' = 60mm.

$MOMENT_{ULT}$ = $6.6 \, kN/m \times 0.06m = 0.4 \, kNm/m$

$P_y = 275 \, N/mm^2$

$Z_{xx \, REQ} = \dfrac{0.4 \, kNm \times 10^6}{275 \, N/mm^2} = 1454 \, mm^3$

TRY 5mm THICK ANGLE

$Z_{xx} = \dfrac{bd^2}{6} = \dfrac{1000 \times 5^2}{6} = 4167 \, mm^3 > 1454 \, mm^3$ ∴ OK

∴ PROVIDE 150×90×5 STAINLESS STEEL ANGLE

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Phone | Fax:	|	Location | Date:	13/08/2017
E-Mail:			

Specifier's comments:

1 Input data

Channel type; bolt	**HAC-50 106/1050 F; HBC-C 50R, M10 x 40 mm**
Effective embedment depth	h_{ef} = 106 mm
Channel specification	Length: 1050 mm, anchor spacing: 250 mm, projection: 25 mm, width: b_{ch} = 42 mm, height: h_{ch} = 31 mm
Material	Anchor & Channel: hot-dip galvanized Bolt: stainless
Europ. Tech. Assessment (ETA)	-
Issued I Valid	- | -
Standard	CEN/TS 1992-4-3
Base material	uncracked, C20/25, $f_{ck,cube}$ = 25.0 N/mm^2, h = ∞ mm
Reinforcement	Exist. Reinf.: Widely spaced Straight edge reinf. present Reinf. to control splitting present
Tolerance data	tolerance interval: -1000 mm/1000 mm most unfavorable tolerance: 0 mm

2 Overall Result

Design ok! (Maximum utilization: 31%)
2.1 Fixtures / Bolt groups / Loads

Fixture 1
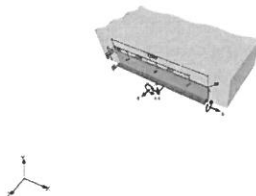
3 Load case / Resulting bolt forces

Load case: Design load

3.1 Load distribution

3.1.1 Fixture 1: bolt: HBC-C 50R, M10 x 40 mm
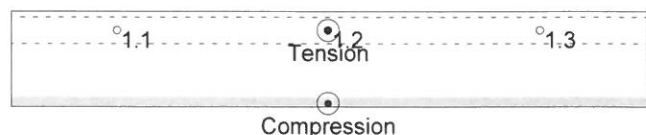
Profile: ; L x W x T = 1000 x 10 x 0 mm
Standoff: No standoff
Plate dimensions: 1000 mm x 150 mm x 10 mm
Anchorplate design calculated: no

Bolt	N [kN]	V [kN]	V_x [kN]	V_y [kN]
1.1	0.959	2.190	0.000	-2.190
1.2	0.959	2.200	0.000	-2.200
1.3	0.959	2.210	0.000	-2.210

°1.1   1.2   °1.3
Tension

Compression

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3.2 Derivation of forces acting on anchor channels

Anchor forces [kN]

Anchor	N	V
a1	0.377	-0.862
a2	0.725	-1.659
a3	0.671	-1.540
a4	0.726	-1.670
a5	0.377	-0.870

3.3 Verifications for anchor channels under tension loading (CEN/TS 1992-4-3:2009 section 6.2)

	Load [kN], [kNm]	Resistance [kN], [kNm]	Utilization [%]	Status
Bolt	0.959	10.150	10	ok

3.4 Verifications for anchor channels under shear loading (CEN/TS 1992-4-3:2009 section 6.3)

	Load [kN], [kNm]	Resistance [kN], [kNm]	Utilization [%]	Status
Bolt w/o lever arm	2.210	7.308	31	ok

3.5 Combined tension and shear loads (CEN/TS 1992-4-3:2009 section 6.4)

Proof of interaction calculated independently for acting load and load distribution

3.5.1 Bolt (Fixture 1, bolt 1.3)

$\beta_{N,s}^{\alpha} + \beta_{V,s}^{\alpha} = 0.095^{2.0} + 0.302^{2.0} = 0.100 \leq 1.000$

$\beta_{N,s}$: governing failure mode - tension: Bolt (Fixture 1, bolt 1.3)
$\beta_{V,s}$: governing failure mode - shear: Bolt w/o lever arm (Fixture 1, bolt 1.3)

3.5.2 Anchor channel (Anchor a3)

$\beta_{N,a}^{\alpha} + \beta_{V,a}^{\alpha} = 0.037^{1.5} + 0.122^{1.5} = 0.050 \leq 1.000$

$\beta_{N,a}$: governing failure mode - tension: Connection anchor-channel (Anchor)
$\beta_{V,a}$: governing failure mode - shear: Concrete edge failure (Anchor)

Remarks and warnings

- Please consider all details and hints/warnings given in the detailed report!
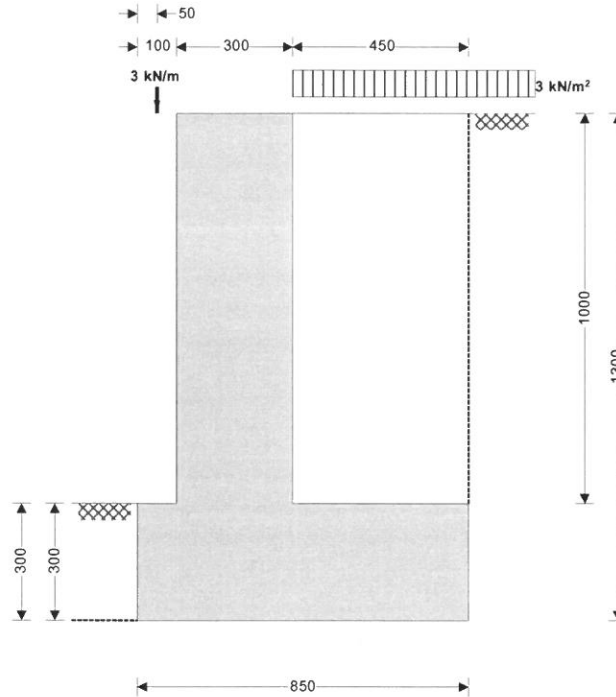
Design ok! (Maximum utilization: 31%)

4 Remarks; Your Cooperation Duties

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RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Wall details

Retaining wall type	**Unpropped cantilever**
Height of retaining wall stem	h_{stem} = **1000** mm
Thickness of wall stem	t_{wall} = **300** mm
Length of toe	l_{toe} = **100** mm
Length of heel	l_{heel} = **450** mm
Overall length of base	l_{base} = l_{toe} + l_{heel} + t_{wall} = **850** mm
Thickness of base	t_{base} = **300** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **450** mm
Thickness of downstand	t_{ds} = **300** mm
Height of retaining wall	h_{wall} = h_{stem} + t_{base} + d_{ds} = **1300** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **300** mm
Height of ground water behind wall	h_{water} = **0** mm
Height of saturated fill above base	h_{sat} = max(h_{water} - t_{base} - d_{ds}, 0 mm) = **0** mm
Density of wall construction	γ_{wall} = **20.0** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	h_{eff} = h_{wall} + l_{heel} × tan(β) = **1300** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **17.5** kN/m^3

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Saturated density of retained material $\qquad$ γ_s = **21.0** kN/m³

Design shear strength $\qquad$ ϕ' = **24.2** deg

Angle of wall friction $\qquad$ δ = **18.6** deg

Base material details

Moist density $\qquad$ γ_{mb} = **18.0** kN/m³

Design shear strength $\qquad$ ϕ'_b = **27.5** deg

Design base friction $\qquad$ δ_b = **21.3** deg

Allowable bearing pressure $\qquad$ $P_{bearing}$ = **150** kN/m²

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = sin(\alpha + \phi')^2 / (sin(\alpha)^2 \times sin(\alpha - \delta) \times [1 + \sqrt{(sin(\phi' + \delta) \times sin(\phi' - \beta) / (sin(\alpha - \delta) \times sin(\alpha + \beta)))}]^2) = \textbf{0.369}$$

Passive pressure coefficient for base material

$$K_p = sin(90 - \phi'_b)^2 / (sin(90 - \delta_b) \times [1 - \sqrt{(sin(\phi'_b + \delta_b) \times sin(\phi'_b) / (sin(90 + \delta_b)))}]^2) = \textbf{5.571}$$

At-rest pressure

At-rest pressure for retained material $\qquad$ K_0 = 1 − sin(ϕ') = **0.590**

Loading details

Surcharge load on plan $\qquad$ Surcharge = **2.5** kN/m²

Applied vertical dead load on wall $\qquad$ W_{dead} = **3.0** kN/m

Applied vertical live load on wall $\qquad$ W_{live} = **0.0** kN/m

Position of applied vertical load on wall $\qquad$ l_{load} = **50** mm

Applied horizontal dead load on wall $\qquad$ F_{dead} = **0.0** kN/m

Applied horizontal live load on wall $\qquad$ F_{live} = **0.0** kN/m

Height of applied horizontal load on wall $\qquad$ h_{load} = **0** mm
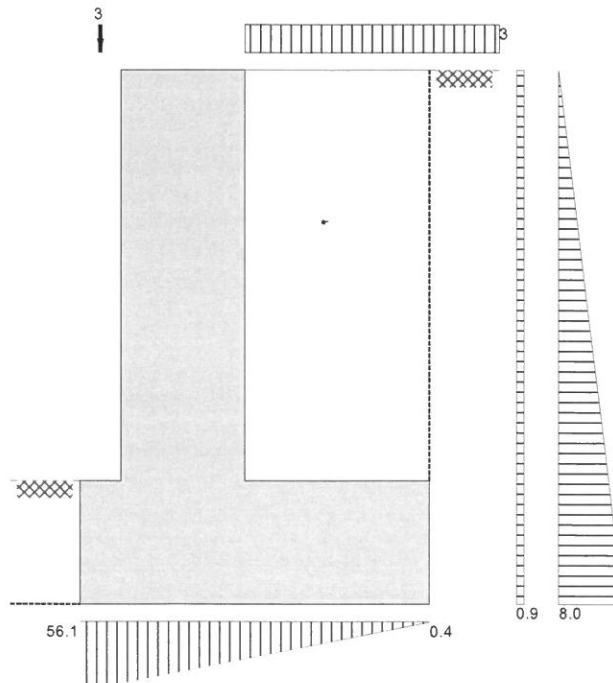
Loads shown in kN/m, pressures shown in kN/m²

Vertical forces on wall

Wall stem $\qquad$ w_{wall} = $h_{stem} \times t_{wall} \times \gamma_{wall}$ = **6** kN/m

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Wall base $\qquad$ $w_{base} = l_{base} \times t_{base} \times \gamma_{base} = \textbf{6 kN/m}$

Surcharge $\qquad$ $w_{sur} = \text{Surcharge} \times l_{heel} = \textbf{1.1 kN/m}$

Moist backfill to top of wall $\qquad$ $w_{m\_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = \textbf{7.9 kN/m}$

Applied vertical load $\qquad$ $W_v = W_{dead} + W_{live} = \textbf{3 kN/m}$

Total vertical load $\qquad$ $W_{total} = w_{wall} + w_{base} + w_{sur} + w_{m\_w} + W_v = \textbf{24 kN/m}$

Horizontal forces on wall

Surcharge $\qquad$ $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff} = \textbf{1.1 kN/m}$

Moist backfill above water table $\qquad$ $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = \textbf{5.2 kN/m}$

Total horizontal load $\qquad$ $F_{total} = F_{sur} + F_{m\_a} = \textbf{6.3 kN/m}$

Calculate stability against sliding

Resistance to sliding $\qquad$ $F_{res} = (W_{total} - w_{sur}) \times \tan(\delta_b) = \textbf{8.9 kN/m}$

PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge $\qquad$ $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = \textbf{0.7 kNm/m}$

Moist backfill above water table $\qquad$ $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = \textbf{2.2 kNm/m}$

Total overturning moment $\qquad$ $M_{ot} = M_{sur} + M_{m\_a} = \textbf{3 kNm/m}$

Restoring moments

Wall stem $\qquad$ $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) = \textbf{1.5 kNm/m}$

Wall base $\qquad$ $M_{base} = w_{base} \times l_{base} / 2 = \textbf{2.6 kNm/m}$

Moist backfill $\qquad$ $M_{m\_r} = (w_{m\_w} \times (l_{base} - l_{heel} / 2) + w_{m\_s} \times (l_{base} - l_{heel} / 3)) = \textbf{4.9 kNm/m}$

Design vertical dead load $\qquad$ $M_{dead} = W_{dead} \times l_{load} = \textbf{0.2 kNm/m}$

Total restoring moment $\qquad$ $M_{rest} = M_{wall} + M_{base} + M_{m\_r} + M_{dead} = \textbf{9.1 kNm/m}$

Check stability against overturning

Total overturning moment $\qquad$ $M_{ot} = \textbf{3.0 kNm/m}$

Total restoring moment $\qquad$ $M_{rest} = \textbf{9.1 kNm/m}$

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge $\qquad$ $M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2) = \textbf{0.7 kNm/m}$

Total moment for bearing $\qquad$ $M_{total} = M_{rest} - M_{ot} + M_{sur\_r} = \textbf{6.9 kNm/m}$

Total vertical reaction $\qquad$ $R = W_{total} = \textbf{24.0 kN/m}$

Distance to reaction $\qquad$ $x_{bar} = M_{total} / R = \textbf{285 mm}$

Eccentricity of reaction $\qquad$ $e = abs((l_{base} / 2) - x_{bar}) = \textbf{140 mm}$

Reaction acts within middle third of base

Bearing pressure at toe $\qquad$ $p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = \textbf{56.1 kN/m}^2$

Bearing pressure at heel $\qquad$ $p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = \textbf{0.4 kN/m}^2$

PASS - Maximum bearing pressure is less than allowable bearing pressure

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RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor $\qquad \gamma_{f\_d} = \textbf{1.4}$

Live load factor $\qquad \gamma_{f\_l} = \textbf{1.6}$

Earth and water pressure factor $\qquad \gamma_{f\_e} = \textbf{1.4}$

Factored vertical forces on wall

Wall stem $\qquad w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = \textbf{8.4 kN/m}$

Wall base $\qquad w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base} = \textbf{8.4 kN/m}$

Surcharge $\qquad w_{sur\_f} = \gamma_{f\_l} \times \text{Surcharge} \times l_{heel} = \textbf{1.8 kN/m}$

Moist backfill to top of wall $\qquad w_{m\_w\_f} = \gamma_{f\_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_{m} = \textbf{11 kN/m}$

Applied vertical load $\qquad W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live} = \textbf{4.2 kN/m}$

Total vertical load $\qquad W_{total\_f} = w_{wall\_f} + w_{base\_f} + w_{sur\_f} + w_{m\_w\_f} + W_{v\_f} = \textbf{33.9 kN/m}$

Factored horizontal at-rest forces on wall

Surcharge $\qquad F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff} = \textbf{3.1 kN/m}$

Moist backfill above water table $\qquad F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_{m} \times (h_{eff} - h_{water})^2 = \textbf{12.2 kN/m}$

Total horizontal load $\qquad F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} = \textbf{15.3 kN/m}$

Factored overturning moments

Surcharge $\qquad M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = \textbf{2 kNm/m}$

Moist backfill above water table $\qquad M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = \textbf{5.3 kNm/m}$

Total overturning moment $\qquad M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} = \textbf{7.3 kNm/m}$

Restoring moments

Wall stem $\qquad M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2) = \textbf{2.1 kNm/m}$

Wall base $\qquad M_{base\_f} = w_{base\_f} \times l_{base} / 2 = \textbf{3.6 kNm/m}$

Surcharge $\qquad M_{sur\_r\_f} = w_{sur\_f} \times (l_{base} - l_{heel} / 2) = \textbf{1.1 kNm/m}$

Moist backfill $\qquad M_{m\_r\_f} = (w_{m\_w\_f} \times (l_{base} - l_{heel} / 2) + w_{m\_s\_f} \times (l_{base} - l_{heel} / 3)) = \textbf{6.9 kNm/m}$

Design vertical load $\qquad M_{v\_f} = W_{v\_f} \times l_{load} = \textbf{0.2 kNm/m}$

Total restoring moment $\qquad M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{m\_r\_f} + M_{v\_f} = \textbf{13.9 kNm/m}$

Factored bearing pressure

Total moment for bearing $\qquad M_{total\_f} = M_{rest\_f} - M_{ot\_f} = \textbf{6.6 kNm/m}$

Total vertical reaction $\qquad R_f = W_{total\_f} = \textbf{33.9 kN/m}$

Distance to reaction $\qquad x_{bar\_f} = M_{total\_f} / R_f = \textbf{196 mm}$

Eccentricity of reaction $\qquad e_f = abs((l_{base} / 2) - x_{bar\_f}) = \textbf{229 mm}$

Reaction acts outside middle third of base

Bearing pressure at toe $\qquad p_{toe\_f} = R_f / (1.5 \times x_{bar\_f}) = \textbf{115.4 kN/m}^2$

Bearing pressure at heel $\qquad p_{heel\_f} = 0 \text{ kN/m}^2 = \textbf{0 kN/m}^2$

Rate of change of base reaction $\qquad rate = p_{toe\_f} / (3 \times x_{bar\_f}) = \textbf{196.78 kN/m}^2\text{/m}$

Bearing pressure at stem / toe $\qquad p_{stem\_toe\_f} = max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2) = \textbf{95.7 kN/m}^2$

Bearing pressure at mid stem $\qquad p_{stem\_mid\_f} = max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = \textbf{66.2 kN/m}^2$

Bearing pressure at stem / heel $\qquad p_{stem\_heel\_f} = max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = \textbf{36.7 kN/m}^2$

Design of reinforced concrete retaining wall toe (BS 8002:1994)

Material properties

Characteristic strength of concrete $\qquad f_{cu} = \textbf{35 N/mm}^2$

Characteristic strength of reinforcement $\qquad f_y = \textbf{500 N/mm}^2$

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Pencoed, Bridgend CF35 5LJ	Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
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Base details
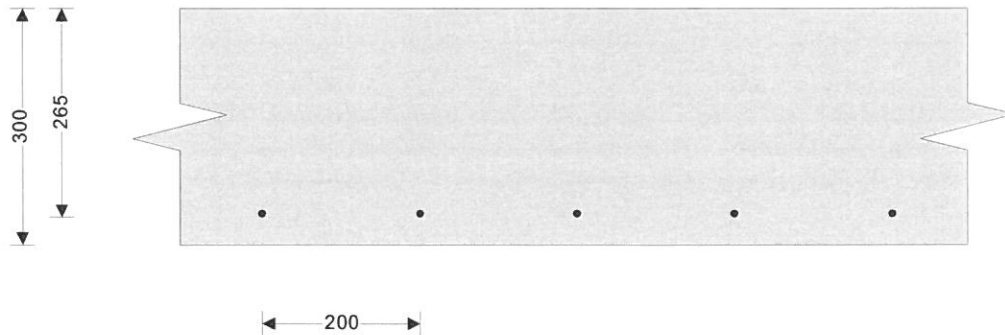
Minimum area of reinforcement

$k = 0.13$ %

Cover to reinforcement in toe

$c_{toe} = 30$ mm

Calculate shear for toe design

Shear from bearing pressure

$V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = 10.6$ kN/m

Shear from weight of base

$V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = 1$ kN/m

Total shear for toe design

$V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = 9.6$ kN/m

Calculate moment for toe design

Moment from bearing pressure

$M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = 3.1$ kNm/m

Moment from weight of base

$M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = 0.3$ kNm/m

Total moment for toe design

$M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = 2.8$ kNm/m

Check toe in bending

Width of toe

$b = 1000$ mm/m

Depth of reinforcement

$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = 265.0$ mm

Constant

$K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = 0.001$

Compression reinforcement is not required

Lever arm

$z_{toe} = min(0.5 + \sqrt{(0.25 - (min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$

$z_{toe} = 252$ mm

Area of tension reinforcement required

$A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = 25$ mm²/m

Minimum area of tension reinforcement

$A_{s\_toe\_min} = k \times b \times t_{base} = 390$ mm²/m

Area of tension reinforcement required

$A_{s\_toe\_req} = Max(A_{s\_toe\_des}, A_{s\_toe\_min}) = 390$ mm²/m

Reinforcement provided

A393 mesh

Area of reinforcement provided

$A_{s\_toe\_prov} = 393$ mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress

$v_{toe} = V_{toe} / (b \times d_{toe}) = 0.036$ N/mm²

Allowable shear stress

$v_{adm} = min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 = 4.733$ N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$v_{c\_toe} = 0.415$ N/mm²

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

Design of reinforced concrete retaining wall heel (BS 8002:1994)

Material properties

Characteristic strength of concrete

$f_{cu} = 35$ N/mm²

Characteristic strength of reinforcement

$f_y = 500$ N/mm²

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Base details

Minimum area of reinforcement $k = 0.13\ \%$

Cover to reinforcement in heel $c_{heel} = 30$ mm

Calculate shear for heel design

Shear from bearing pressure $V_{heel\_bear} = p_{stem\_heel\_f} \times ((3 \times x_{bar\_f}) - l_{toe} - t_{wall}) / 2 = 3.4$ kN/m

Shear from weight of base $V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base} = 4.5$ kN/m

Shear from weight of moist backfill $V_{heel\_wt\_m} = w_{m\_w\_f} = 11$ kN/m

Shear from surcharge $V_{heel\_sur} = w_{sur\_f} = 1.8$ kN/m

Total shear for heel design $V_{heel} = -V_{heel\_bear} + V_{heel\_wt\_base} + V_{heel\_wt\_m} + V_{heel\_sur} = 13.9$ kN/m

Calculate moment for heel design

Moment from bearing pressure $M_{heel\_bear} = p_{stem\_mid\_f} \times ((3 \times x_{bar\_f}) - l_{toe} - t_{wall} / 2)^2 / 6 = 1.3$ kNm/m

Moment from weight of base $M_{heel\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 1.8$ kNm/m

Moment from weight of moist backfill $M_{heel\_wt\_m} = w_{m\_w\_f} \times (l_{heel} + t_{wall}) / 2 = 4.1$ kNm/m

Moment from surcharge $M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2 = 0.7$ kNm/m

Total moment for heel design $M_{heel} = -M_{heel\_bear} + M_{heel\_wt\_base} + M_{heel\_wt\_m} + M_{heel\_sur} = 5.3$ kNm/m
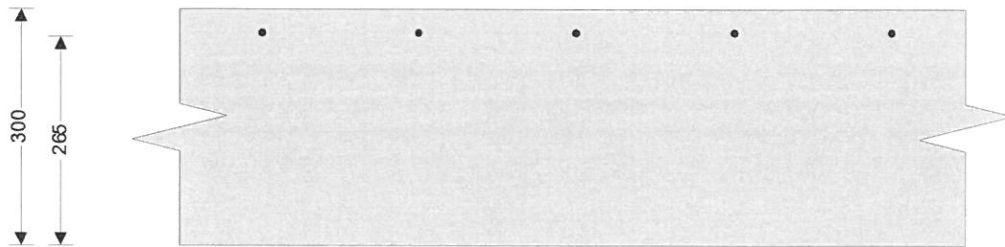
Check heel in bending

Width of heel $b = 1000$ mm/m

Depth of reinforcement $d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2) = 265.0$ mm

Constant $K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = 0.002$

Compression reinforcement is not required

Lever arm $z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))}, 0.95) \times d_{heel}$

$z_{heel} = 252$ mm

Area of tension reinforcement required $A_{s\_heel\_des} = M_{heel} / (0.87 \times f_y \times z_{heel}) = 49$ mm²/m

Minimum area of tension reinforcement $A_{s\_heel\_min} = k \times b \times t_{base} = 390$ mm²/m

Area of tension reinforcement required $A_{s\_heel\_req} = \max(A_{s\_heel\_des}, A_{s\_heel\_min}) = 390$ mm²/m

Reinforcement provided   **A393 mesh**

Area of reinforcement provided $A_{s\_heel\_prov} = 393$ mm²/m

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress $v_{heel} = V_{heel} / (b \times d_{heel}) = 0.052$ N/mm²

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \text{N/mm}^2)}, 5) \times 1\ \text{N/mm}^2 = 4.733$ N/mm²

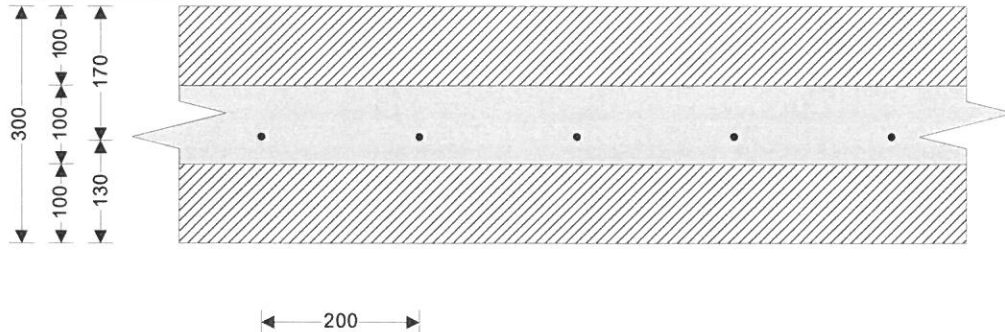*PASS - Design shear stress is less than maximum shear stress*

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_heel} = 0.415$ N/mm²

$v_{heel} < v_{c\_heel}$ - No shear reinforcement required

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Design of cavity reinforced masonry retaining wall stem - BS5628-2:2000

Wall details

Thickness of outer leaf of wall $\qquad$ t_{outer} = **100** mm

Thickness of inner leaf of wall $\qquad$ t_{inner} = **100** mm

Thickness of reinforced cavity $\qquad$ t_{cavity} = t_{wall} - t_{outer} - t_{inner} = **100** mm

Depth of stem reinforcement $\qquad$ d_{stem} = **170** mm

Masonry details

Masonry type $\qquad$ **Aggregate concrete blocks no voids**

Compressive strength of units $\qquad$ p_{unit} = **7.3** N/mm²

Mortar designation $\qquad$ **(ii)**

Category of manufactoring control of units $\qquad$ **Category I**

Partial safety factor for material strength $\qquad$ γ_{mm} = **2.0**

Characteristic compressive strength of masonry

Least horizontal dimension of masonry units $\qquad$ b_{unit} = **100.0** mm

Height of masonry units $\qquad$ h_{unit} = **215.0** mm

Ratio of height to least horizontal dimension $\qquad$ ratio = h_{unit} / b_{unit} = **2.2**

From BS5628:2 Table 3d, mortar ii

Characteristic compressive strength $\qquad$ f_k = **6.4** N/mm²

Factored horizontal at-rest forces on stem

Surcharge $\qquad$ $F_{s\_sur\_f}$ = $\gamma_{f\_l} \times K_0 \times$ Surcharge $\times (h_{eff} - t_{base} - d_{ds})$ = **2.4** kN/m

Moist backfill above water table $\qquad$ $F_{s\_m\_a\_f}$ = $0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **7.2** kN/m

Calculate shear for stem design

Shear at base of stem $\qquad$ V_{stem} = $F_{s\_sur\_f} + F_{s\_m\_a\_f}$ = **9.6** kN/m

Calculate moment for stem design

Surcharge $\qquad$ M_{s_sur} = $F_{s\_sur\_f} \times (h_{stem} + t_{base})$ / 2 = **1.5** kNm/m

Moist backfill above water table $\qquad$ $M_{s\_m\_a}$ = $F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base}$ / 2) / 3 = **3.5** kNm/m

Total moment for stem design $\qquad$ M_{stem} = $M_{s\_sur} + M_{s\_m\_a}$ = **5** kNm/m

Check maximum design moment for wall stem

Width of wall $\qquad$ b = **1000** mm/m

Maximum design moment $\qquad$ M_{d_stem} = $0.4 \times f_k \times b \times d_{stem}^2$ / γ_{mm} = **37.0** kNm/m

PASS - Applied moment is less than maximum design moment

Check wall stem in bending

Moment of resistance factor $\qquad$ Q = M_{stem} / d_{stem}^2 = **0.174** N/mm²

$\qquad$ Q = $2 \times c \times (1 - c) \times f_k$ / γ_{mm}

Lever arm factor $\qquad$ c = **0.972**

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	Approved by JM	Approved date 14/11/2017		

Lever arm $\qquad$ $z_{stem} = min(0.95, c) \times d_{stem} = \textbf{161.5 mm}$

Area of tension reinforcement required $\qquad$ $A_{s\_stem\_des} = M_{stem} \times \gamma_{ms} / (f_y \times z_{stem}) = \textbf{72 mm}^2\textbf{/m}$

Minimum area of tension reinforcement $\qquad$ $A_{s\_stem\_min} = k \times b \times t_{wall} = \textbf{390 mm}^2\textbf{/m}$

Area of tension reinforcement required $\qquad$ $A_{s\_stem\_req} = Max(A_{s\_stem\_des}, A_{s\_stem\_min}) = \textbf{390 mm}^2\textbf{/m}$

Reinforcement provided $\qquad$ **A393 mesh**

Area of reinforcement provided $\qquad$ $A_{s\_stem\_prov} = \pi \times \phi_{stem}^2 / (4 \times s_{stem}) = \textbf{393 mm}^2\textbf{/m}$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $\qquad$ $v_{stem} = V_{stem} / (b \times d_{stem}) = \textbf{0.056 N/mm}^2$

Basic characteristic shear strength of masonry $\qquad$ $f_{vbas} = min[0.35 + (17.5 \times A_{s\_stem\_prov} / (b \times d_{stem})), 0.7] \times 1 \text{ N/mm}^2$

$f_{vbas} = \textbf{0.390 N/mm}^2$

Shear span $\qquad$ $a = M_{stem} / V_{stem} = \textbf{524.4 mm}$

Characteristic shear strength of masonry $\qquad$ $f_v = Min(f_{vbas} \times max(2.5 - 0.25 \times (a / d_{stem}), 1), 1.75 \text{ N/mm}^2)$

$f_v = \textbf{0.675 N/mm}^2$

Allowable shear stress $\qquad$ $v_{adm} = f_v / \gamma_{mv} = \textbf{0.337 N/mm}^2$

PASS - Design shear stress is less than maximum shear stress

Check limiting dimensions

Limiting span/effective depth ratio $\qquad$ $ratio_{max} = \textbf{18.00}$

Actual span/effective depth ratio $\qquad$ $ratio_{act} = (h_{stem} + d_{stem} / 2) / d_{stem} = \textbf{6.38}$

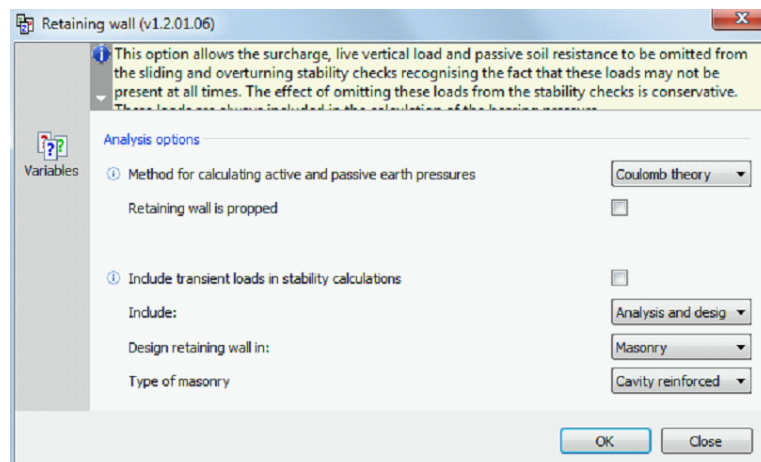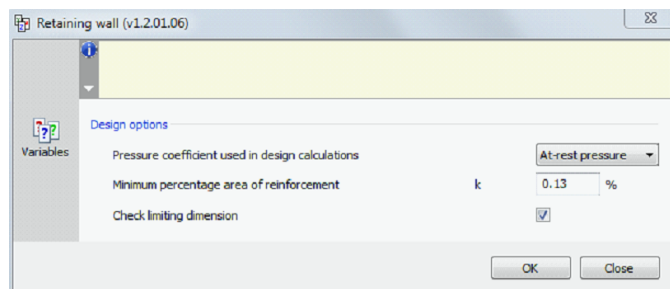*PASS - Span to depth ratio is acceptable*

Axial load check

Factored axial load on wall $\qquad$ $N_{wall} = ([t_{wall} \times h_{stem} \times \gamma_{wall} + W_{dead}] \times \gamma_{f\_d}) + (W_{live} \times \gamma_{f\_l}) = \textbf{12.6 kN/m}$

Limiting axial load $\qquad$ $N_{limit} = 0.1 \times f_k \times t_{wall} = \textbf{192.0 kN/m}$

Applied axial load may be ignored - calculations valid

Retaining wall (v1.2.01.06)

Design options

Pressure coefficient used in design calculations — At-rest pressure

Minimum percentage area of reinforcement — k — 0.13 — %

Check limiting dimension — ☑

OK — Close

Retaining wall (v1.2.01.06)

This option allows the surcharge, live vertical load and passive soil resistance to be omitted from the sliding and overturning stability checks recognising the fact that these loads may not be present at all times. The effect of omitting these loads from the stability checks is conservative.

Analysis options

Method for calculating active and passive earth pressures — Coulomb theory

Retaining wall is propped — ☐

Include transient loads in stability calculations — ☐

Include: — Analysis and desig

Design retaining wall in: — Masonry

Type of masonry — Cavity reinforced

OK — Close

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Indicative retaining wall reinforcement diagram
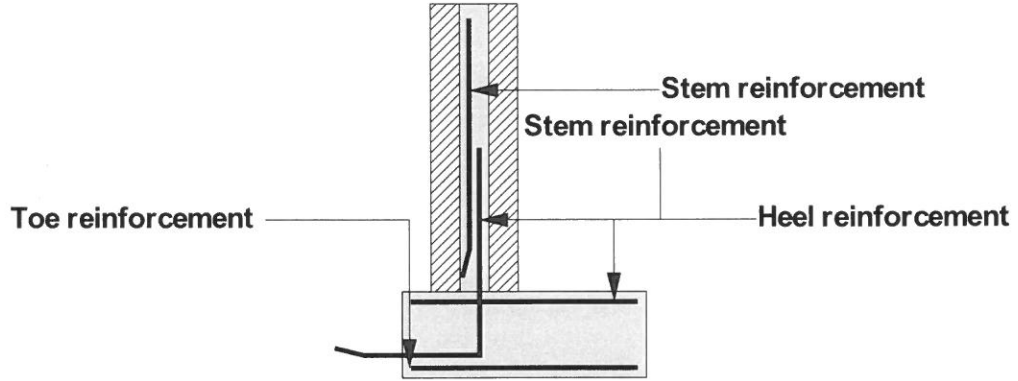
Toe mesh - A393 - (393 mm^2/m)
Heel mesh - A393 - (393 mm^2/m)
Stem mesh - A393 - (393 mm^2/m)