HIGHWAYS RETAINING WALL DESIGN

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 2.9.22

Retaining wall details

Stem type	Cantilever
Stem height	h_{stem} = **2850** mm
Stem thickness	t_{stem} = **300** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Toe length	l_{toe} = **1000** mm
Heel length	l_{heel} = **1000** mm
Base thickness	t_{base} = **350** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **2850** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **0** mm

Retained soil properties

Soil type	Medium dense well graded sand
Moist density	γ_{mr} = **18** kN/m^3
Saturated density	γ_{sr} = **23** 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

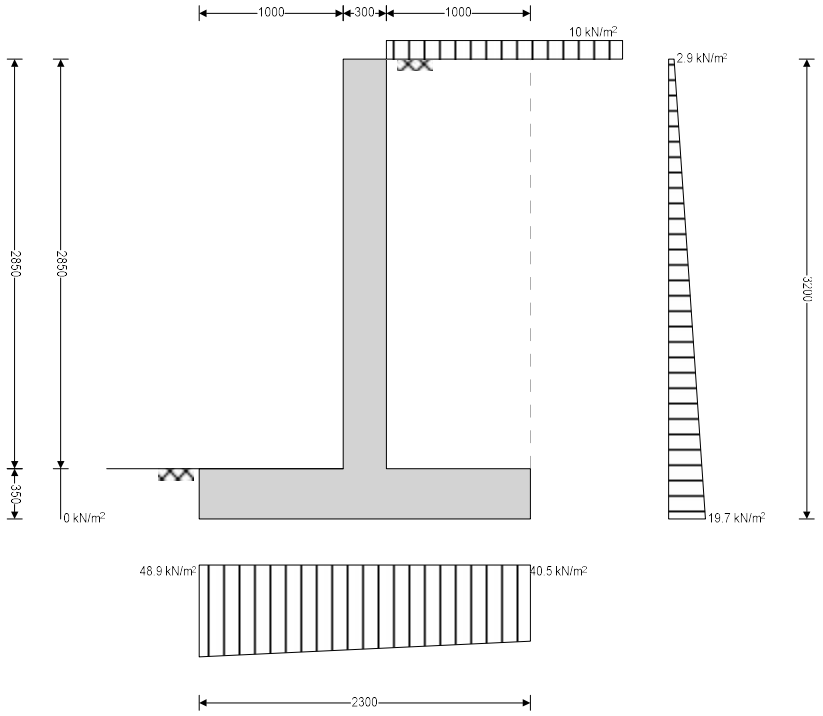
Soil type	Very dense rock fill
Soil density	γ_b = **18** kN/m^3
Characteristic effective shear resistance angle	$\phi'_{b.k}$ = **42** deg
Characteristic wall friction angle	$\delta_{b.k}$ = **21** deg
Characteristic base friction angle	$\delta_{bb.k}$ = **36** deg
Presumed bearing capacity	$P_{bearing}$ = **100** kN/m^2

Loading details

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

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Job No.	Section Nos /Page No. /Revision	Calc By	Calc Date
12063	**HRW / 2**	DSH	01/06/2026



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} + l_{heel} =$ **2300** mm
Moist soil height	$h_{moist} = h_{soil} =$ **2850** mm
Length of surcharge load	$l_{sur} = l_{heel} =$ **1000** mm
- Distance to vertical component	$x_{sur_v} = l_{base} - l_{heel} / 2 =$ **1800** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} =$ **3200** mm
- Distance to horizontal component	$x_{sur_h} = h_{eff} / 2 =$ **1600** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} =$ **0.855** m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 =$ **1150** mm
Area of wall base	$A_{base} = l_{base} \times t_{base} =$ **0.805** m^2
- Distance to vertical component	$x_{base} = l_{base} / 2 =$ **1150** mm
Area of moist soil	$A_{moist} = h_{moist} \times l_{heel} =$ **2.85** m^2
- Distance to vertical component	$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} =$ **1800** mm
- Distance to horizontal component	$x_{moist_h} = h_{eff} / 3 =$ **1067** mm

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times [1 + \sqrt{[\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))]}]^2) = \mathbf{0.301}$

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

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = A_{stem} \times \gamma_{stem} = \mathbf{21.4}$ kN/m

Wall base $F_{base} = A_{base} \times \gamma_{base} = \mathbf{20.1}$ kN/m

Surcharge load $F_{sur_v} = Surcharge_Q \times l_{heel} = \mathbf{10}$ kN/m

Moist retained soil $F_{moist_v} = A_{moist} \times \gamma_{mr} = \mathbf{51.3}$ kN/m

Total $F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{102.8}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r.k}) \times Surcharge_Q \times h_{eff} = \mathbf{9.3}$ kN/m

Moist retained soil $F_{moist_h} = K_A \times \cos(\delta_{r.k}) \times \gamma_{mr} \times h_{eff}^2 / 2 = \mathbf{26.8}$ kN/m

Total $F_{total_h} = \max(F_{sur_h} + F_{moist_h} - F_{total_v} \times \tan(\delta_{bb.k}), 0\ kN/m) = \mathbf{0}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{24.6}$ kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = \mathbf{23.1}$ kNm/m

Surcharge load $M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} = \mathbf{3.1}$ kNm/m

Moist retained soil $M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} = \mathbf{63.7}$ kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} = \mathbf{114.5}$ kNm/m

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total_v} = \mathbf{1114}$ mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = \mathbf{-36}$ mm

Loaded length of base $l_{load} = l_{base} = \mathbf{2300}$ mm

Bearing pressure at toe $q_{toe} = F_{total_v} / l_{base} \times (1 - 6 \times e / l_{base}) = \mathbf{48.9}$ kN/m²

Bearing pressure at heel $q_{heel} = F_{total_v} / l_{base} \times (1 + 6 \times e / l_{base}) = \mathbf{40.5}$ kN/m²

Factor of safety $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{2.046}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

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

Partial factor set A1

Permanent unfavourable action $\gamma_G = \mathbf{1.350}$

Permanent favourable action $\gamma_{Gf} = \mathbf{1.000}$

Variable unfavourable action $\gamma_Q = \mathbf{1.500}$

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	$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma}$ = **18** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma}$ = **23** 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	$\gamma_b' = \gamma_b / \gamma_{\gamma}$ = **18** 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	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **36** deg
Design effective cohesion	$c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]}^2)$ = **0.301**
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**

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **21.4** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **20.1** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **51.3** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v}$ = **92.8** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **14** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **36.2** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h}$ = **50.2** kN/m

Check stability against sliding

Base soil resistance	F_{exc_h} = **0** kN/m
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb.d})$ = **67.4** kN/m
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction}$ = **67.4** kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h}$ = **1.343**

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} =$ **21.4** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **20.1** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **51.3** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} =$ **92.8** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} =$ **14** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **36.2** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} =$ **50.2** kN/m

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times x_{sur_h} =$ **22.4** kNm/m
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times x_{moist_h} =$ **38.6** kNm/m
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} =$ **61** kNm/m

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times x_{stem} =$ **24.6** kNm/m
Wall base	$M_{base_R} = F_{base} \times x_{base} =$ **23.1** kNm/m
Moist retained soil	$M_{moist_R} = F_{moist_v} \times x_{moist_v} =$ **92.3** kNm/m
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} =$ **140.1** kNm/m

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{total_R} / M_{total_OT} =$ **2.296**

PASS - Maximum restoring moment is greater than overturning moment

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set	A2
Permanent unfavourable action	$\gamma_G =$ **1.000**
Permanent favourable action	$\gamma_{Gf} =$ **1.000**
Variable unfavourable action	$\gamma_Q =$ **1.300**
Variable favourable action	$\gamma_{Qf} =$ **0.000**

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

Soil parameter set	M2
Angle of shearing resistance	$\gamma_{\phi'} =$ **1.25**
Effective cohesion	$\gamma_{c'} =$ **1.25**
Weight density	$\gamma_\gamma =$ **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma =$ **18** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma =$ **23** kN/m^3
Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **24.8** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) =$ **12.1** deg

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma =$ **18** kN/m^3
Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) =$ **35.8** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) =$ **17.1** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **30.2** deg
Design effective cohesion	$c'_{b.d} = c'_{b.k} / \gamma_{c'} =$ **0** kN/m^2

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2}) = \mathbf{0.371}$$

Passive pressure coefficient

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

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} =$ **21.4** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **20.1** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **51.3** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} =$ **92.8** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} =$ **15.1** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **33.4** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} =$ **48.5** kN/m

Check stability against sliding

Base soil resistance	$F_{exc_h} =$ **0** kN/m
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb.d}) =$ **53.9** kN/m
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction} =$ **53.9** kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h} =$ **1.112**

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} =$ **21.4** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **20.1** kN/m

Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **51.3** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} =$ **92.8** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} =$ **15.1** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **33.4** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} =$ **48.5** kN/m

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times x_{sur_h} =$ **24.1** kNm/m
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times x_{moist_h} =$ **35.7** kNm/m
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} =$ **59.8** kNm/m

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times x_{stem} =$ **24.6** kNm/m
Wall base	$M_{base_R} = F_{base} \times x_{base} =$ **23.1** kNm/m
Moist retained soil	$M_{moist_R} = F_{moist_v} \times x_{moist_v} =$ **92.3** kNm/m
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} =$ **140.1** kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} =$ **2.342**

PASS - Maximum restoring moment is greater than overturning moment

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

Tedds calculation version 2.9.22

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

Concrete strength class	C30/37	
Characteristic compressive cylinder strength		$f_{ck} =$ **30** N/mm²
Characteristic compressive cube strength	$f_{ck,cube} =$ **37** N/mm²	
Mean value of compressive cylinder strength		$f_{cm} = f_{ck} + 8$ N/mm² = **38** N/mm²
Mean value of axial tensile strength	$f_{ctm} = 0.3$ N/mm² $\times (f_{ck} /$ 1 N/mm²$)^{2/3} =$ **2.9** N/mm²	
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} =$ **2.0** N/mm²	
Secant modulus of elasticity of concrete	$E_{cm} = 22$ kN/mm² $\times (f_{cm} /$ 10 N/mm²$)^{0.3} =$ **32837** N/mm²	
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		$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C =$ **17.0** N/mm²
Maximum aggregate size	$h_{agg} =$ **20** mm	
Ultimate strain - Table 3.1	$\varepsilon_{cu2} =$ **0.0035**	

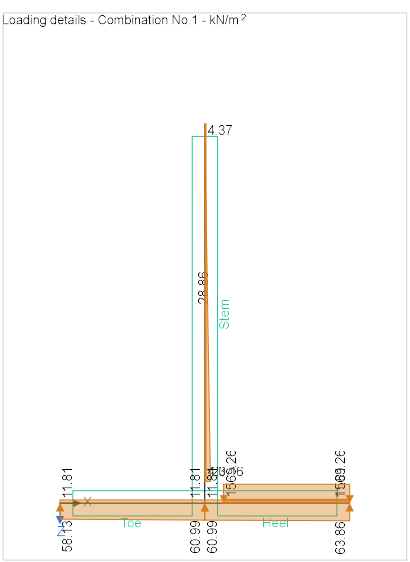
Shortening strain - Table 3.1	ε_{cu3} = **0.0035**
Effective compression zone height factor	λ = **0.80**
Effective strength factor	η = **1.00**
Bending coefficient k_1	K_1 = **0.40**
Bending coefficient k_2	$K_2 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2})$ = **1.00**
Bending coefficient k_3	K_3 =**0.40**
Bending coefficient k_4	$K_4 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2})$ =**1.00**

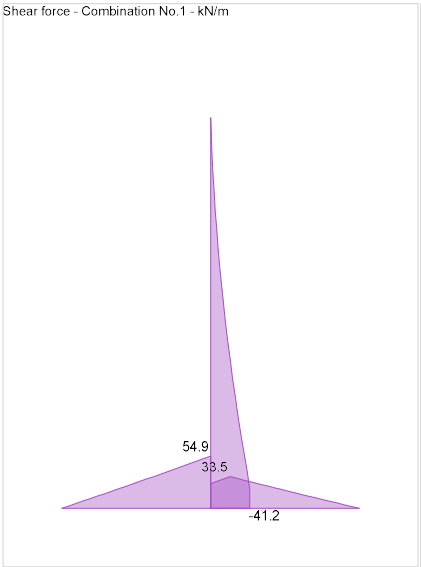
Reinforcement details

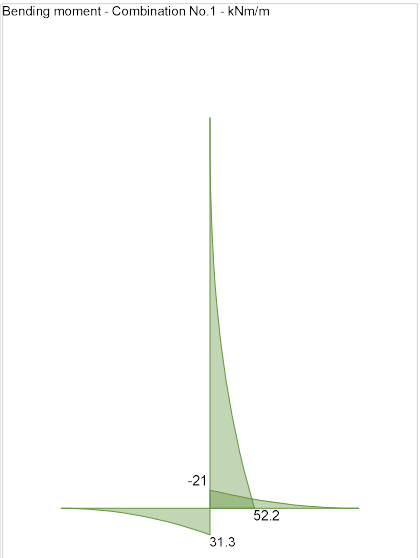
Characteristic yield strength of reinforcement		f_{yk} = **500** N/mm^2
Modulus of elasticity of reinforcement	E_s = **200000** N/mm^2	
Partial factor for reinforcing steel - Table 2.1N		γ_S = **1.15**
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm^2	

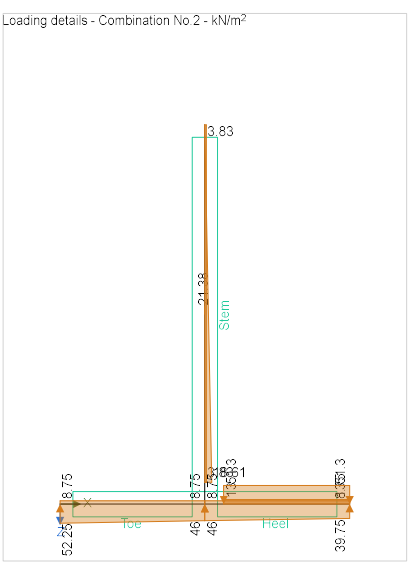
Cover to reinforcement

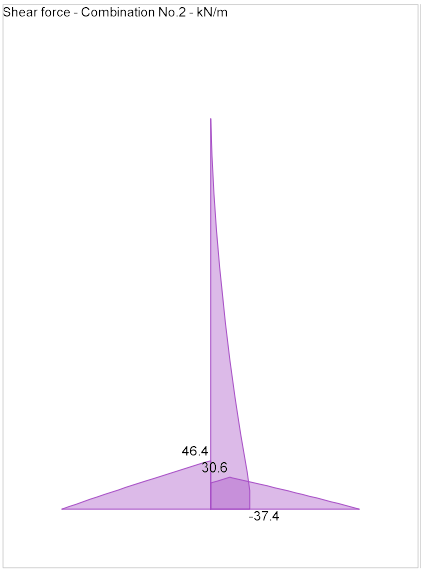
Front face of stem	c_{sf} = **40** mm
Rear face of stem	c_{sr} = **50** mm
Top face of base	c_{bt} = **50** mm
Bottom face of base	c_{bb} = **75** mm

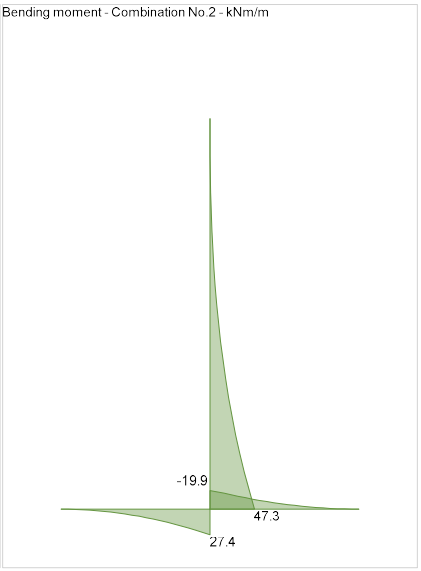












Check stem design at base of stem

Depth of section h = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 M = **45** kNm/m

Depth to tension reinforcement $d = h - c_{sr} - \phi_{sr} / 2$ = **242** mm

$K = M / (d^2 \times f_{ck})$ = **0.026**

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

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **230** mm

Depth of neutral axis $x = 2.5 \times (d - z)$ = **30** mm

Area of tension reinforcement required $A_{sr.req} = M / (f_{yd} \times z)$ = **451** mm²/m

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

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

Minimum area of reinforcement - exp.9.1N $A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **364** mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{sr.max} = 0.04 \times h$ = **12000** mm²/m

$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov}$ = **0.448**

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

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio	$\rho_0 = \sqrt{(f_{ck} / 1\ N/mm^2)} / 1000 =$ **0.005**
Required tension reinforcement ratio	$\rho = A_{sr.req} / d =$ **0.002**
Required compression reinforcement ratio	$\rho' = A_{sr.2.req} / d_2 =$ **0.000**
Structural system factor - Table 7.4N	$K_b =$ **0.4**
Reinforcement factor - exp.7.17	$K_s = \min(500\ N/mm^2 / (f_{yk} \times A_{sr.req} / A_{sr.prov}), 1.5) =$ **1.5**
Limiting span to depth ratio - exp.7.16.a	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) =$ **16**
Actual span to depth ratio	$h_{stem} / d =$ **11.8**

PASS - Span to depth ratio is less than deflection control limit

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	$M_{sls} =$ **27.3** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z) =$ **118.2** N/mm^2
Load duration	Long term
Load duration factor	$k_t =$ **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff} =$ **89917** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm} =$ **2.9** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sr.prov} / A_{c.eff} =$ **0.011**
Modular ratio	$\alpha_e = E_s / E_{cm} =$ **6.091**
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	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff} =$ **413** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	$w_k =$ **0.147** mm
	$w_k / w_{max} =$ **0.488**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	$V =$ **41.2** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C =$ **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2) =$ **1.909**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr.prov} / d, 0.02) =$ **0.004**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.506** N/mm^2

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

$V_{Rd.c}$ = **128.5** kN/m

$V / V_{Rd.c}$ = **0.320**

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1) $A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem})$ = **300** mm²/m

Maximum spacing of reinforcement – cl.9.6.3(2) s_{sx_max} = **400** mm

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

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

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

Check base design at toe

Depth of section h = **350** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 M = **23.6** kNm/m

Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2$ = **269** mm

$K = M / (d^2 \times f_{ck})$ = **0.011**

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

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **256** mm

Depth of neutral axis $x = 2.5 \times (d - z)$ = **34** mm

Area of tension reinforcement required $A_{bb.req} = M / (f_{yd} \times z)$ = **212** mm²/m

Tension reinforcement provided 12 dia.bars @ 200 c/c

Area of tension reinforcement provided $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb})$ = **565** mm²/m

Minimum area of reinforcement - exp.9.1N $A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **405** mm²/m

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

$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov}$ = **0.716**

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

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width w_{max} = **0.3** mm

Variable load factor - EN1990 – Table A1.1 ψ_2 = **0.6**

Serviceability bending moment M_{sls} = **15** kNm/m

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb.prov} \times z)$ = **103.5** N/mm²

Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff}$ = min(2.5 × (h - d), (h - x) / 3, h / 2)
	$A_{c.eff}$ = **105458** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff}$ = f_{ctm} = **2.9** N/mm²
Reinforcement ratio	$\rho_{p.eff}$ = $A_{bb.prov}$ / $A_{c.eff}$ = **0.005**
Modular ratio	α_e = E_s / E_{cm} = **6.091**
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 × c_{bb} + k_1 × k_2 × k_4 × ϕ_{bb} / $\rho_{p.eff}$ = **635** mm
Maximum crack width - exp.7.8	w_k = $s_{r.max}$ × max(σ_s – k_t × ($f_{ct.eff}$ / $\rho_{p.eff}$) × (1 + α_e × $\rho_{p.eff}$), 0.6 × σ_s) / E_s
	w_k = **0.197** mm
	w_k / w_{max} = **0.658**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	V = **47.6** kN/m
	$C_{Rd,c}$ = 0.18 / γ_C = **0.120**
	k = min(1 + √(200 mm / d), 2) = **1.862**
Longitudinal reinforcement ratio	ρ_l = min($A_{bb.prov}$ / d, 0.02) = **0.002**
	v_{min} = 0.035 N$^{1/2}$/mm × $k^{3/2}$ × $f_{ck}^{0.5}$ = **0.487** N/mm²
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c}$ = max($C_{Rd.c}$ × k × (100 N²/mm⁴ × ρ_l × f_{ck})$^{1/3}$, v_{min}) × d
	$V_{Rd.c}$ = **131.1** kN/m
	V / $V_{Rd.c}$ = **0.363**

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 1	M = **16.5** kNm/m
Depth to tension reinforcement	d = h - c_{bt} - ϕ_{bt} / 2 = **294** mm
	K = M / (d^2 × f_{ck}) = **0.006**
	K' = (2 × η × α_{cc}/γ_C)×(1 - λ × (δ - K_1)/(2 × K_2))×(λ × (δ - K_1)/(2 × K_2))
	K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d =$ **279**
mm	
Depth of neutral axis	$x = 2.5 \times (d - z) =$ **37** mm
Area of tension reinforcement required	$A_{bt.req} = M / (f_{yd} \times z) =$ **136** mm²/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) =$ **565** mm²/m
Minimum area of reinforcement - exp.9.1N	$A_{bt.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ **443** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{bt.max} = 0.04 \times h =$ **14000**
mm²/m	
	$\max(A_{bt.req}, A_{bt.min}) / A_{bt.prov} =$ **0.783**

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

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width	$w_{max} =$ **0.3** mm
Variable load factor - EN1990 – Table A1.1	$\psi_2 =$ **0.6**
Serviceability bending moment	$M_{sls} =$ **9.4** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{bt.prov} \times z) =$ **59.5** N/mm²
Load duration	Long term
Load duration factor	$k_t =$ **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff} =$ **104417** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm} =$ **2.9** N/mm²
Reinforcement ratio	$\rho_{p.eff} = A_{bt.prov} / A_{c.eff} =$ **0.005**
Modular ratio	$\alpha_e = E_s / E_{cm} =$ **6.091**
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	$s_{r.max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p.eff} =$ **547** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	$w_k =$ **0.098** mm
	$w_k / w_{max} =$ **0.325**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	$V =$ **33.5** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C =$ **0.120**
	$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) =$ **1.825**

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

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.473** N/mm^2

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

$V_{Rd.c} =$ **138.9** kN/m

$V / V_{Rd.c} =$ **0.241**

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

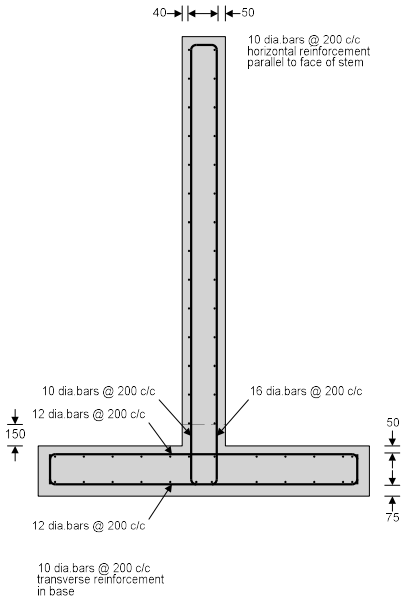
Minimum area of reinforcement – cl.9.3.1.1(2) $A_{bx.req} = 0.2 \times A_{bb.prov} =$ **113** mm^2/m

Maximum spacing of reinforcement – cl.9.3.1.1(3) $s_{bx_max} =$ **450** mm

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

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

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



Reinforcement details