Appendix B Burland and Potts Building Damage Classification Table

Category of damage		Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain e _{im} (per cent)	
0	Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible.	< 0.1	0.0-0.05	
I	Very slight	Fine cracks that can easily be treated during normal decoration. Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection.	<1	0.05-0.075	
2	Slight	<u>Cracks easily filled. Redecoration probably</u> <u>required.</u> Several slight fractures showing inside of building. Cracks are visible externally and <u>some repointing may be required externally</u> to ensure weathertightness. Doors and windows may stick slightly.	< 5	0.075-0.15	
3	Moderate	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired.	5-15 or a number of cracks > 3	0.15-0.3	
4	Severe	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Windows and frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	15–25 but also depends on number of cracks	> 0.3	
S	Very severe	This requires a major repair involving partial or <u>complete rebuilding</u> . Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion. Danger of instability.	usually > 25 but depends on number of cracks.		

- In assessing the degree of damage, account must be taken of its location in the building or structure.
- Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.





	24 HEATTH DRIVE	JOB NUMBER/FILE	CALCULATION NUMBER	Form
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	Project	Job no. 162637				
Form Structural Design 77 St John Street	Calcs for	RC L RETAI	NING WALL		Start page no./Re	vision 1
London EC1M 4NN	Calcs by CEM	Calcs date 29/01/2018	Checked by	Checked date	Approved by	Approved date

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 2.9.03

Retaining wall details	
Stem type	Cantilever
Stem height	h _{stem} = 4620 mm
Stem thickness	t _{stem} = 450 mm
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	Itee = 2500 mm
Base thickness	t _{base} = 450 mm
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	h _{ret} = 4620 mm
Angle of soil surface	$\beta = 0 \operatorname{deg}$
Depth of cover	d _{cover} = 0 mm
Height of water	h _{water} = 4620 mm
Water density	γ _w = 9.8 kN/m ³
Retained soil properties	
Soil type	Medium dense well graded sand
Moist density	$\gamma_{mr} = 21 \text{ kN/m}^3$
Saturated density	$\gamma_{sr} = 23 \text{ kN/m}^3$
Characteristic effective shear resistance angle	φ' _{r.k} = 30 deg
Characteristic wall friction angle	$\delta_{r.k}$ = 15 deg
Base soil properties	
Soil type	Stiff clay
Soil density	$\gamma_b = 19 \text{ kN/m}^3$
Characteristic cohesion	c' _{b.k} = 18 kN/m ²
Characteristic adhesion	a _{b.k} = 18 kN/m ²
Characteristic effective shear resistance angle	φ' _{b.k} = 18 deg
Characteristic wall friction angle	$\delta_{b,k} = 9 \deg$
Characteristic base friction angle	$\delta_{bb.k} = 12 \text{ deg}$
Loading details	
- Variable surcharge load	Surcharge _Q = 2.5 kN/m ²
Vertical line load at 2700 mm	P _{G1} = 60 kN/m
	$P_{01} = 3 \text{ kN/m}$

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Calculate retaining wall geometry

Base length	I _{base} = I _{toe} + t _{stem} = 2950 mm					
Saturated soil height	h _{sat} = h _{water} + d _{cover} = 4620 mm					
Moist soil height	$h_{moist} = h_{ret} - h_{water} = 0 mm$					
Length of surcharge load	I _{sur} = I _{heel} = 0 mm					
- Distance to vertical component	$x_{sur_v} = I_{base} - I_{heel} / 2 = 2950 \text{ mm}$					
Effective height of wall	$h_{\text{eff}} = h_{\text{base}} + d_{\text{cover}} + h_{\text{ret}} = 5070 \text{ mm}$					
- Distance to horizontal component	x _{sur_h} = h _{eff} / 2 = 2535 mm					
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} = 2.079 \text{ m}^2$					
- Distance to vertical component	x _{stem} = I _{toe} + t _{stem} / 2 = 2725 mm					
Area of wall base	$A_{\text{base}} = I_{\text{base}} \times t_{\text{base}} = 1.328 \text{ m}^2$					
- Distance to vertical component	x _{base} = I _{base} / 2 = 1475 mm					
Partial factors on actions - Table A.3 - Combination 1						
Permanent unfavourable action	γ _G = 1.35					

	/G = 1.33				
Permanent favourable action	$\gamma_{Gf} = 1.00$				
Variable unfavourable action	γ _Q = 1.50				
Variable favourable action	$\gamma_{Qf} = 0.00$				
Partial factors for soil parameters – Table A.4 - Combination 1					
Partial factors for soil parameters – Table A.4	I - Combination 1				
Partial factors for soil parameters – Table A.4 Angle of shearing resistance	4 - Combination 1 γ _¢ = 1.00				
Partial factors for soil parameters – Table A.4 Angle of shearing resistance Effective cohesion	4 - Combination 1 γ _¢ = 1.00 γ _{c'} = 1.00				
Partial factors for soil parameters – Table A.4 Angle of shearing resistance Effective cohesion Weight density	4 - Combination 1 γ _{0'} = 1.00 γ _{c'} = 1.00 γ _γ = 1.00				

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Water properties

Design water density

Retained soil properties Design moist density Design saturated density Design effective shear resistance angle Design wall friction angle

Base soil properties

Design soil density Design effective shear resistance angle Design wall friction angle Design base friction angle Design effective cohesion Design adhesion

Using Coulomb theory Active pressure coefficient

Passive pressure coefficient

Overturning check

Vertical forces on wall Wall stem Wall base

Line loads Total

Horizontal forces on wall Surcharge load

Saturated retained soil Water Moist retained soil

Base soil Total

Overturning moments on wall Surcharge load Saturated retained soil Water Moist retained soil Total

Restoring moments on wall Wall stem Wall base Line loads

$\gamma_w' = \gamma_w / \gamma_\gamma = 9.8 \text{ kN/m}^3$

 $\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = 21 \text{ kN/m}^3$ $\gamma_{sr}' = \gamma_{sr} / \gamma_{r} = 23 \text{ kN/m}^3$ $\phi'_{r,d} = \operatorname{atan}(\operatorname{tan}(\phi'_{r,k}) / \gamma_{\phi'}) = 30 \operatorname{deg}$ $\delta_{r.d} = \operatorname{atan}(\operatorname{tan}(\delta_{r.k}) / \gamma_{0'}) = 15 \operatorname{deg}$

 $\gamma_{\rm b}' = \gamma_{\rm b} / \gamma_{\rm v} = 19 \text{ kN/m}^3$ $\phi'_{b.d} = \operatorname{atan}(\operatorname{tan}(\phi'_{b.k}) / \gamma_{\phi'}) = 18 \operatorname{deg}$ $\delta_{b.d} = \operatorname{atan}(\operatorname{tan}(\delta_{b.k}) / \gamma_{\phi'}) = 9 \operatorname{deg}$ $\delta_{bb.d} = \operatorname{atan}(\operatorname{tan}(\delta_{bb.k}) / \gamma_{\Psi}) = 12 \operatorname{deg}$ $c'_{b.d} = c'_{b.k} / \gamma_{c'} = 18 \text{ kN/m}^2$ $a_{b,d} = a_{b,k} / \gamma_{c'} = 18 \text{ kN/m}^2$

 $K_{A} = \sin(\alpha + \phi'_{r,d})^{2} / (\sin(\alpha)^{2} \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{\sin(\phi'_{r,d} + \delta_{r,d})} \times$ $sin(\phi'_{r.d} - \beta) / (sin(\alpha - \delta_{r.d}) \times sin(\alpha + \beta))]]^2) = 0.301$ $K_{P} = \sin(90 - \phi'_{b,d})^{2} / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{\sin(\phi'_{b,d} + \delta_{b,d})} \times \sin(\phi'_{b,d}) / (1 - \sqrt{\sin(\phi'_{b,d} + \delta_{b,d})}) \times \sin(\phi'_{b,d}) / (1 - \sqrt{\sin(\phi'_{b,d} + \delta_{b,d})})$ $(\sin(90 + \delta_{b,d}))]]^2) = 2.359$

 $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 52 \text{ kN/m}$ $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 33.2 \text{ kN/m}$ $F_{P v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1} = 60 \text{ kN/m}$ Ftotal y = Fstem + Fbase + Fwater y + FP y = 145.2 kN/m

 $F_{sur h} = K_A \times cos(\delta_{r,d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = 5.5 \text{ kN/m}$ $F_{sat_h} = \gamma_G \times K_A \times cos(\delta_{r.d}) \times (\gamma_{sr'} - \gamma_{w'}) \times (h_{sat} + h_{base})^2 / 2 = 66.6 \text{ kN/m}$ $F_{water_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 = 170.2 \text{ kN/m}$ $F_{\text{moist h}} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr'} \times ((\text{heff - hsat - hbase})^2 / 2 + (\text{heff - hbase})^2$ h_{base} (h_{sat} + h_{base})) = 0 kN/m $F_{exc h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = -4.5 \text{ kN/m}$ Ftotal h = Fsat h + Fmoist h + Fexc h + Fwater h + Fsur h = 237.9 kN/m

 $M_{sur_OT} = F_{sur_h} \times x_{sur_h} = 14 \text{ kNm/m}$ Msat OT = Fsat h × xsat h = 112.6 kNm/m Mwater OT = Fwater h × Xwater h = 287.7 kNm/m $M_{moist OT} = F_{moist h} \times x_{moist h} = 0 \text{ kNm/m}$ Mtotal OT = Msat OT + Mmoist OT + Mwater OT + Msur OT = 414.3 kNm/m

M_{stem R} = F_{stem} × x_{stem} = **141.6** kNm/m M_{base R} = F_{base} × x_{base} = 49 kNm/m $M_{P R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1 = 162 \text{ kNm/m}$

m²

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Total

Wall stem

Wall base

Line loads

Total

Water

Base soil

Wall stem Wall base

Line loads

Water Moist retained soil

Total

Total

Check stability against overturning Factor of safety

Bearing pressure check Vertical forces on wall

Horizontal forces on wall Surcharge load

Saturated retained soil

Moist retained soil

Moments on wall

Surcharge load

Propping force

Saturated retained soil

M_{total_R} = M_{stem_R} + M_{base_R} + M_{P_R} = **352.6** kNm/m

FoSot = Mtotal R / Mtotal OT = 0.851 FAIL - Overturning moment is greater than maximum restoring moment

 $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = 70.2 \text{ kN/m}$ $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = 44.8 \text{ kN/m}$ $F_{P,v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} = 85.5 \text{ kN/m}$ Ftotal_v = Fstem + Fbase + Fwater_v + FP_v = 200.5 kN/m

 $F_{sur h} = K_A \times cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = 5.5 \text{ kN/m}$ $F_{sat h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2 = 66.6 \text{ kN/m}$ $F_{water h} = \gamma_G \times \gamma_W' \times (h_{water} + d_{cover} + h_{base})^2 / 2 = 170.2 \text{ kN/m}$ $F_{moist h} = \gamma_G \times K_A \times cos(\delta_{r.d}) \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{base}) / 2 + (h_{eff}$ h_{base} (h_{sat} + h_{base})) = 0 kN/m $F_{pass h} = -\gamma_{Gf} \times K_{P} \times \cos(\delta_{b.d}) \times \gamma_{b}' \times (d_{cover} + h_{base})^{2} / 2 = -4.5 \text{ kN/m}$ Ftotal h = Fsat h + Fmoist h + Fpass h + Fwater h + Fsur h = 237.9 kN/m

M_{stem} = F_{stem} × x_{stem} = **191.2** kNm/m $M_{\text{hase}} = F_{\text{hase}} \times x_{\text{hase}} = 66.1 \text{ kNm/m}$ $M_{sur} = -F_{sur h} \times x_{sur h} = -14 \text{ kNm/m}$ $M_{P} = (\gamma_{G} \times P_{G1} + \gamma_{Q} \times P_{Q1}) \times p_{1} = 230.9 \text{ kNm/m}$ $M_{sat} = -F_{sat_h} \times x_{sat_h} = -112.6 \text{ kNm/m}$ $M_{water} = -F_{water h} \times x_{water h} = -287.7 \text{ kNm/m}$ $M_{moist} = -F_{moist h} \times x_{moist h} = 0 \text{ kNm/m}$ Mtotal = Mstem + Mbase + Msat + Mmoist + Mwater + Msur + MP = 73.8 kNm/m

Check bearing pressure

Fprop base = Ftotal h = 237.9 kN/m $\overline{x} = M_{total} / F_{total v} = 368 \text{ mm}$ Distance to reaction Eccentricity of reaction $e = \overline{x} - \frac{1}{107}$ mm $l_{load} = 2 \times \overline{x} = 737 \text{ mm}$ Loaded length of base $q_{toe} = F_{total v} / I_{load} = 272.1 \text{ kN/m}^2$ Bearing pressure at toe Bearing pressure at heel $q_{\text{heel}} = 0 \text{ kN/m}^2$ Effective overburden pressure $q = max((t_{base} + d_{cover}) \times \gamma_b' - (t_{base} + d_{cover} + h_{water}) \times \gamma_w', 0 \text{ kN/m}^2) = 0$ kN/m² Design effective overburden pressure $q' = q / \gamma_{\gamma} = 0 \text{ kN/m}^2$ Bearing resistance factors $N_q = Exp(\pi \times tan(\phi'_{b.d})) \times (tan(45 deg + \phi'_{b.d} / 2))^2 = 5.258$ $N_c = (N_q - 1) \times cot(\phi'_{b.d}) = 13.104$ $N_{\gamma} = 2 \times (N_{q} - 1) \times tan(\phi'_{b.d}) = 2.767$ Foundation shape factors s_q = 1 s_γ = 1 s_c = 1 Load inclination factors H = Fsur h + Fsat h + Fwater h + Fmoist h + Fpass h - Fprop base = 0 kN/m

Tekla Tedds	Project	24 HEA1	TH DRIVE		Job no. 16	2637
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77 St John Street		RC L RETA	RC L RETAINING WALL			5
EC1M 4NN	Calcs by CEM	Calcs date 29/01/2018	Checked by	Checked date	Approved by	Approved date
		V - E	- 200 5 kN/m			
		$w = 1 \text{ total_v} = m = 2$	- 200.3 KN/III			
		i _q = [1 - H /	(V + I _{load} × c' _{b.d} :	< cot(\u00f6'b.d))] ^m = 1		
		i _γ = [1 - Η /	(V + I _{load} × c' _{b.d} >	< cot(\(\phi'_{b.d}))] ^(m + 1)	= 1	
		i _c = i _q - (1 -	i_q) / (N _c × tan(ϕ'_1	b.d)) = 1		
Net ultimate bearing capacity		$n_f = c'_{b.d} \times N$	$N_c \times S_c \times i_c + q' >$	$\times N_q \times s_q \times i_q + 0.$	$.5 imes (\gamma_b' - \gamma_w') imes$	$I_{\text{load}} \times N_{\gamma} \times s_{\gamma} \times$
		İγ				
		n _f = 245.2 k	kN/m²			
Factor of safety		$FoS_{bp} = n_f / $	max(q _{toe} , q _{heel})	= 0.901		
	FAIL - M	aximum applied	d bearing pres	sure exceeds a	llowable bear	ing pressure
Partial factors on actions - Ta	ble A.3 - Comb	ination 2				
Permanent unfavourable action		$\gamma_{\rm G}$ = 1.00				
Permanent favourable action		γ _{Gf} = 1.00				
Variable unfavourable action		γ _Q = 1.30				
Variable favourable action		$\gamma_{\rm Qf}$ = 0.00				
Partial factors for soil parame	ters – Table A.	4 - Combinatio	n 2			
Angle of shearing resistance		γ _{φ'} = 1.25				
Effective cohesion		γ _{c'} = 1.25				
Weight density		$\gamma_{\gamma} = 1.00$				
Water properties						
Design water density		$\gamma_w' = \gamma_w / \gamma_\gamma$	= 9.8 kN/m ³			
Retained soil properties						
Design moist density		γmr' = γmr / γ	γ = 21 kN/m ³			
Design saturated density		$\gamma_{ m sr}$ ' = $\gamma_{ m sr}$ / γ_{γ}	= 23 kN/m ³			
Design effective shear resistance	e angle	φ' _{r.d} = atan(tan(φ' _{r.k}) / γ _ኛ) = 2	24.8 deg		
Design wall friction angle		$\delta_{r.d} = atan(t)$	$an(\delta_{r.k}) / \gamma_{\phi}) = 1$	2.1 deg		
Base soil properties						
Design soil density		$\gamma_{\rm b}' = \gamma_{\rm b} / \gamma_{\gamma} =$	= 19 kN/m ³			
Design effective shear resistance	e angle	φ' _{b.d} = atan($tan(\phi'_{b.k}) / \gamma_{\phi'}) =$	14.6 deg		
Design wall friction angle		$\delta_{b,d} = atan(t)$	tan(δ _{b.k}) / γ _{Φ'}) = 7	7.2 deg		
Design base friction angle		$\delta_{bb.d}$ = atan	(tan(δ _{bb.k}) / γ _{φ'}) =	9.7 deg		
Design effective cohesion		c' _{b.d} = c' _{b.k} /	γ _{c'} = 14.4 kN/m	2		
Design adhesion		$a_{b.d} = a_{b.k} / r$	γ _{c'} = 14.4 kN/m²			
Using Coulomb theory						
Active pressure coefficient		$K_A = sin(\alpha \cdot$	+ $\phi'_{r.d})^2 / (\sin(\alpha)^2$	$^{2} \times \sin(\alpha - \delta_{r.d}) \times$	[1 + √[sin(¢'r.d +	⊦δr.d)×
		sin(φ' _{r.d} - β)	/ (sin(α - $\delta_{r.d}$) ×	$sin(\alpha + \beta))]]^2) =$	0.371	
Passive pressure coefficient		K _P = sin(90 (sin(90 + δ _t	- φ' _{b.d})² / (sin(90 d))]]²) = 1.965	$(1 + \delta_{b.d}) \times [1 - \sqrt{s}]$	$sin(\phi'_{b.d} + \delta_{b.d})$	< sin(¢' _{b.d}) /
Overturning check						
Vertical forces on wall						
Wall stem		F _{stem} = γ _{Crf} ×	Astem × γstem =	52 kN/m		
Wall base		F _{base} = y _{Gf} ×	$A_{base} \times \gamma_{base} = 3$	33.2 kN/m		
Line loads		$F_{P,v} = \gamma_{GF} \times$	PG1 + YOF X PO1	= 60 kN/m		
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Total		F _{total_v} = F _{stem}	+ F _{base} + F _{wate}	_{r_v} + F _{P_v} = 145 .	2 kN/m		
Horizontal forces on wall							
Surcharge load		$F_{sur_h} = K_A \times G$	$\cos(\delta_{r.d}) \times \gamma_Q \times$	Surchargeo × h	n _{eff} = 6 kN/m		
Saturated retained soil		$F_{sat_h} = \gamma_G \times P$	$X_A \times \cos(\delta_{r.d}) \times$	$(\gamma_{\rm sr}' - \gamma_{\rm w}') \times (h_{\rm sat})$	+ h _{base}) ² / 2 =	61.5 kN/m	
Water		$F_{water_h} = \gamma_G \times$	$\gamma_w' \times (h_{water} +$	d _{cover} + h _{base}) ² / 2	2 = 126.1 kN/m	n	
Moist retained soil		$F_{moist_h} = \gamma_G \times$	$K_A \times cos(\delta_{r.d})$	$\times \gamma_{mr}' \times ((h_{eff} - h_{eff}))$	_{sat} - h _{base}) ² / 2 +	+ (h _{eff} - h _{sat} -	
		h _{base}) × (h _{sat} +	+ h _{base})) = 0 kN	l/m			
Base soil		$F_{exc_h} = -\gamma_{Gf} \times$	$K_P \times \cos(\delta_{b.d})$	$\times \gamma_b' \times (h_{pass} + h)$	n _{base}) ² / 2 = -3.8	3 kN/m	
Total		$F_{total_h} = F_{sat_h}$	h + F _{moist_h} + Fe	exc_h + F _{water_h} + I	F _{sur_h} = 189.8 k	:N/m	
Overturning moments on wa	all		-	-	_		
Surcharge load		Msur ot = Fsur	$h \times X_{sur h} = 15$. 2 kNm/m			
Saturated retained soil		Msat OT = Fsat	$h \times X_{\text{sat } h} = 103$	3.9 kNm/m			
Water		Mwater OT = Fw	ater h × Xwater h	= 213.1 kNm/m			
Moist retained soil		M _{moist OT} = F _m	noist h \times Xmoist h	= 0 kNm/m			
Total		$\frac{1}{10000000000000000000000000000000000$			√lsur ot = 332.2 kNm/m		
Restoring moments on wall							
Wall stem		M _{stem R} = F _{ste}	m × Xstem = 141	. 6 kNm/m			
Wall base		Mbase R = Fbas	a × Xhaea = 49	kNm/m			
l ine loads	$M_{D,P} = (abs(v_{CY} + v_{CY} + v_{CY} + v_{CY} + v_{CY}) \times p_1 = 162 \text{ kNm/m}$						
Total		$M_{\text{intral} P} = M_{\text{stam} P} + M_{\text{have } P} + M_{\text{p} P} = 352.6 \text{ kNm/m}$					
Check stability against over	turnina						
Factor of safety	turning	FoSot = Mtotal	P / Mtotal OT = 1	1.062			
		PASS - Maximum	restoring mo	ment is greate	r than overtui	rning moment	
Bearing pressure check			•	Ū		•	
Vortical foreas on wall							
Wall stem		$F_{\text{true}} = \gamma_0 \times \Delta$		2 kN/m			
Wall been		$\Gamma \text{ stem} = \gamma G \wedge P$	stem ∧ γstem − J	2 2 kN/m			
		Fbase - YG X A	where $\times \gamma_{\text{base}} - \mathbf{J}$	63 9 kN/m			
Total		$F_v = \gamma G \times P($	γu × FQ1 = + Fhans + Fo		1 kN/m		
		i total_v - Fstem	• i base ' i wate	r_v · I P_v - 143.			
Horizontal forces on wall		F - K	(\$)	C	- C hbl/m		
Surcharge load		$F_{sur_h} = K_A \times 0$	COS(Or.d) × γα ×	Surchargeo × r	$1eff = \mathbf{b} KIN/III$	CA E Ichi/ma	
		$r_{sat_h} = \gamma_G \times P$	$XA \times CUS(0r.d) \times$	(γsr − γw)×(nisat d t	T libase) ² / 2 =	01.3 KIN/M	
waler		Γ water_h = $\gamma_G \times$	γw × (Πwater +	ucover + Nbase)* / 2	2 - 120.1 KIN/M	1 (h., h	
WOIST RELATIEN SOIL		$r_{\text{moist}_h} = \gamma_G \times$	$r_A \times COS(O_{r.d})$	×γmr×((Πeff-Π J/m	sat - Hbase) ² / 2 +	「(Fleff = Flsat =	
Base soil		Face of the set	$(1base) = \mathbf{U} K \mathbf{V}$	wiii)∨w'∨(d i	$(h_{1}, h_{2})^{2}/2 = 2$	8 kN/m	
Dase SUII Total		rpass_h = -γGf >	× r\P × COS(0b.d	/×Ύb×(Clcover+ ·····	$11base = 120 \circ$.o KIN/III kNl/m	
		i total_h − ⊏sat_h	ι · ι moist_h τ Γρ	bass_n ' i`water_h ∓	sur_n - 103.0	M N/111	
Moments on wall							
vvall stem		M _{stem} = F _{stem} :	× x _{stem} = 141.6	кNm/m			
vvali base		Mbase = Hbase	× x _{base} = 49 kN	vm/m			
Surcharge load		Msur = -Fsur_h	× X _{sur_h} = -15.2	KNm/m	,		
Line loads		$M_P = (\gamma_G \times P_G)$	s1 + γα × Pα1)>	<p1 172.5="" =="" knr<="" td=""><td>n/m</td><td></td></p1>	n/m		
Saturated retained soil		M _{sat} = -F _{sat_h} :	× x _{sat_h} = -103.	9 KNm/m			
Water		Mwater = -Fwate	$r_h \times X_{water_h} = -$	-213.1 kNm/m			

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Moist retained soil		Mmoiet = -En	noiet h X Xmoiet h =	0 kNm/m				
Total		M _{total} = M _{ste}	m + M _{base} + M _{sa}	t + M _{moist} + M _{water}	+ M _{sur} + M _P =	31 kNm/m		
Check bearing pressure								
Propping force		Fprop base =	Ftotal h = 189.8	kN/m				
Distance to reaction		$\overline{\mathbf{x}} = \mathbf{M}_{\text{total}}$ /	F _{total_v} = 208 m	ım				
Eccentricity of reaction		$e = \overline{x} - I_{bas}$		ım				
Loaded length of base		$I_{load} = 2 \times$	x = 415 mm					
Bearing pressure at toe		q _{toe} = F _{total}	v / lload = 358.8	kN/m ²				
Bearing pressure at heel		q _{heel} = 0 kN	l/m²					
Effective overburden pressure		q = max((t _t kN/m²	$_{\rm base}$ + d _{cover}) $ imes$ $\gamma_{\rm c}$	d' - (t _{base} + d _{cover} +	· h _{water}) × γ _w ', 0	kN/m²) = 0		
Design effective overburden pressu	re	q' = q / γ _γ =	0 kN/m ²					
Bearing resistance factors		$N_q = Exp(\pi$	$\times tan(\phi'_{b.d})) \times ($	tan(45 deg + φ'ь.	d / 2)) ² = 3.784			
		$N_{c} = (N_{q} - 1)$	$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = 10.711$					
		$N_{\gamma} = 2 \times (N_{\gamma})$	q - 1) × tan(∳'ь.o	i) = 1.447				
Foundation shape factors		s _q = 1	. , .	,				
		s _γ = 1	s _Y = 1					
		s _c = 1						
Load inclination factors		H = F _{sur_h} +	Fsat_h + Fwater_h	+ F _{moist_h} + F _{pass}	_h - F _{prop_base} =	0 kN/m		
		$V = F_{total_v}$	= 149.1 kN/m					
		m = 2						
		i _q = [1 - H /	(V + $I_{load} \times c'_{b.d}$	$\times \cot(\phi'_{b.d}))]^m = 1$	1			
		i _γ = [1 - Η /	(V + $I_{load} \times c'_{b.d}$	$\times \text{cot}(\phi'_{b.d}))]^{(m + 1)}$	= 1			
		ic = iq - (1 -	i_q) / (N _c × tan(¢	o'b.d)) = 1				
Net ultimate bearing capacity		$\begin{split} n_{f} &= c^{*}_{b.d} \times N_{c} \times s_{c} \times i_{c} + q^{'} \times N_{q} \times s_{q} \times i_{q} + 0.5 \times (\gamma_{b}^{'} - \gamma_{w}^{'}) \times I_{bad} \times N_{\gamma} \times s_{\gamma} \times i_{\gamma} \end{split}$						
		n _f = 157 kN	l/m ²					
Factor of safety		$FoS_{bp} = n_f$	/ max(q _{toe} , q _{heel}) = 0.438				
	FAIL - Ma	aximum applie	d bearing pres	ssure exceeds a	allowable bea	ring pressure		
RETAINING WALL DESIGN								
In accordance with EN1992-1-1:20	004 incorpo	rating Corrige	ndum dated J	anuary 2008 and	d the UK Nati	onal Annex		
incorporating National Amendme	nt NO.1				Tedds calcul	ation version 2.9.0		
Concrete details - Table 3.1 - Stre	ngth and de	oformation cha	racteristics fo	or concrete				
Concrete strength class		C32/40						
Characteristic compressive cylinder	strength	f _{ck} = 32 N/r	nm²					
Characteristic compressive cube str	rength	f _{ck,cube} = 40	N/mm ²					
Mean value of compressive cylinder	rstrength	$f_{cm} = f_{ck} + 8$	N/mm ² = 40 N	l/mm²				
Mean value of axial tensile strength		f _{ctm} = 0.3 N	$/\text{mm}^2 \times (f_{ck} / 1)$	N/mm ²) ^{2/3} = 3.0 M	N/mm ²			
5% fractile of axial tensile strength		$f_{ctk,0.05} = 0.7$	7 × f _{ctm} = 2.1 N/	mm²				
Secant modulus of elasticity of cond	crete	E _{cm} = 22 kl	$V/mm^2 \times (f_{cm} / T)$	10 N/mm ²) ^{0.3} = 33	3346 N/mm ²			
Partial factor for concrete - Table 2.	1N	γc = 1.50						
Compressive strength coefficient - of	3.1.6(1)	α_{cc} = 0.85						
Design compressive concrete stren	gth - exp.3.1	5 $f_{cd} = \alpha_{cc} \times f$	_{ck} / γ _C = 18.1 N	/mm²				
Maximum aggregate size		h _{agg} = 20 m	ım					

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einforcement details						
haracteristic yield strength of	of reinforcement	f _{yk} = 500 N/	/mm ²			
odulus of elasticity of reinfo	rcement	E _s = 20000	0 N/mm ²			
artial factor for reinforcing s	teel - Table 2.1N	γ _s = 1.15	405 N/ ²			
esign yield strength of reinfo	orcement	$T_{yd} = T_{yk} / \gamma_S$	= 435 N/mm ²			
over to reinforcement						
ront face of stem		c _{sf} = 40 mm	1			
ear face of base		$C_{sr} = 50 \text{ mm}$	1			
ottom face of base		c _{bb} = 50 mr	n			
Loading details - Combination No.1 -	kN/m ² She	ar force - Combination No.1 - kN/m	Bend	ling moment - Combination No.	- kNm/m	
	1,09					
	E					
	0					
		184				
е Ф	© ≓ 239 5					
Toe			-201.7		314.5	
e e					379.9	
	Latter 2					
coading details - Combination H0.2 -	She	ar force - Combination No.2 - kN/m	Bend	ling moment - Combination No.	2 - kNm/m	
	0.95					
	Sea					

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max(Asr.reg, Asr.min) / Asr.prov = 0.5

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

Check stem design at base of stem Depth of section h = **450** mm Rectangular section in flexure - Section 6.1 Design bending moment combination 1 M = 314.5 kNm/m Depth to tension reinforcement $d = h - c_{sr} - \phi_{sr} / 2 = 384 \text{ mm}$ $K = M / (d^2 \times f_{ck}) = 0.067$ K' = 0.207 K' > K - No compression reinforcement is required Lever arm $z = min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = 360 mm$ Depth of neutral axis $x = 2.5 \times (d - z) = 60 \text{ mm}$ Area of tension reinforcement required $A_{sr.reg} = M / (f_{yd} \times z) = 2010 \text{ mm}^2/\text{m}$

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

 Area of tension reinforcement provided
 $A_{er.prov} = \pi \times \phi_{er}^2 / (4 \times s_{er}) = 4021 \text{ mm}^2/\text{m}$

 Minimum area of reinforcement - exp.9.1N
 $A_{er.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 604 \text{ mm}^2/\text{m}$

 Maximum area of reinforcement - cl.9.2.1.1(3)
 $A_{er.max} = 0.04 \times h = 18000 \text{ mm}^2/\text{m}$

Deflection control - Section 7.4 Reference reinforcement ratio

Required tension reinforcement ratio

Structural system factor - Table 7.4N

Limiting span to depth ratio - exp.7.16.a

Variable load factor - EN1990 - Table A1.1

Reinforcement factor - exp.7.17

Actual span to depth ratio

Crack control - Section 7.3

Serviceability bending moment Tensile stress in reinforcement

Effective area of concrete in tension Mean value of concrete tensile strength

Maximum crack spacing - exp.7.11 Maximum crack width - exp.7.8

Limiting crack width

Reinforcement ratio Modular ratio Bond property coefficient Strain distribution coefficient

Load duration Load duration factor

Required compression reinforcement ratio

$$\begin{split} \rho_0 &= \sqrt{(f_{ck} \ / \ 1 \ N/mm^2) \ / \ 1000 = 0.006 } \\ \rho &= A_{sr.req} \ / \ d = 0.005 \\ \rho' &= A_{sr.2req} \ / \ d_2 = 0.000 \\ K_b &= 0.4 \\ K_s &= \min(500 \ N/mm^2 \ / \ (f_{yk} \times A_{sr.req} \ / \ A_{sr.prov}), \ 1.5) = 1.5 \\ \min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} \ / \ 1 \ N/mm^2)} \times \rho_0 \ / \ \rho + 3.2 \times \sqrt{(f_{ck} \ / \ 1 \ N/mm^2)} \times (\rho_0 \ / \ \rho - 1)^{3/2}], \ 40 \times K_b) = 12.4 \\ h_{stem} \ / \ d = 12 \\ PASS - Span \ to \ depth \ ratio \ is \ less \ than \ deflection \ control \ limit \end{split}$$

w_{max} = **0.3** mm

ψ2 = 0.6
M _{sis} = 229 kNm/m
$\sigma_{s} = M_{sis} / (A_{sr,prov} \times z) = 158.2 \text{ N/mm}^{2}$
Long term
k _t = 0.4
$A_{c.eff} = min(2.5 \times (h - d), (h - x) / 3, h / 2) = 129916 mm^2/m$
$f_{ct.eff} = f_{ctm} = 3.0 \text{ N/mm}^2$
$\rho_{p.eff} = A_{sr,prov} / A_{c.eff} = 0.031$
$\alpha_{e} = E_{s} / E_{cm} = 5.998$
k ₁ = 0.8
k ₂ = 0.5
k ₃ = 3.4
k ₄ = 0.425
$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} \ / \ \rho_{p.eff} = \textbf{346} \ mm$
$w_{k} = s_{r.max} \times max(\sigma_{s} - k_{t} \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_{e} \times \rho_{p.eff}), \ 0.6 \times \sigma_{s}) \ / \ E_{s}$
w _k = 0.193 mm

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		w _k / w _{max} =	0.645					
		PASS	- Maximum c	rack width is le	ss than limitir	ig crack width		
Rectangular section in shea	ir - Section 6.2	\/ - 201 7	/M/m					
Design shear lorce		V = 201.7	$\frac{1}{2} \frac{1}{2} \frac{1}$					
		$k = \min(1 + 1)$	$-\sqrt{200} \text{mm} l c$	() 2) = 1 722				
Longitudinal reinforcement rat	tio	$\kappa = \min(\Lambda)$		- 0.010				
Longitudinar reiniorcement rai	10	pi = min(As	5 N1/2/mm × k ³	$^{2} \sim f_{1} 0.5 - 0.447$	N/mm ²			
		Vmin - 0.03	/C	$\sim \times 1_{ck} \sim - 0.447$	ישער אין אוויד דייער אינאר אינאר			
Design snear resistance - exp	0.0.2a & 0.2D		$(\mathbf{U}_{\mathrm{Rd.c}} \times \mathbf{K} \times (1))$	$00 \text{ N}^{-}/\text{mm}^{-} \times \rho_{1} \times$	T_{ck}) ^{1,0} , V_{min}) × d			
		V Rd.c = 255	.0 KIN/III					
			S - Desian st	near resistance	exceeds desi	on shear force		
Horizontal reinforcement pa	rallel to face of	stem - Section 9	9.6					
Minimum area of reinforcement	nt - cl.9.6.3(1)	Asy reg = ma	1X(0.25 × Aer nor	w. $0.001 \times t_{\text{starr}}$ =	1005 mm ² /m			
Maximum spacing of reinforce	ement – cl 9 6 3(2	2) Sex max = 40	Sex max = 400 mm					
Transverse reinforcement pro	vided	16 dia.bars	16 dia.bars @ 200 c/c					
Area of transverse reinforcem	ent provided	$A_{sx prov} = \pi$	$A_{sx,prov} = \pi \times \phi_{sx^2} / (4 \times s_{sx}) = 1005 \text{ mm}^2/\text{m}$					
	PASS - Area o	of reinforcement	einforcement provided is greater than area of reinforcement required					
Check base design at tes								
Depth of section		h = 450 mr	n					
		n - 430 mi						
Rectangular section in flexu	ire - Section 6.1	14 - 270 0	h los (m					
Design bending moment com	bination 1	M = 379.9	M = 3/9.9 KNm/m					
Depth to tension reinforcement	IL	$u = n - c_{bb}$	$K = M / (d^2 \times f_{\star}) = 0.081$					
		K = M / (d²	× T _{ck}) = 0.081					
		K = 0.207	K' N	No comprossio	n roinforcom	ant is required		
Lover orm		$z = \min(0.5)$	~~~~		v d = 254 mm	ent is required		
		z = 1111(0.5)	$z = 1111(0.5 + 0.5 \times (1 - 5.55 \times K)^{-3}, 0.95) \times 0 = 354$ mm					
Area of tension rainforcement	required	∧ – ∠.0 × (C	$x - 2.5 \times (0 - 2) = 14$ [1][] $\Delta_{11} = M/(f_{11} \times 7) = 2465 \text{ mm}^2/\text{m}$					
Tension reinforcement provide	ad	Abb.reg - IVI	Abb.req – M / $(I_{yd} \times Z) = 2465 \text{ mm}^2/\text{m}$					
Area of tension reinforcement	provided	52 ula.bais	$32 \text{ uia.bats } (200 \text{ G/G}) = 4021 \text{ mm}^2/\text{m}$					
Minimum area of rainforcement		Abb.prov = n	$A_{bb,prov} = \pi \times \phi_{bb}^{-1} (4 \times S_{bb}) = 4021 \text{ mm}^{-1} \text{m}^{-1}$					
Maximum area of reinforcement	III - exp.9. IN	Abb.min = IIIa	$A_{bb.min} = \max(0.26 \times T_{ctm} / T_{yk}, 0.0013) \times d = 604 \text{ mm}^2/\text{m}$					
Maximum area or remorceme	ent - 01.9.2. 1. 1(3)	$A_{bb.max} = 0.$	$Abb.max = 0.04 \times \Pi = 10000 \Pi\Pi\Pi^{2}/\Pi$ $max(A_{bb.max} = A_{bb.max}) / A_{bb.max} = 0.613$					
	PASS - Area (f reinforcement	max(Abb.req, Abb.min) / Abb.prov = 0.613					
	FASS - Alea C	n rennorcement	provided is	greater than are	a or remiorce	inent required		
Limiting grock width			~~~					
Variable load factor EN1000	Table A1 1	$w_{max} = 0.3$						
Serviceshility bonding manage		$\psi_2 = 0.0$	4 kNm/m					
Tensile stress in reinforcement	n. St	$\sigma = M \cdot I $	φ κινιι//// Δ	96 7 N/mm ²				
Load duration	it.	Us - IVIsis / (\neg DD.prov $\land \angle) = 1$	30.7 N/IIIII-				
Load duration factor								
Effective area of concrete in the	ension	$\Delta_{} = \min($	$(2.5 \times (h - d))$	h = x / / 3 h / 2 -	: 125370 mm ^{2/}	m		
Mean value of concrete topoli	e strenath	f	$(2.0 \land (11 - U), ($ $(3.0 \text{ N}/mm^2)$	··· → ∧j / 3, 11 / 2) =	- 123370 11111-/			
Reinforcement ratio	e suenyui	$i_{ct.eff} = i_{ctm} =$	· 5.5 N/IIII/-	32				
Reinforcement ratio		Pp.eff - Abb.p	$\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = 0.032$					

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Modular ratio		αe = Es / Ec	m = 5.998						
Bond property coefficient		k ₁ = 0.8							
Strain distribution coefficient		k ₂ = 0.5							
		k ₃ = 3.4							
		k4 = 0.425							
Maximum crack spacing - exp.7	.11	$s_{r.max} = k_3 \times$	$c_{bb} + k_1 \times k_2 \times k_2$	$\kappa_4 \times \phi_{bb} / \rho_{p.eff} = 3$	40 mm				
Maximum crack width - exp.7.8		$W_k = S_{r.max} \times$	$max(\sigma_s - k_t \times ($	$f_{ct.eff} / \rho_{p.eff} \times (1 +$	⊢α _e ×ρ _{p.eff}), 0.	$6 \times \sigma_s) / E_s$			
		w _k = 0.258	mm						
		$w_k / w_{max} =$	0.859						
		PASS	- Maximum cra	ack width is les	s than limitin	ng crack width			
Rectangular section in shear	- Section 6.2								
Design shear force		V = 184 kN	/m						
		$C_{Rd,c} = 0.18$	8 / γ _C = 0.120						
		k = min(1 +	√(200 mm / d),	2) = 1.722					
Longitudinal reinforcement ratio		$\rho_1 = min(A_{bt})$	_{o.prov} / d, 0.02) =	0.010					
		v _{min} = 0.035	$5 \text{ N}^{1/2}/\text{mm} \times \text{k}^{3/2}$	× f _{ck} ^{0.5} = 0.447 N	l/mm ²				
Design shear resistance - exp.6	.2a & 6.2b	V _{Rd.c} = max	$V_{\text{Rd.c}} = \max(C_{\text{Rd.c}} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{\text{ck}})^{1/3}, v_{\text{min}}) \times d$						
-		V _{Rd.c} = 255.	.8 kN/m						
		$V / V_{Rd.c} = 0$	0.720						
		PAS	S - Design she	ar resistance e	xceeds desig	n shear force			
Secondary transverse reinfore	cement to base	- Section 9.3							
Minimum area of reinforcement	– cl.9.3.1.1(2)	A _{bx.req} = 0.2	× A _{bb.prov} = 804	mm²/m					
Maximum spacing of reinforcem	nent – cl.9.3.1.1(3	3) s _{bx_max} = 45	0 mm						
Transverse reinforcement provid	ded	16 dia.bars	@ 200 c/c						
Area of transverse reinforcement	nt provided	$A_{bx.prov} = \pi$	$A_{bx,prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx}) = 1005 \text{ mm}^2/\text{m}$						
	PASS - Area of	reinforcement	provided is gr	reater than area	of reinforce	ment required			

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Reinforcement details

Toka	Project				Job no.	
Tedds		162	637			
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77 St John Street		RC L RETAI	NING WALL			1
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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 2.9.03
Retaining wall details		
Stem type	Cantilever	
Stem height	h _{stem} = 3000 mm	
Stem thickness	t _{stem} = 300 mm	
Angle to rear face of stem	$\alpha = 90 \text{ deg}$	
Stem density	$\gamma_{stem} = 25 \ kN/m^3$	
Toe length	ltoe = 1200 mm	
Base thickness	$t_{\text{base}} = 300 \text{ mm}$	
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$	
Height of retained soil	$h_{ret} = 3000 mm$	
Angle of soil surface	$\beta = 0 \operatorname{deg}$	
Depth of cover	$d_{cover} = 0 mm$	
Height of water	h _{water} = 3000 mm	
Water density	$\gamma_w = 9.8 \text{ kN/m}^3$	
Retained soil properties		
Soil type	Medium dense well graded sand	
Moist density	$\gamma_{mr} = 21 \ kN/m^3$	
Saturated density	$\gamma_{sr} = \textbf{23} \ kN/m^3$	
Characteristic effective shear resistance angle	$\phi'_{r.k} = 30 \operatorname{deg}$	
Characteristic wall friction angle	$\delta_{r.k} = 15 \text{ deg}$	
Base soil properties		
Soil type	Stiff clay	
Soil density	$\gamma_b = 19 \ kN/m^3$	
Characteristic cohesion	$c'_{b.k} = 18 \text{ kN/m}^2$	
Characteristic adhesion	$a_{b,k} = 18 \ kN/m^2$	
Characteristic effective shear resistance angle	$\phi'_{\mathrm{b.k}} = 18 \deg$	
Characteristic wall friction angle	$\delta_{b,k} = 9 deg$	
Characteristic base friction angle	$\delta_{bb.k} = 12 \text{ deg}$	
Loading details		
Variable surcharge load	$Surcharge_Q = 2.5 \text{ kN/m}^2$	
Vertical line load at 1350 mm	$P_{G1} = 60 \text{ kN/m}$	
	$P_{Q1} = 3 \text{ kN/m}$	

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Calculate retaining wall geometry

Effective cohesion

Weight density

Base length	$l_{base} = l_{toe} + t_{stem} = \textbf{1500} mm$				
Saturated soil height	$h_{sat} = h_{water} + d_{cover} = \textbf{3000} mm$				
Moist soil height	$h_{moist} = h_{ret} - h_{water} = 0 mm$				
Length of surcharge load	$l_{sur} = l_{heel} = 0 mm$				
- Distance to vertical component	$x_{sur_v} = l_{base} - l_{heel} / 2 = 1500 \ mm$				
Effective height of wall	$h_{\rm eff} = h_{\rm base} + d_{\rm cover} + h_{\rm ret} = \textbf{3300} \ mm$				
- Distance to horizontal component	$x_{sur_h} = h_{eff} / 2 = 1650 \ mm$				
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} = \boldsymbol{0.9}~m^2$				
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 = 1350 \text{ mm}$				
Area of wall base	$A_{base} = l_{base} \times t_{base} = \textbf{0.45} \ m^2$				
- Distance to vertical component	$x_{base} = l_{base} \ / \ 2 = \textbf{750} \ mm$				
Partial factors on actions - Table A.3 - Combinat	ion 1				
Permanent unfavourable action	$\gamma_{\rm G}=1.35$				
Permanent favourable action	$\gamma_{\rm Gf} = 1.00$				
Variable unfavourable action	$\gamma_{\rm Q}=1.50$				
Variable favourable action	$\gamma_{Qf}=\boldsymbol{0.00}$				
Partial factors for soil parameters – Table A.4 - Combination 1					
Angle of shearing resistance	$\gamma_{0'} = 1.00$				

 $\gamma_{c'} = 1.00$

 $\gamma_{\gamma} = 1.00$

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Water properties

To I

Design water density

Retained soil properties Design moist density Design saturated density Design effective shear resistance angle Design wall friction angle

Base soil properties

Design soil density Design effective shear resistance angle Design wall friction angle Design base friction angle Design effective cohesion Design adhesion

Using Coulomb theory Active pressure coefficient

Passive pressure coefficient

Overturning check

Vertical forces on wall Wall stem Wall base Line loads Total Horizontal forces on wall Surcharge load Saturated retained soil

Water Moist retained soil

Base soil Total

Overturning moments on wall Surcharge load Saturated retained soil Water Moist retained soil Total Restoring moments on wall

Wall stem Wall base Line loads

γw'	=	γw	/ γ ₁	= 9	.8	kN/m ³
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 $\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = 21 \text{ kN/m}^3$ $\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = 23 \text{ kN/m}^3$ $\phi'_{r.d} = \operatorname{atan}(\operatorname{tan}(\phi'_{r.k}) / \gamma_{\phi'}) = 30 \operatorname{deg}$ $\delta_{r.d} = \operatorname{atan}(\operatorname{tan}(\delta_{r.k}) / \gamma_0) = 15 \operatorname{deg}$

 $\gamma_{\rm h}' = \gamma_{\rm h} / \gamma_{\rm v} = 19 \ \rm kN/m^3$ $\phi'_{b.d} = \operatorname{atan}(\operatorname{tan}(\phi'_{b.k}) / \gamma_{\phi'}) = 18 \operatorname{deg}$ $\delta_{b.d} = \operatorname{atan}(\operatorname{tan}(\delta_{b.k}) / \gamma_{\phi}) = 9 \operatorname{deg}$ $\delta_{bb.d} = atan(tan(\delta_{bb.k}) / \gamma_{\psi}) = 12 \text{ deg}$ $c'_{b.d} = c'_{b.k} / \gamma_{c'} = 18 \text{ kN/m}^2$ $a_{b.d} = a_{b.k} / \gamma_{c'} = 18 \text{ kN/m}^2$

 $K_{A} = \sin(\alpha + \phi'_{r.d})^{2} / (\sin(\alpha)^{2} \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d})} \times (1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d})]^{2} + \delta_{r.d}}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d})]^{2} + \delta_{r.d}} \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d})]^{2} + \delta_{r.d}}]$ $\sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))||^2) = 0.301$ $K_{\rm P} = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{\sin(\phi'_{b,d} + \delta_{b,d})} \times \sin(\phi'_{b,d}) / (1 - \sqrt{\sin(\phi'_{b,d})} \times \sin(\phi'_{b,d})) / (1 - \sqrt{\sin(\phi'_{b,d})} \times \sin(\phi'_{b,d})) / (1 - \sqrt{\sin(\phi'_{b,d})} / (1 - \sqrt{\cos(\phi'_{b,d})} / (1 - \sqrt$ $(\sin(90 + \delta_{b,d}))||^2) = 2.359$

 $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \textbf{22.5 kN/m}$ $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 11.2 \text{ kN/m}$ $F_{P_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Of} \times P_{O1} = 60 \text{ kN/m}$ $F_{\text{total } v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{water } v} + F_{P v} = 93.8 \text{ kN/m}$

 $F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_O \times Surcharge_O \times h_{eff} = 3.6 \text{ kN/m}$ $F_{sat_h} = \gamma_G \times K_A \times cos(\delta_{r.d}) \times (\gamma_{sr'} - \gamma_{w'}) \times (h_{sat} + h_{base})^2 / 2 = 28.2 \text{ kN/m}$ $F_{water_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 = 72.1 \text{ kN/m}$ $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr'} \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base})^2 / 2$ h_{base} × (h_{sat} + h_{base})) = 0 kN/m $F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = -2 \text{ kN/m}$ $F_{total_h} = F_{sat_h} + F_{moist_h} + F_{exc_h} + F_{water_h} + F_{sur_h} = 102 \text{ kN/m}$

 $M_{sur OT} = F_{sur h} \times x_{sur h} = 5.9 \text{ kNm/m}$ $M_{sat_OT} = F_{sat_h} \times x_{sat_h} = 31.1 \text{ kNm/m}$ $M_{water_OT} = F_{water_h} \times x_{water_h} = 79.3 \text{ kNm/m}$ $M_{moist_OT} = F_{moist_h} \times x_{moist_h} = 0 \text{ kNm/m}$ $M_{total_OT} = M_{sat_OT} + M_{moist_OT} + M_{water_OT} + M_{sur_OT} = 116.3 \text{ kNm/m}$

 $M_{\text{stem R}} = F_{\text{stem}} \times x_{\text{stem}} = 30.4 \text{ kNm/m}$ $M_{\text{base R}} = F_{\text{base}} \times x_{\text{base}} = 8.4 \text{ kNm/m}$ $M_{P_R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Of} \times P_{O1})) \times p_1 = 81 \text{ kNm/m}$

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 $M_{total_R} = M_{stem_R} + M_{base_R} + M_{P_R} = \textbf{119.8} \text{ kNm/m}$

Check stability against overturning Factor of safety

Bearing pressure check Vertical forces on wall

Horizontal forces on wall Surcharge load

Saturated retained soil

Total

Wall stem

Wall base

Line loads

Total

Water Moist retained soil

Base soil

Wall base

Line loads

Water Moist retained soil

Total

Moments on wall Wall stem

Surcharge load

Saturated retained soil

Total

 ${\rm FoS}_{\rm ot} = M_{\rm total_R} \,/\, M_{\rm total_OT} = 1.03$ PASS - Maximum restoring moment is greater than overturning moment

$$\begin{split} F_{stem} &= \gamma_G \times A_{stem} \times \gamma_{stem} = \textbf{30.4 kN/m} \\ F_{base} &= \gamma_G \times A_{base} \times \gamma_{base} = \textbf{15.2 kN/m} \\ F_{P_-v} &= \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} = \textbf{85.5 kN/m} \\ F_{total_v} &= F_{stem} + F_{base} + F_{water_v} + F_{P_-v} = \textbf{131.1 kN/m} \end{split}$$

$$\begin{split} &F_{sur_{,h}} = K_A \times cos(\delta_{r,d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = \textbf{3.6 kN/m} \\ &F_{sat_{,h}} = \gamma_G \times K_A \times cos(\delta_{r,d}) \times (\gamma_{sr}' - \gamma_{sr}') \times (h_{sat} + h_{base})^2 / 2 = \textbf{28.2 kN/m} \\ &F_{water_{,h}} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 = \textbf{72.1 kN/m} \\ &F_{moist_{,h}} = \gamma_G \times K_A \times cos(\delta_{r,d}) \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) = \textbf{0 kN/m} \\ &F_{pass_{,h}} = -\gamma_{Cf} \times K_P \times cos(\delta_{b,d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = -\textbf{2 kN/m} \\ &F_{total_{,h}} = F_{sat_{,h}} + F_{moist_{,h}} + F_{water_{,h}} + F_{sur_{,h}} = \textbf{102 kN/m} \end{split}$$

$$\begin{split} M_{stem} &= F_{stem} \times x_{stem} = 41 \ kNm/m \\ M_{base} &= F_{base} \times x_{base} = 11.4 \ kNm/m \\ M_{sur} &= .F_{sur_{a}h} \times x_{sur_{a}h} = -5.9 \ kNm/m \\ M_{P} &= (\gamma_{G} \times P_{G1} + \gamma_{Q} \times P_{Q1}) \times p_{1} = 115.4 \ kNm/m \\ M_{sat} &= .F_{sat_{a}h} \times x_{sat_{a}h} = -31.1 \ kNm/m \\ M_{water} &= .F_{water_{a}h} \times x_{water_{a}h} = -79.3 \ kNm/m \\ M_{moist} &= .F_{moist_{a}h} \times x_{moist_{a}h} = 0 \ kNm/m \\ M_{total} &= M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{water} + M_{sur} + M_{P} = 51.5 \ kNm/m \end{split}$$

 $q = max((t_{base} + d_{cover}) \times \gamma_b' - (t_{base} + d_{cover} + h_{water}) \times \gamma_w', 0 \text{ kN/m}^2) = 0$

 $N_q = Exp(\pi \times tan(\phi'_{b.d})) \times (tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 = 5.258$

 $H = F_{sur_h} + F_{sat_h} + F_{water_h} + F_{moist_h} + F_{pass_h} - F_{prop_base} = 0 \text{ kN/m}$

Line loads

 $F_{prop_base} = F_{total_h} = 102 \text{ kN/m}$ $\overline{x} = M_{total} / F_{total_v} = 393 \text{ mm}$

 $e = \overline{x} - l_{base} / 2 = -357 \text{ mm}$ $l_{load} = 2 \times \overline{x} = 786 \text{ mm}$

 $q_{heel} = 0 \text{ kN/m}^2$

 $q' = q \; / \; \gamma_{\gamma} = \boldsymbol{0} \; kN/m^2$

kN/m²

 $s_q = 1$ $s_\gamma = 1$ $s_c = 1$

 $q_{toe} = F_{total v} / l_{load} = 166.8 \text{ kN/m}^2$

$$\begin{split} N_{c} &= (N_{q} - 1) \times cot(\phi'_{b.d}) = \textbf{13.104} \\ N_{\gamma} &= 2 \times (N_{q} - 1) \times tan(\phi'_{b.d}) = \textbf{2.767} \end{split}$$

Check bearing pressure

Propping force Distance to reaction Eccentricity of reaction Loaded length of base Bearing pressure at toe Bearing pressure at heel Effective overburden pressure

Design effective overburden pressure Bearing resistance factors

Foundation shape factors

Load inclination factors

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	Tiojeet	24 HEAT	TH DRIVE		16	2637
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		V - Foot -	- 131 1 kN/m			
		$w = 1 \text{ total_v} = 1$ m = 2	- 1 51.1 Kiwin			
		$i_q = [1 - H /$	$(V + l_{load} \times c'_{b.d})$	$(\times \cot(\phi'_{b.d}))]^m = 1$	L	
		$i_{\gamma} = [1 - H /$	$(V + l_{load} \times c'_{b.d})$	$\times \cot(\phi'_{b.d}))]^{(m+1)}$	= 1	
		$i_{\rm c}$ = $i_{\rm q}$ - (1 -	i_q) / ($N_c \times tan(\phi)$	$(b'_{b.d}) = 1$		
Net ultimate bearing capacity		$n_{\rm f}=c'_{\rm b.d}\times l$	$N_c imes s_c imes i_c + q'$	$ imes N_q imes s_q imes i_q + 0$	$.5 imes(\gamma_{ m b}'$ - $\gamma_{ m w}') imes$	$l_{load} \times N_{\gamma} \times s_{\gamma} \times$
		iγ				
		$n_{\rm f} = 245.9$ l	cN/m ²			
Factor of safety		$FoS_{bp} = n_f /$	max(qtoe, qheel	l) = 1.474	m anniad haa	
	PA55-F		g pressure ex	ceeus maximui	n applied bea	ring pressure
Partial factors on actions - Ta	ble A.3 - Com	bination 2				
Permanent unfavourable action		$\gamma_{\rm G} = 1.00$				
Veriable surfacement action		$\gamma_{\rm Gf} = 1.00$				
Variable uniavourable action		$\gamma_{\rm Q} = 1.30$				
		YQi = 0.00	0			
Angle of choosing resistance	ters – Table A	.4 - Combination	n 2			
Effective cohosion		$\gamma_{\phi} = 1.25$				
Weight density		$\gamma_{c} = 1.23$				
weight density		$\gamma\gamma = 1.00$				
Water properties		or ' - or / or	0 9 kN/m3			
Design water density		$\gamma_{\rm W} = \gamma_{\rm W} / \gamma_{\gamma}$	= 9.8 KIN/III"			
Retained soil properties			21 hN/3			
Design moist density		$\gamma_{mr} = \gamma_{mr} / \gamma$	$\gamma = 21 \text{ KIN/m}^3$			
Design effective shear resistant	so anglo	$\gamma_{sr} = \gamma_{sr} / \gamma_{\gamma}$	$= 23 \text{ km/m}^{\circ}$	24 8 dog		
Design wall friction angle	e angle	$\psi_{r,d} = atan(t)$	$an(\phi_{r,k}) / \gamma \phi) = 1$	24.0 ueg		
Design war menon angle		or.d – attalite	$dif(O_{\Gamma,K}) / I_{\phi}) = 1$	12.1 ueg		
Base soil properties		an' - an / ar	10 kN/m3			
Design offective shear resistant	so anglo	$\gamma_{\rm b} = \gamma_{\rm b} / \gamma_{\gamma}$	$(\tan(\theta_{11}))/(11)$	- 146 dog		
Design wall friction angle	e angle	φ _{b.d} = atan($\tan(\psi_{\text{D},k}) / \psi_{0} =$	- 14.0 ueg		
Design was include angle		$\delta_{bbd} = atan$	$(\tan(\delta_{bb}, k) / \gamma_{e}) =$	= 9.7 deg		
Design effective cohesion		$C'_{bd} = C'_{bk}/$	$\gamma_{c'} = 14.4 \text{ kN/m}$	m^2		
Design adhesion		$a_{b,d} = a_{b,k}/2$	$\gamma_{c'} = 14.4 \text{ kN/m}$	1 ²		
Using Coulomb theory			•			
Active pressure coefficient		$K_A = \sin(\alpha \cdot$	+ φ'rd) ² / (sin(α)	$)^2 \times \sin(\alpha - \delta_{rd}) \times$	[1 + √[sin(¢'rd)	+δrd)×
····· P		$\sin(\phi'_{r,d} - \beta)$	$/(\sin(\alpha - \delta_{r,d}))$	$\times \sin(\alpha + \beta))] ^2) =$	0.371	
Passive pressure coefficient		$K_P = sin(90)$	- \u00f6'_b.d) ² / (sin(9	$90 + \delta_{b.d} \times [1 - \sqrt{3}]$	$sin(\phi'_{b.d} + \delta_{b.d})$	× sin(¢' _{b.d}) /
		$(\sin(90 + \delta_t))$	(.d))]] ²) = 1.965			
Overturning check						
Vertical forces on wall						
Wall stem		$F_{stem} = \gamma_{Gf} \times$	$A_{stem} \times \gamma_{stem} =$	22.5 kN/m		
Wall base		$F_{base} = \gamma_{Gf} \times$	$A_{base} \times \gamma_{base} =$	11.2 kN/m		

 $F_{P_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Of} \times P_{Q1} = 60 \text{ kN/m}$

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Total		$F_{total_v} = F_{stem}$	+ F _{base} + F _{wat}	_{er_v} + F _{P_v} = 93.8	kN/m	
Horizontal forces on wall						
Surcharge load		$F_{sur_h} = K_A \times \alpha$	$\cos(\delta_{r.d}) \times \gamma_Q$	$<$ Surcharge _Q \times h	eff = 3.9 kN/m	
Saturated retained soil		$F_{sat_h} = \gamma_G \times K$	$A_A \times \cos(\delta_{r.d}) >$	$<$ ($\gamma_{\rm sr'}$ - $\gamma_{\rm w'}$) $ imes$ ($h_{\rm sat}$	$(+ h_{base})^2 / 2 = 2$	26.1 kN/m
Water		$F_{water_h} = \gamma_G \times$	$\gamma_{w'} imes (h_{water} +$	$d_{cover} + h_{base})^2 / 2$	2 = 53.4 kN/m	
Moist retained soil		$F_{moist_h} = \gamma_G \times$	$K_A \times \cos(\delta_{r.d})$	$\times\gamma_{mr}'\times((h_{\rm eff}$ - h_s	$_{at} - h_{base})^2 / 2 +$	(h _{eff} - h _{sat} -
		h_{base} (h_{sat} +	h_{base}) = 0 k	N/m		
Base soil		$F_{exc_h} = -\gamma_{Gf} \times$	$K_P \times \cos(\delta_{b.d})$	$) \times \gamma_b' \times (h_{pass} + h_{pass})$	$(base)^2 / 2 = -1.7$	kN/m
Total		$F_{total_h} = F_{sat_h}$	$+ F_{moist_h} + F$	$e_{xc_h} + F_{water_h} + I$	$G_{sur_h} = 81.7 \text{ kN}$	/m
Overturning moments on w	all					
Surcharge load		$M_{sur_OT} = F_{sur_}$	$h \times x_{sur_h} = 6.$	4 kNm/m		
Saturated retained soil		$M_{sat_OT} = F_{sat_}$	$h \times x_{sat_h} = 28$.7 kNm/m		
Water		$M_{water_OT} = F_w$	ater_h $ imes$ Xwater_h	= 58.8 kNm/m		
Moist retained soil		$M_{moist_OT} = F_m$	$_{oist_h} \times x_{moist_h}$	= 0 kNm/m		
Total		$M_{total_{OT}} = M_{sa}$	$t_{OT} + M_{moist_O}$	$T + M_{water_OT} + M_{s}$	$ur_{OT} = 93.8 \text{ kN}$	[m/m
Restoring moments on wall						
Wall stem		$M_{stem_R} = F_{ster}$	$x_{stem} = 30.$	4 kNm/m		
Wall base		$M_{base_R} = F_{bas}$	$x_{base} = 8.4$	kNm/m		
Line loads		$M_{P_R} = (abs(\gamma$	$V_{\rm Gf} imes P_{\rm G1} + \gamma_{\rm Qf}$	$\times P_{Q1})) \times p_1 = 81$	kNm/m	
Total		$M_{total_R} = M_{ster}$	$n_R + M_{base_R}$	+ M _{P_R} = 119.8 k	Nm/m	
Check stability against over	turning					
Factor of safety		$FoS_{ot} = M_{total}$	$_{\rm R}$ / $M_{\rm total_OT}$ =	1.277		
	PA	55 - Maximum	restoring mo	oment is greater	r tnan overtur	ning moment
Bearing pressure check						
Vertical forces on wall						
Wall stem		$F_{stem} = \gamma_G \times A$	$_{\rm stem} imes \gamma_{\rm stem} = 2$	22.5 kN/m		
Wall base		$F_{base} = \gamma_G \times A$	$_{base} \times \gamma_{base} = 1$	1 1.2 kN/m		
Line loads		$F_{P_v} = \gamma_G \times P_G$	$_{s_1} + \gamma_Q \times P_{Q_1} =$	= 63.9 kN/m		
Total		$F_{total_v} = F_{stem}$	+ F _{base} + F _{wat}	$er_v + F_{P_v} = 97.7$	kN/m	
Horizontal forces on wall						
Surcharge load		$F_{sur_h} = K_A \times G$	$\cos(\delta_{r.d}) \times \gamma_Q$	< Surchargeo × h	eff = 3.9 kN/m	
Saturated retained soil		$F_{sat_h} = \gamma_G \times K$	$_{A} \times \cos(\delta_{r.d}) >$	$\langle (\gamma_{\rm sr'} - \gamma_{\rm w'}) \times (h_{\rm sat})$	$(+ h_{base})^2 / 2 = 2$	26.1 kN/m
Water		$F_{water_h} = \gamma_G \times$	$\gamma_w' \times (h_{water} +$	$d_{cover} + h_{base})^2 / 2$	2 = 53.4 kN/m	
Moist retained soil		$F_{moist_h} = \gamma_G \times$	$K_A \times \cos(\delta_{r.d})$	$\times \gamma_{mr'} \times ((h_{eff} - h_s))$	$_{at} - h_{base})^2 / 2 +$	(h _{eff} - h _{sat} -
		h_{base} × (h_{sat} +	h_{base}) = 0 kl	N/m	1 12/0	71 31/
Base soil		$F_{pass_h} = -\gamma_{Gf} >$	KP×cos(δb.	d) $\times \gamma_{b'} \times (d_{cover} + \Gamma)$	$h_{base}^2 / 2 = -1.$	7 kN/m
Total		$F_{total_h} = F_{sat_h}$	+ I ⁺ moist_h + F	pass_h + Fwater_h +	r'sur_h = 81.7 kl	N/M
Moments on wall						
Wall stem		M _{stem} = F _{stem} >	< x _{stem} = 30.4	kNm/m		
wall base		M _{base} = F _{base} >	$\times x_{\text{base}} = 8.4 \text{ k}$	Nm/m		
Surcharge load		$M_{sur} = -F_{sur_h}$	$\times x_{sur_h} = -6.4$	kNm/m	,	
Line loads		$M_P = (\gamma_G \times P_G)$	$1 + \gamma_Q \times P_{Q1}$	× p1 = 86.3 kNm/	m	
Saturated retained soil		$M_{sat} = -F_{sat_h}$	$< x_{sat_h} = -28.7$	KNM/M		
Water		$M_{water} = -F_{water}$	$r_h \times x_{water_h} =$	- 58.8 kNm/m		

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Moist retained soil		Mmoist = -Fm	oist_h × Xmoist_h =	0 kNm/m			
Total		$M_{total} = M_{ster}$	m + M _{base} + M _{sa}	$H + M_{moist} + M_{water}$	$+ M_{sur} + M_{P} =$	31.2 kNm/m	
Check bearing pressure							
Propping force		Fprop_base =	F _{total_h} = 81.7 kl	N/m			
Distance to reaction		$\overline{\mathbf{x}} = \mathbf{M}_{\text{total}}$	$F_{total_v} = 320 \text{ m}$	m			
Eccentricity of reaction		$e = \overline{x} - l_{bas}$	r / 2 = -430 mm	ı			
Loaded length of base		$l_{load} = 2 \times \frac{1}{2}$	$\bar{x} = 640 \text{ mm}$				
Bearing pressure at toe		Gtoe = Etotal	152.6	kN/m ²			
Bearing pressure at heel		$q_{heel} = 0 \text{ kN}$	/m ²				
Effective overburden pressure		$q = max((t_b kN/m^2))$	$_{\rm ase}$ + $d_{\rm cover}$) $ imes$ γ_b	- $(t_{\text{base}} + d_{\text{cover}} +$	h_{water}) $ imes \gamma_w'$, 0	kN/m ²) = 0	
Design effective overburden pressu	re	$\mathbf{q}' = \mathbf{q} / \gamma_{\gamma} =$	0 kN/m ²				
Bearing resistance factors		$N_q = Exp(\pi$	$\times \tan(\phi'_{b.d})) \times (t$	tan(45 deg + φ' _{b.c}	a / 2)) ² = 3.784		
-	$N_{c} = (N_{q} - 1)$	$N_{c} = (N_{0} - 1) \times \cot(\phi_{bd}) = 10.711$					
		$N_{\gamma} = 2 \times (N_{\gamma})$	$(a - 1) \times \tan(\phi'_{hd})$) = 1.447			
Foundation shape factors		$s_{q} = 1$, ,				
1		$s_{\gamma} = 1$					
		$s_c = 1$					
Load inclination factors		$H = F_{sur_h} + V = F_{total v} = F_{total v}$	F _{sat_h} + F _{water_h} = 97.7 kN/m	+ F _{moist_h} + F _{pass}	_h - F _{prop_base} =	0 kN/m	
		m = 2					
		$i_q = [1 - H /$	$(V + l_{load} \times c'_{b.d})$	$\times \cot(\phi'_{b.d}))]^m = 1$	l		
		$i_{\gamma} = [1 - H]$	$(V + l_{load} \times c'_{b.d})$	$\times \cot(\phi'_{b.d}))^{(m+1)}$	= 1		
		$i_c = i_q - (1 - 1)$	ig) / (Nc × tan(\$	'b.d)) = 1			
Net ultimate bearing capacity		$n_f = c'_{b,d} \times N$	$\mathbf{N}_{c} \times \mathbf{S}_{c} \times \mathbf{i}_{c} + \mathbf{q}'$	$\times N_{q} \times s_{q} \times i_{q} + 0$	$.5 \times (\gamma_b' - \gamma_w') \times$	$(l_{load} \times N_{\gamma} \times s_{\gamma})$	
8 1 5		iγ			(1- 1-)		
		$n_{\rm f} = 158.5$ l	xN/m ²				
Factor of safety		$FoS_{bp} = n_f$	max(q _{toe} , q _{heel})	= 1.039			
	PASS - All	owable bearin	g pressure ex	ceeds maximur	n applied bea	aring pressur	
RETAINING WALL DESIGN							
In accordance with EN1992-1-1:20	004 incorpo	rating Corriger	ndum dated Ja	anuary 2008 and	d the UK Nati	onal Annex	
incorporating National Amendmen					Tedds calcul	ation version 2.9.0	
Concrete details - Table 3.1 - Stree	ngth and de	eformation cha	racteristics fo	r concrete			
Concrete strength class		C32/40					
Characteristic compressive cylinder	strength	$f_{ck} = 32 \text{ N/m}$	nm ²				
Characteristic compressive cube str	ength	$f_{ck,cube} = 40$	N/mm ²				
Mean value of compressive cylinder	strength	$f_{cm} = f_{ck} + 8$	$N/mm^2 = 40 N$	/mm ²	1 2		
Mean value of axial tensile strength		$t_{ctm} = 0.3 N$	$/\text{mm}^2 \times (f_{ck} / 1)$	$N/mm^2)^{2/3} = 3.0 N$	N/mm²		
5% tractile of axial tensile strength		$f_{ctk,0.05} = 0.7$	$\times f_{ctm} = 2.1 \text{ N/s}$	mm²			
Secant modulus of elasticity of conc	rete	$E_{cm} = 22 \text{ kM}$	$N/mm^2 \times (f_{cm} / 1)$	$(0 \text{ N/mm}^2)^{0.3} = 33$	3346 N/mm ²		
Partial factor for concrete - Table 2.	1N	$\gamma_{\rm C} = 1.50$					
Compressive strength coefficient - c	1.3.1.6(1)	$\alpha_{\rm cc}=0.85$					
Design compressive concrete streng	gth - exp.3.1	5 $f_{cd} = \alpha_{cc} \times f_{cd}$	$_{\rm tk} / \gamma_{\rm C} = 18.1 \ {\rm N}/$	mm ²			
Maximum aggregate size		$h_{acc} = 20 \text{ m}$	m				

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Reinforcement details						
Characteristic yield strength of	reinforcement	$f_{yk} = 500 \text{ N/}$	mm ²			
Modulus of elasticity of reinforc	ement	E _s = 20000	0 N/mm ²			
Partial factor for reinforcing ste	el - Table 2.1N	$\gamma_{\rm S} = 1.15$				
Design yield strength of reinfore	cement	$f_{yd} = f_{yk} / \gamma_S$	= 435 N/mm ²			
Cover to reinforcement						
Front face of stem		$c_{sf} = 40 \text{ mm}$	1			
Rear face of stem		$c_{sr} = 50 \text{ mm}$	1			
Top face of base		$c_{bt} = 50 \text{ mm}$	1			
Bottom face of base		$c_{bb} = 50 \text{ mm}$	n			
Londing details - Combin	ation No.1 . kN/m²					
	s	hear force - Combination No.1 - kN	/m Bending m	oment - Combination No.1 - kNm/m		
	E					
			119.4			
			-86.2		87.8	
8				91	3.5	
Loading details - Combin	ation No.2 - kN/m ²	hear force - Combination No.2 - kN	/m Bending m	oment - Combination No.2 - kNm/m		
	D .95					
	Sem					
		90.6				
5 	29.33		.68.5		69.9	
8					15	
N				8		
1						

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Check stem design at base of stem Depth of section h = **300** mm Rectangular section in flexure - Section 6.1 M = 87.8 kNm/mDesign bending moment combination 1 Depth to tension reinforcement $d = h - c_{sr} - \phi_{sr} / 2 = 240 \text{ mm}$ $K = M / (d^2 \times f_{ck}) = 0.048$ K' = **0.207** K' > K - No compression reinforcement is required Lever arm $z = min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = 228 mm$ Depth of neutral axis $x = 2.5 \times (d - z) = 30 \text{ mm}$ Area of tension reinforcement required $A_{sr.reg} = M / (f_{vd} \times z) = 886 \text{ mm}^2/\text{m}$ Tension reinforcement provided 20 dia.bars @ 200 c/c Area of tension reinforcement provided $A_{sr,prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = 1571 \text{ mm}^2/\text{m}$ Minimum area of reinforcement - exp.9.1N $A_{sr.min} = max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 377 mm^2/m$ Maximum area of reinforcement - cl.9.2.1.1(3) $A_{sr max} = 0.04 \times h = 12000 \text{ mm}^2/\text{m}$

 $max(A_{sr.req}, A_{sr.min}) / A_{sr.prov} = 0.564$

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

Deflection control - Section 7.4 Reference reinforcement ratio Required tension reinforcement ratio Required compression reinforcement ratio Structural system factor - Table 7.4N Reinforcement factor - exp.7.17 Limiting span to depth ratio - exp.7.16.a

Actual span to depth ratio

 Crack control - Section 7.3

 Limiting crack width
 w_{max}

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

 Serviceability bending moment
 M_{sk} :

 Tensile stress in reinforcement
 $\sigma_s =$

 Load duration
 Long

 Load duration factor
 $k_t =$

 Effective area of concrete in tension
 $A_{c.eff}$

 Mean value of concrete tensile strength
 $f_{ct.eff}$

 Reinforcement ratio
 $\rho_{p.eff}$

 Modular ratio
 $\alpha_e =$

 Bond property coefficient
 $k_1 =$

 Strain distribution coefficient
 $k_2 =$

Maximum crack spacing - exp.7.11 Maximum crack width - exp.7.8
$$\begin{split} \rho_0 &= \sqrt{(f_{ck} \ / \ 1 \ N/mm^2) \ / \ 1000 = 0.006} \\ \rho &= A_{sr.req} \ / \ d = 0.004 \\ \rho' &= A_{sr.2.req} \ / \ d_2 = 0.000 \\ K_b &= 0.4 \\ K_s &= \min(500 \ N/mm^2 \ / \ (f_{yk} \times A_{sr.req} \ / \ A_{sr.prov}), \ 1.5) = 1.5 \\ \min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} \ / \ 1 \ N/mm^2)} \times \rho_0 \ / \ \rho + 3.2 \times \sqrt{(f_{ck} \ / \ 1 \ N/mm^2)} \times (\rho_0 \ / \ \rho - 1)^{3/2}], \ 40 \times K_b) = 16 \\ h_{stem} \ / \ d = 12.5 \\ \hline PASS - Span \ to \ depth \ ratio \ is \ less \ than \ deflection \ control \ limit \end{split}$$

 $w_{max} = 0.3 \text{ mm}$ $\Psi_2 = 0.6$ $M_{sls} = 63.4 \text{ kNm/m}$ $\sigma_s = M_{sls} \ / \ (A_{sr.prov} \times z) = 177 \ N/mm^2$ Long term $k_t = 0.4$ $A_{c.eff} = min(2.5 \times (h - d), (h - x) / 3, h / 2) = 90000 mm^2/m$ $f_{ct.eff} = f_{ctm} = 3.0 \text{ N/mm}^2$ $\rho_{p.eff} = A_{sr.prov} \ / \ A_{c.eff} = \boldsymbol{0.017}$ $\alpha_{e} = E_{s} / E_{cm} = 5.998$ $k_1 = 0.8$ $k_2 = 0.5$ $k_3 = 3.4$ $k_4 = 0.425$ $s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff} = 365 mm$ $w_k = s_{r.max} \times max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), \ 0.6 \times \sigma_s) \ / \ E_s$ $w_k = 0.194 \text{ mm}$

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		wk / wmax =	0.646						
		PASS	- Maximum c	rack width is les	s than limitin	g crack width			
Rectangular section in shear	- Section 6.2								
Design shear force		V = 86.2 kl	N/m						
		$C_{Rd,c} = 0.18$	8 / γc = 0.120						
		k = min(1 +	- √(200 mm / d), 2) = 1.913					
Longitudinal reinforcement ratio)	$\rho_l = min(A_{st})$	r.prov / d, 0.02) =	= 0.007					
		$v_{min} = 0.033$	$5 \text{ N}^{1/2}/\text{mm} \times \text{k}^{3/2}$	$^{2} \times f_{ck}^{0.5} = 0.524$!	N/mm ²				
Design shear resistance - exp.6	6.2a & 6.2b	$V_{Rd.c} = max$	$(C_{Rd.c} \times k \times (10))$	$00~N^2/mm^4 \times \rho_l \times$	$(f_{ck})^{1/3}$, v_{min}) × d				
		$V_{\rm Rd.c}=151$.9 kN/m						
		$V / V_{Rd.c} = 0$	0.568						
		PAS	S - Design sh	ear resistance e	exceeds desig	n shear force			
Horizontal reinforcement para	allel to face of s	tem - Section 9	9.6						
Minimum area of reinforcement	- cl.9.6.3(1)	$A_{sx.req} = ma$	$x(0.25 \times A_{sr.prov})$	v, $0.001 \times t_{stem}$) =	393 mm²/m				
Maximum spacing of reinforcen	nent – cl.9.6.3(2)	$s_{sx_max} = 40$	$s_{sx_max} = 400 \text{ mm}$						
Transverse reinforcement provi	ded	16 dia.bars	16 dia.bars @ 200 c/c						
Area of transverse reinforcement	nt provided	$A_{sx.prov} = \pi$	$A_{\text{sx.prov}} = \pi \times \phi_{\text{sx}^2} / (4 \times s_{\text{sx}}) = 1005 \text{ mm}^2/\text{m}$						
	PASS - Area of	reinforcement	provided is g	preater than area	a of reinforce	ment required			
Check base design at toe									
Depth of section		h = 300 mr	n						
Rectangular section in flexure	e - Section 6.1								
Design bending moment combi	nation 1	M = 98.5 k	Nm/m						
Depth to tension reinforcement		$d = h - c_{bb}$	$\phi_{bb} / 2 = 240 \text{ r}$	nm					
		$K = M / (d^2)$	\times f _{ck}) = 0.053						
		K' = 0.207							
			K' > K -	No compressio	n reinforceme	ent is required			
Lever arm		z = min(0.5	K' > K - $5 + 0.5 \times (1 - 3)$	No compression $53 \times \text{K}$) ^{0.5} , 0.95)	n reinforceme × d = 228 mm	ent is required			
Lever arm Depth of neutral axis		$z = \min(0.5)$ $x = 2.5 \times (d)$	K' > K - $b + 0.5 \times (1 - 3)$ (1 - z) = 30 mm	No compression 53 × K) ^{0.5} , 0.95) :	n reinforceme × d = 228 mm	ent is required			
Lever arm Depth of neutral axis Area of tension reinforcement re	equired	$z = \min(0.5)$ $x = 2.5 \times (d)$ $A_{bb,req} = M$	K' > K - $b + 0.5 \times (1 - 3)$ (1 - z) = 30 mm $f(f_{yd} \times z) = 993$	No compression $53 \times K$) ^{0.5} , 0.95) = mm ² /m	n reinforceme × d = 228 mm	ent is required			
Lever arm Depth of neutral axis Area of tension reinforcement re Tension reinforcement provided	equired 1	$z = \min(0.5)$ $x = 2.5 \times (c)$ $A_{bb,req} = M$ 20 dia.bars	K' > K - $5 + 0.5 \times (1 - 3)$ 1 - z) = 30 mm $\frac{1}{2} (f_{yd} \times z) = 993$ $\frac{1}{2} @ 200 \text{ c/c}$	No compression $53 \times K$) ^{0.5} , 0.95) : mm^2/m	n reinforceme × d = 228 mm	ent is required			
Lever arm Depth of neutral axis Area of tension reinforcement re Tension reinforcement provided Area of tension reinforcement p	equired 1 rrovided	$z = \min(0.5)$ $x = 2.5 \times (c$ $A_{bb,req} = M$ 20 dia, bars $A_{bb,prov} = \pi$	$K' > K - \frac{1}{2} + 0.5 \times (1 - 3)$ (1 - z) = 30 mm $(f_{yd} \times z) = 993$ (g @ 200 c/c) $(\chi \phi_{bb}^2 / (4 \times s_{bb})^2)$	No compression 53 × K) ^{0.5} , 0.95) : 5 mm ² /m) = 1571 mm ² /m	n reinforceme × d = 228 mm	ent is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement	equired 1 vrovided - exp.9.1N	$z = \min(0.5]$ $x = 2.5 \times (c$ $A_{bb,req} = M$ 20 dia.bars $A_{bb,prov} = \pi$ $A_{bb,min} = ma$	$\begin{aligned} \mathbf{K'} &> \mathbf{K} - \\ \mathbf{i} + 0.5 \times (1 - 3. \\ \mathbf{i} - z) &= 30 \text{ mm} \\ / (\mathbf{f}_{yd} \times z) &= 993 \\ \mathbf{s} @ 200 \text{ c/c} \\ \mathbf{s} & \phi_{bb}^2 / (4 \times \mathbf{s}_{bb}) \\ \mathbf{ax}(0.26 \times \mathbf{f}_{ctm} / \mathbf{s}_{bb}) \end{aligned}$	No compression 53 × K) ^{0.5} , 0.95) : 4 mm ² /m) = 1571 mm ² /m f _{yk} , 0.0013) × d =	n reinforceme × d = 228 mm 377 mm²/m	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3)	$z = \min(0.5)$ $x = 2.5 \times (c$ $A_{bb,req} = M$ $20 dia.bars$ $A_{bb,prov} = \pi$ $A_{bb,min} = \max$ $A_{bb,max} = 0.$	K' > K - $i + 0.5 \times (1 - 3)$ 1 - z) = 30 mm / $(f_{yd} \times z) = 9933$ i @ 200 c/c $x \phi_{bb}^2 / (4 \times s_{bb})^2$ $ax(0.26 \times f_{ctm} / 4)$ $04 \times h = 12000$	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m) = 1571 mm ² /m f _{yk} , 0.0013) × d = 0 mm ² /m	n reinforceme × d = 228 mm 377 mm²/m	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3)	$z = min(0.5)$ $x = 2.5 \times (c$ $A_{bb,req} = M$ $20 dia.bars$ $A_{bb,rov} = \pi$ $A_{bb,min} = ma$ $A_{bb,max} = 0.$ $max(A_{bb,req})$	$\begin{array}{l} {\rm K}' > {\rm K} - \\ {\rm i} + 0.5 \times (1 - 3. \\ {\rm I} - z) = {\rm 30 \ mm} \\ {\rm /} \ ({\rm f}_{\rm yd} \times z) = {\rm 993} \\ {\rm i} \ \odot \ 200 \ {\rm c/c} \\ {\rm x} \\ {\rm \phi}_{\rm bb}^2 / \ (4 \times {\rm s}_{\rm bb} \\ {\rm ax} (0.26 \times {\rm f}_{\rm cm} / {\rm H} \\ {\rm 04} \times {\rm h} = {\rm 12000} \\ {\rm A}_{\rm bb,min} \ / \ {\rm A}_{\rm bb,min} $	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m b) = 1571 mm ² /m f _{yk} , 0.0013) × d = 0 mm ² /m ov = 0.632	n reinforceme × d = 228 mm 377 mm²/m	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of	$\begin{split} z &= \min(0.5 \\ x &= 2.5 \times (c \\ A_{bb,req} &= M \\ 20 \ dia.bars \\ A_{bb,prov} &= \pi \\ A_{bb,min} &= ma \\ A_{bb,max} &= 0. \\ max(A_{bb,req}, \textbf{reinforcement}) \end{split}$	$\begin{array}{c} {\bf K}' > {\bf K} \\ {\bf i} + 0.5 \times (1 - 3, \\ {\bf l} - z) = {\bf 30} \ mm \\ {\bf \prime} \ ({\bf f}_{yd} \times z) = {\bf 993} \\ {\bf i} \ @ 200 \ c/c \\ {\bf x} \\ {\bf \phi}_{bb}^2 / \ ({\bf 4} \times {\bf s}_{bb} \\ {\bf ax}(0.26 \times {\bf f}_{ctm} / {\bf 1} \\ 04 \times {\bf h} = {\bf 12000} \\ {\bf A}_{bb,min} \ / \ {\bf A}_{bb,min} \ / \ {\bf A}_{bb,min} \) / {\bf A}_{bb,min} \ ({\bf ax}(z) = {\bf 0}) \\ {\bf ax}(z) = {\bf 0} \\ {\bf ax}(z) = {\bf 0} \\ {\bf 0} $	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m b) = 1571 mm ² /m f _{yk} , 0.0013) × d = 0 mm ² /m ov = 0.632 greater than area	n reinforceme × d = 228 mm 377 mm²/m a of reinforce	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement ro Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement Crack control - Section 7.3	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of	$\begin{aligned} z &= \min(0.3 \\ x &= 2.5 \times (c \\ A_{bb,req} &= M \\ 20 & dia.bars \\ A_{bb,prov} &= \pi \\ A_{bb,min} &= ma \\ A_{bb,max} &= 0. \\ max(A_{bb,req}, end) \end{aligned}$	$\begin{array}{c} {\bf K}' > {\bf K} - \\ {\bf 5} + 0.5 \times (1 - 3), \\ {\bf 1} - z) = {\bf 30} \ mm \\ {} / \ ({\bf f}_{yd} \times z) = {\bf 993} \\ {\bf 5} \ @ \ 200 \ c/c \\ {} \times \phi_{bb}^2 / \ (4 \times s_{bb} \\ ax(0.26 \times f_{ctm} / 1 \\ 04 \times h = {\bf 12000}, \\ {\bf A}_{bb,min} / \ A_{bb,min} / A_{bb,min} \\ {} + \ {\bf provided is g} \end{array}$	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m b) = 1571 mm ² /m f _{yk} , 0.0013) × d = c) mm ² /m greater than area	n reinforceme × d = 228 mm 377 mm²/m a of reinforce	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement ro Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement Crack control - Section 7.3 Limiting crack width	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of	$\begin{aligned} z &= min(0.5 \\ x &= 2.5 \times (c \\ A_{bb,req} &= M \\ 20 & dia.bars \\ A_{bb,prov} &= \pi \\ A_{bb,min} &= ma \\ A_{bb,max} &= 0 \\ max(A_{bb,req}, \\ reinforcement \\ w_{max} &= 0.3 \end{aligned}$	$\begin{array}{c} {\bf K}' > {\bf K} - \\ {\bf i} + 0.5 \times (1 - 3, \\ {\bf l} - z) = {\bf 30} \ mm \\ {} / \ ({\bf f}_{yd} \times z) = {\bf 993} \\ {\bf i} \ @ \ 200 \ c/c \\ {} \times \phi_{bb}^2 / \ (4 \times s_{bb} \\ {\bf ax}(0.26 \times {\bf f}_{ctm} / {\bf 1} \\ 04 \times {\bf h} = {\bf 12000} \\ {\bf A}_{bb,min} / \ A_{bb,priv} \\ {\bf c} \ {\bf provided \ is \ g} \end{array}$	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m b) = 1571 mm ² /m f _{yk} , 0.0013) × d = c) mm ² /m ov = 0.632 greater than area	n reinforceme × d = 228 mm 377 mm²/m a of reinforcer	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement Crack control - Section 7.3 Limiting crack width Variable load factor - EN1990 –	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of - Table A1.1	$\begin{aligned} z &= \min(0.3 \\ x &= 2.5 \times (c \\ A_{bb,req} &= M \\ 20 \ dia.bars \\ A_{bb,prov} &= \pi \\ A_{bb,min} &= ma \\ A_{bb,max} &= 0 \\ max(A_{bb,req}, \\ reinforcement \\ w_{max} &= 0.3 \\ \psi_2 &= 0.6 \end{aligned}$	$\begin{array}{l} {\bf K' > K -} \\ {\bf i} + 0.5 \times (1 - 3, \\ {\bf l} - z) = {\bf 30} \ mm \\ {} / \ ({\bf fy}_{\rm d} \times z) = {\bf 993} \\ {\bf i} \ @ \ 200 \ c/c \\ {} \times \phi_{bb}^2 / \ (4 \times s_{bb} \\ {\bf ax}(0.26 \times f_{ctm} / 1 \\ 04 \times h = {\bf 12000} \\ {\bf A}_{bb,min} / \ A_{bb,priv} \\ {\bf i} \ {\bf provided \ is \ g} \end{array}$	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m b) = 1571 mm ² /m f _{yk} , 0.0013) × d = c) mm ² /m ov = 0.632 greater than area	n reinforceme × d = 228 mm 377 mm²/m a of reinforcer	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement Crack control - Section 7.3 Limiting crack width Variable load factor - EN1990 – Serviceability bending moment	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of - Table A1.1	$z = min(0.5)$ $x = 2.5 \times (c$ $A_{bb,req} = M$ 20 dia.bars $A_{bb,min} = ma$ $A_{bb,max} = 0.$ $max(A_{bb,req}$ reinforcement $w_{max} = 0.3$ $\psi_2 = 0.6$ $M_{sbs} = 72.6$	$\begin{array}{l} {\bf K'>K-}\\ {\bf i}+0.5\times(1-3),\\ {\bf l}-z)={\bf 30}\ mm\\ {\bf \prime}({\bf fy}_d\times z)={\bf 993}\\ {\bf i}@200\ c/c\\ {\bf x}\phi_{bb}^2/({\bf 4}\times s_{bb}\\ {\bf ax}(0.26\times f_{ctm}/{\bf 1}\\ 04\times h={\bf 12000}\\ {\bf A}_{bb,min}/A_{bb,priv}\\ {\bf c}{\bf provided}{\bf is}{\bf g}\\ {\bf mm}\\ {\bf kNm/m} \end{array}$	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m b) = 1571 mm ² /m f _{yk} , 0.0013) × d = c) mm ² /m greater than area	n reinforceme × d = 228 mm 377 mm²/m a of reinforcer	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement Crack control - Section 7.3 Limiting crack width Variable load factor - EN1990 – Serviceability bending moment Tensile stress in reinforcement	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of - Table A1.1	$\begin{split} z &= \min(0.5 \\ x &= 2.5 \times (c \\ A_{bb,req} &= M \\ 20 \ dia.bars \\ A_{bb,prov} &= \pi \\ A_{bb,max} &= 0. \\ max(A_{bb,req}, \\ reinforcement \\ w_{max} &= 0.3 \\ \psi_2 &= 0.6 \\ M_{sbs} &= 72.6 \\ \sigma_s &= M_{sbs} / (c \\ \sigma_s &= M_{s$	$\begin{array}{l} {\bf K'>K-}\\ {\bf i}+0.5\times (1-3),\\ {\bf l}-z)={\bf 30}\ mm\\ {\bf \prime}({\bf fy}_{d}\times z)={\bf 993}\\ {\bf i}\ @\ 200\ c/c\\ {\bf x}\ \phi_{bb}{}^{2}/\ (4\times s_{bb}\\ {\bf ax}(0.26\times f_{ctm}/t)\\ {\bf 04}\times h={\bf 12000}\\ {\bf A}_{bb,min}/\ A_{bb,min}/\ A_{bb,min}\\ {\bf s}\ provided\ is\ g\\ mm\\ {\bf k}Nm/m\\ A_{bb,prov}\times z)={\bf 2}\end{array}$	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m b) = 1571 mm ² /m f _{yk} , 0.0013) × d = 0 mm ² /m ov = 0.632 greater than area 02.6 N/mm ²	n reinforceme × d = 228 mm 377 mm²/m a of reinforcer	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement Crack control - Section 7.3 Limiting crack width Variable load factor - EN1990 – Serviceability bending moment Tensile stress in reinforcement Load duration	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of - Table A1.1	$\begin{split} z &= \min(0.5 \\ x &= 2.5 \times (c \\ A_{bb,req} &= M \\ 20 \\ dia.bars \\ A_{bb,prov} &= \pi \\ A_{bb,max} &= 0. \\ max(A_{bb,req} \\ reinforcement \\ w_{max} &= 0.3 \\ \psi_2 &= 0.6 \\ M_{sbs} &= 72.6 \\ \sigma_s &= M_{sbs} / (c \\ Long term \end{split}$	$\begin{array}{l} {\bf K' > K -} \\ {\bf i + 0.5 \times (1 - 3.)} \\ {\bf l - z) = 30 \ mm} \\ {\bf \prime \ (f_{Vd} \times z) = 993} \\ {\bf i \oplus 200 \ c/c} \\ {\bf x > \phi_{bb}^2 / \ (4 \times s_{bb} \\ ax(0.26 \times f_{ctm} / 1 \\ 04 \times h = 12000 \\ {\bf A}_{bb,min} / \ A_{bb,min} / A_{bb,prov} \\ {\bf x \ provided \ is \ g} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m b) = 1571 mm ² /m f _{yk} , 0.0013) × d = c) mm ² /m greater than area 02.6 N/mm ²	n reinforceme × d = 228 mm 377 mm²/m a of reinforcer	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement Crack control - Section 7.3 Limiting crack width Variable load factor - EN1990 – Serviceability bending moment Tensile stress in reinforcement Load duration Load duration factor	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of - Table A1.1	$\begin{split} z &= \min(0.5 \\ x &= 2.5 \times (c \\ A_{bb,req} &= M \\ 20 \\ dia.bars \\ A_{bb,prov} &= \pi \\ A_{bb,max} &= 0. \\ max(A_{bb,req} \\ reinforcement \\ w_{max} &= 0.3 \\ \psi_2 &= 0.6 \\ M_{sbs} &= 72.6 \\ \sigma_s &= M_{sbs} / (c \\ Long term \\ k_t &= 0.4 \end{split}$	$\begin{array}{l} {\bf K' > K - }\\ {\bf i + 0.5 \times (1 - 3.)}\\ {\bf l - z) = 30 \ mm }\\ {\bf \prime \ (f_{Vd} \times z) = 993}\\ {\bf i \oplus 200 \ c/c }\\ {\bf x < \phi_{bb}^2 / \ (4 \times s_{bb} \\ ax(0.26 \times f_{ctm} / 1 \\ 04 \times h = 12000 \\ {\bf A}_{bb,min} / \ A_{bb,min} / A_{bb,prov} \\ {\bf x \ provided \ is \ g}\\ mm \\ kNm/m \\ A_{bb,prov} \times z) = 2 \end{array}$	No compression 53 × K) ^{0.5} , 0.95) : a mm ² /m b) = 1571 mm ² /m f _{yk} , 0.0013) × d = c) mm ² /m ov = 0.632 greater than area 02.6 N/mm ²	n reinforceme × d = 228 mm 377 mm²/m a of reinforcer	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement Crack control - Section 7.3 Limiting crack width Variable load factor - EN1990 – Serviceability bending moment Tensile stress in reinforcement Load duration Load duration factor	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of - Table A1.1	$\begin{split} z &= \min(0.5 \\ x &= 2.5 \times (c \\ A_{bb,req} &= M \\ 20 \\ dia.bars \\ A_{bb,prov} &= \pi \\ A_{bb,max} &= 0. \\ max(A_{bb,req} \\ reinforcement \\ w_{max} &= 0.3 \\ \psi_2 &= 0.6 \\ M_{sb} &= 72.6 \\ \sigma_s &= M_{sbs} / (c \\ Long term \\ k_i &= 0.4 \\ A_{c,eff} &= \min(c_s) \\ \end{bmatrix}$	$\begin{array}{l} {\bf K' > K - }\\ {\bf i + 0.5 \times (1 - 3.)}\\ {\bf l - z) = 30 \ mm }\\ {\bf \prime \ (f_{Vd} \times z) = 993}\\ {\bf i \oplus 200 \ c/c }\\ {\bf x < \phi_{bb}^2 / \ (4 \times s_{bb} \\ ax(0.26 \times f_{ctm} / 1 \\ 04 \times h = 12000 \\ {\bf 04 \times h = 12000 \\ A_{bb,min} \ / \ A_{bb,min} \ / \ A_{bb,min} \ / \ A_{bb,min} \ / \ A_{bb,prov} \times z) = 2 \\ mm \\ {\bf kNm/m} \\ A_{bb,prov} \times z) = 2 \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d), \ (l - 1)) \\ (2.5 \times (h - d)) \\ (2.5 \times ($	No compression $53 \times K$) ^{0.5} , 0.95) : mm^2/m f_{yk} , 0.0013) × d = 0 mm ² /m g_{vx} = 0.632 greater than area 02.6 N/mm ² h - x) / 3, h / 2) =	n reinforceme × d = 228 mm 377 mm²/m a of reinforcen 90000 mm²/m	nt is required			
Lever arm Depth of neutral axis Area of tension reinforcement r Tension reinforcement provided Area of tension reinforcement p Minimum area of reinforcement Maximum area of reinforcement Crack control - Section 7.3 Limiting crack width Variable load factor - EN1990 – Serviceability bending moment Tensile stress in reinforcement Load duration Load duration factor Effective area of concrete in ter Mean value of concrete tensile	equired 1 rovided - exp.9.1N t - cl.9.2.1.1(3) PASS - Area of - Table A1.1 stion strength	$\begin{split} z &= \min(0.5 \\ x &= 2.5 \times (c \\ A_{bb,req} &= M \\ 20 \\ dia.bars \\ A_{bb,prov} &= \pi \\ A_{bb,max} &= 0. \\ max(A_{bb,req} \\ reinforcement \\ w_{max} &= 0.3 \\ \psi_2 &= 0.6 \\ M_{sb} &= 72.6 \\ \sigma_s &= M_{sbs} / (c \\ Long term \\ k_i &= 0.4 \\ A_{c.eff} &= \min(c_{ctm}) \\ f_{ct.eff} &= f_{ctm} \\ \end{split}$	$\begin{array}{l} {\bf K' > K - }\\ {\bf i} + 0.5 \times (1 - 3),\\ {\bf l} - z) = {\bf 30} \ mm\\ {\it /} \ ({\bf fy}_{\rm d} \times z) = {\bf 993}\\ {\bf i} \ @ \ 200 \ c/c\\ {\it \times} \ \phi_{bb}{}^2 \ / \ (4 \times s_{bb}\\ {\rm ax}(0.26 \times {\bf f}_{\rm cut} / 1)\\ 04 \times {\bf h} = {\bf 12000}\\ {\it Abb,min} \ / \ A_{bb,min} \ Z = {\bf 2}\\ mm\\ {\bf kNm/m} \ {\bf kNm/m} \ {\bf kNm/m} \ {\bf k}_{bb,min} \times {\bf z}) = {\bf 2}\\ {\it (2.5 \times ({\bf h} - {\bf d}), ({\bf l} = {\bf 3.0} \ {\bf N/mm^2}) \ - {\bf 10}\\ {\bf M}_{abb,min} \ - {\bf 10}\\ -$	No compression $53 \times K$) ^{0.5} , 0.95) : $3 \text{ mm}^2/\text{m}$ $4 \text{ mm}^2/\text{m}$ f_{yk} , 0.0013) × d = $0 \text{ mm}^2/\text{m}$ $0 \text{ mm}^2/\text{m}^2/$	n reinforceme × d = 228 mm 377 mm²/m a of reinforcen 90000 mm²/m	nt is required			

	Project	24 HEAT	TH DRIVE		Job no. 16	62637			
Form Structural Design	Calcs for			Start page no./Revision 11					
77 St John Street		RC L RETA	INING WALL						
London EC1M 4NN	Calcs by CEM	Calcs date 29/01/2018	Checked by	Checked date	Approved by	Approved date			
Modular ratio		$\alpha_e = E_s / E_c$	m = 5.998						
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	$s_{r.max} = k_3 \times$	$c_{bb} + k_1 \times k_2 >$	$< k_4 \times \phi_{bb} / \rho_{p.eff} =$	365 mm				
Maximum crack width - exp.7.8	8	$w_k = s_{r.max} >$	$max(\sigma_s - k_t > $	$(f_{\rm ct.eff} / \rho_{p.eff}) \times (1)$	+ $\alpha_{e} \times \rho_{p.eff}$), 0	$.6 imes \sigma_s$) / E _s			
		$w_k = 0.23 n$	ım						
		$w_k / w_{max} =$	0.766						
		PASS	- Maximum o	rack width is les	ss than limitir	ng crack widt			
Rectangular section in shear	r - Section 6.2								
Design shear force		V = 119.4 k	N/m						
		$C_{Rd,c} = 0.18$	$3 / \gamma_{\rm C} = 0.120$						
		k = min(1 +	√(200 mm / o	l), 2) = 1.913					
Longitudinal reinforcement rati	io	$\rho_l = min(A_{bl})$	o.prov / d, 0.02)	= 0.007					
		$v_{min} = 0.035$	$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = 0.524 \text{ N}/\text{mm}^2$						
Design shear resistance - exp.	.6.2a & 6.2b	$V_{Rd,c} = max$	$V_{Rd,c} = max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$						
8		$V_{Rdc} = 151$	9 kN/m		.,,				
		$V / V_{Rd.c} = 0$	0.786						
		PAS	S - Design sl	near resistance of	exceeds desig	n shear forc			
Secondary transverse reinfo	rcement to base	- Section 9.3	•						
Minimum area of reinforcement	nt – cl.9.3.1.1(2)	$A_{bx,req} = 0.2$	$\times A_{bb.prov} = 31$	4 mm ² /m					
Maximum spacing of reinforce	ment – cl.9.3.1.1 (3	$s_{bx_{max}} = 45$	0 mm						
Transverse reinforcement prov	/ided	16 dia.bars	@ 200 c/c						
Area of transverse reinforceme	ent provided	$A_{bx,prov} = \pi$	$\times \phi_{bx}^2$ / (4 \times s _b	$a) = 1005 \text{ mm}^2/\text{m}^2$					
	PASS - Area of	reinforcement	provided is	greater than are	a of reinforce	ment require			

Tekla Tedds	Project 24 HEATH DRIVE				Job no. 162637	
Form Structural Design 77 St John Street	Calcs for RC L RETAINING WALL				Start page no./Revision 12	
London EC1M 4NN	Calcs by CEM	Calcs date 29/01/2018	Checked by	Checked date	Approved by	Approved date



Reinforcement details