Tekla Tedds P&M	Project 35 Templewood Avenue				Job no. 28585	
	Calcs for	Start page no./Revision 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	Propped cantilever
Stem height	h <sub>stem</sub> = <b>4200</b> mm
Prop height	h <sub>prop</sub> = <b>4200</b> mm
Stem thickness	t <sub>stem</sub> = <b>350</b> mm
Angle to rear face of stem	α = <b>90</b> deg
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	l <sub>toe</sub> = <b>1000</b> mm
Base thickness	t <sub>base</sub> = <b>350</b> mm
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	h <sub>ret</sub> = <b>4200</b> mm
Angle of soil surface	$\beta = 0 \deg$
Depth of cover	d <sub>cover</sub> = <b>0</b> mm
Height of water	h <sub>water</sub> = <b>3200</b> mm
Water density	γ <sub>w</sub> = <b>9.8</b> kN/m <sup>3</sup>
Retained soil properties	
Soil type	Firm clay
Moist density	$\gamma_{mr} = 18 \text{ kN/m}^3$
Saturated density	$\gamma_{sr} = 18 \text{ kN/m}^3$
Characteristic effective shear resistance angle	φ'r.k = <b>18</b> deg
Characteristic wall friction angle	$\delta_{r,k} = 9 \text{ deg}$
Base soil properties	
Soil type	Firm clay
Soil density	$\gamma_{\rm b}$ = <b>18</b> kN/m <sup>3</sup>
Characteristic effective shear resistance angle	φ' <sub>b.k</sub> = <b>18</b> deg
Characteristic wall friction angle	$\delta_{b,k} = 9 \text{ deg}$
Characteristic base friction angle	$\delta_{\text{bb.k}} = \textbf{12} \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 150 \text{ kN/m}^2$
Loading details	
Permanent surcharge load	Surcharge <sub>G</sub> = 30 kN/m <sup>2</sup>
Variable surcharge load	$Surcharge_Q = 5 \text{ kN/m}^2$
Vertical line load at 1163 mm	P <sub>G1</sub> = <b>50</b> kN/m

Tekla <sub>Tedds</sub> P&M	Project 35 Templewood Avenue				Job no. 28585	
	Calcs for Typical basement retaining wall				Start page no./Revision 2	
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#### Calculate retaining wall geometry

Base length Saturated soil height Moist soil height Length of surcharge load - Distance to vertical component Effective height of wall - Distance to horizontal component Area of wall stem - Distance to vertical component Area of wall base - Distance to vertical component **Using Coulomb theory** 

At rest pressure coefficient Passive pressure coefficient

### Bearing pressure check

# Vertical forces on wall Wall stem Wall base Line loads

$$\begin{split} & |_{base} = |_{toe} + t_{stem} = \textbf{1350} \text{ mm} \\ & h_{sat} = h_{water} + d_{cover} = \textbf{3200} \text{ mm} \\ & h_{moist} = h_{ret} - h_{water} = \textbf{1000} \text{ mm} \\ & l_{sur} = l_{heel} = \textbf{0} \text{ mm} \\ & x_{sur\_v} = l_{base} - l_{heel} / 2 = \textbf{1350} \text{ mm} \\ & h_{eff} = h_{base} + d_{cover} + h_{ret} = \textbf{4550} \text{ mm} \\ & x_{sur\_h} = h_{eff} / 2 = \textbf{2275} \text{ mm} \\ & A_{stem} = h_{stem} \times t_{stem} = \textbf{1.47} \text{ m}^2 \\ & x_{stem} = l_{toe} + t_{stem} / 2 = \textbf{1175} \text{ mm} \\ & A_{base} = l_{base} \times t_{base} = \textbf{0.473} \text{ m}^2 \\ & x_{base} = l_{base} / 2 = \textbf{675} \text{ mm} \end{split}$$

$$\begin{split} & \mathsf{K}_0 = 1 - \sin(\varphi'_{r,k}) = \textbf{0.691} \\ & \mathsf{K}_\mathsf{P} = \sin(90 - \varphi'_{b,k})^2 \ / \ (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{[\sin(\varphi'_{b,k} + \delta_{b,k}) \times \sin(\varphi'_{b,k}) \ / \ (\sin(90 + \delta_{b,k}))]]^2)} = \textbf{2.359} \end{split}$$

$$\begin{split} F_{stem} &= A_{stem} \times \gamma_{stem} = \textbf{36.8 kN/m} \\ F_{base} &= A_{base} \times \gamma_{base} = \textbf{11.8 kN/m} \\ F_{P\_v} &= P_{G1} = \textbf{50 kN/m} \end{split}$$

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Total		F <sub>total_v</sub> = F <sub>ste</sub>	em + Fbase + Fwa	ater_v + FP_v = <b>98.6</b>	i kN/m	
Horizontal forces on wall						
Surcharge load		$F_{sur_h} = K_0 >$	$<\cos(\delta_{ m r.d})  imes ( m Sr$	urcharge <sub>G</sub> + Surc	$harge_Q) \times h_{eff} =$	<b>108.7</b> kN/m
Saturated retained soil		$F_{sat_h} = K_0 >$	$ imes \cos(\delta_{ m r.d})  imes (\gamma_{ m sr})$	r' - γw') × (h <sub>sat</sub> + h <sub>b</sub>	ase) <sup>2</sup> / 2 = <b>35.2</b>	κN/m
Water		$F_{water_h} = \gamma_w$	$' \times (h_{water} + d_{cov})$	$(h_{er} + h_{base})^2 / 2 = 6$	<b>51.8</b> kN/m	
Moist retained soil		$F_{moist_h} = K_0$	$ imes cos(\delta_{\mathrm{r.d}})  imes \gamma_{\mathrm{r}}$	mr' $ imes$ ((h <sub>eff</sub> - h <sub>sat</sub> - h	$h_{base})^2 / 2 + (h_{eff})^2$	- h <sub>sat</sub> - h <sub>base</sub> ) ×
		(h <sub>sat</sub> + h <sub>base</sub> )	)) = <b>49.8</b> kN/m			
Base soil	$F_{pass_h} = -K_P \times cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = -2.6 \text{ kN/m}$					
Total	F <sub>total_h</sub> = F <sub>sat_h</sub> + F <sub>moist_h</sub> + F <sub>pass_h</sub> + F <sub>water_h</sub> + F <sub>sur_h</sub> = <b>252.9</b> kN/m					
Moments on wall						
Wall stem		$M_{\text{stem}} = F_{\text{ster}}$	$m \times X_{stem} = 43.2$	2 kNm/m		
Wall base	$M_{base} = F_{base} \times x_{base} = 8 \text{ kNm/m}$					
Surcharge load	$M_{sur} = -F_{sur_h} \times x_{sur_h} = -247.3 \text{ kNm/m}$					
Line loads		$M_P = P_{G1} \times$	p1 = <b>58.2</b> kNm	ı/m		
Saturated retained soil		$M_{sat} = -F_{sat}$	$h \times X_{sat_h} = -41.$	. <b>7</b> kNm/m		
Water		$M_{water} = -F_{w}$	$_{ater_h \times X_{water_h}} =$	₌ <b>-73.1</b> kNm/m		
Moist retained soil		$M_{\text{moist}} = -F_{\text{m}}$	oist_h $\times$ Xmoist_h =	- <b>101.3</b> kNm/m		
Total		$M_{total} = M_{ster}$	m + Mbase + Msa	at + Mmoist + Mwater	+ $M_{sur}$ + $M_P$ = -	<b>354</b> kNm/m
Check bearing pressure						
Propping force to stem		F <sub>prop_stem</sub> =	$(F_{total_v} \times I_{base} / I_{base})$	2 - M <sub>total</sub> ) / (h <sub>prop</sub> +	⊦ t <sub>base</sub> ) = <b>92.4</b> kN	√m
Propping force to base		F <sub>prop_base</sub> =	F <sub>total_h</sub> - F <sub>prop_ste</sub>	em = <b>160.5</b> kN/m		
Moment from propping force		$M_{prop} = F_{prop}$	$b_{stem} \times (h_{prop} +$	t <sub>base</sub> ) = <b>420.6</b> kN	m/m	
Distance to reaction		$\overline{\mathbf{x}} = (\mathbf{M}_{\text{total}} -$	⊢ M <sub>prop</sub> ) / F <sub>total_v</sub>	/ = <b>675</b> mm		
Eccentricity of reaction		$e = \overline{x} - I_{base}$	₀ / 2 = <b>0</b> mm			
Loaded length of base		I <sub>load</sub> = I <sub>base</sub> =	<b>1350</b> mm			
Bearing pressure at toe		$q_{toe} = F_{total_v}$	/ $I_{base} \times (1 - 6)$	× e / I <sub>base</sub> ) = <b>73</b> k	N/m²	
Bearing pressure at heel		$q_{\text{heel}} = F_{\text{total}}$	$_v$ / I <sub>base</sub> × (1 + 6	$6 \times e / I_{base}$ = 73	kN/m²	
Factor of safety		$FoS_{bp} = P_{be}$	earing / max(q <sub>toe</sub> ,	q <sub>heel</sub> ) = <b>2.055</b>		
	PASS -	Allowable bearin	g pressure ex	ceeds maximu	m applied bear	ing pressure

## **RETAINING WALL DESIGN**

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 2.9.03

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

Concrete strength class	C32/40
Characteristic compressive cylinder strength	f <sub>ck</sub> = <b>32</b> N/mm <sup>2</sup>
Characteristic compressive cube strength	$f_{ck,cube} = 40 \text{ N/mm}^2$
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8 N/mm^2 = 40 N/mm^2$
Mean value of axial tensile strength	$f_{ctm} = 0.3 \; N/mm^2 \times (f_{ck} \; / \; 1 \; N/mm^2)^{2/3} = \textbf{3.0} \; N/mm^2$
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} = 2.1 \text{ N/mm}^2$
Secant modulus of elasticity of concrete	$E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = 33346 \text{ N/mm}^2$
Partial factor for concrete - Table 2.1N	γc = <b>1.50</b>
Compressive strength coefficient - cl.3.1.6(1)	$\alpha_{cc} = 0.85$
Design compressive concrete strength - exp.3.15	$f_{cd} = \alpha_{cc} \times f_{ck} \ / \ \gamma_C = \textbf{18.1} \ N/mm^2$

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Maximum aggregate size		h <sub>agg</sub> = <b>20</b> m	ım			
Reinforcement details						
Characteristic yield strengt	h of reinforcement	f <sub>yk</sub> = <b>500</b> N/mm²				
Modulus of elasticity of reir	forcement	E <sub>s</sub> = <b>200000</b> N/mm <sup>2</sup>				
Partial factor for reinforcing	steel - Table 2.1N	γs = 1.15	γs = 1.15			
Design yield strength of rei	nforcement	$f_{yd} = f_{yk}  /  \gamma_S$	$f_{yd} = f_{yk} / \gamma_S = \textbf{435} \ N/mm^2$			
Cover to reinforcement						
Front face of stem		c <sub>sf</sub> = <b>25</b> mn	c <sub>sf</sub> = <b>25</b> mm			
Rear face of stem		c <sub>sr</sub> = <b>75</b> mn	c <sub>sr</sub> = <b>75</b> mm			
Top face of base		c <sub>bt</sub> = <b>25</b> mn	c <sub>bt</sub> = <b>25</b> mm			
Bottom face of base		c <sub>bb</sub> = <b>50</b> mr	m			





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Check stem design at 2456	mm						
Depth of section		h = <b>350</b> mn	n				
Rectangular section in flexu	re - Section 6.1						
Design bending moment com	bination 1	M = <b>80.9</b> ki	Nm/m				
Depth to tension reinforcemer	nt	$d = h - c_{sf} - c_$	$\phi_{sx} - \phi_{sfM} / 2 = 2$	<b>297</b> mm			
		$K=M/(d^2$	× f <sub>ck</sub> ) = <b>0.029</b>				
		K' = <b>0.207</b>					
		· (0 5	K'>K-	No compressio	n reinforceme	ent is required	
Lever arm		z = min(0.5)	$0 + 0.5 \times (1 - 3)$	$53 \times \text{K})^{0.5}, 0.95)$	× d = 282 mm		
Depth of neutral axis		$x = 2.5 \times (d$	l – z) = <b>37</b> mm				
Area of tension reinforcement	required	$A_{sfM.req} = M$	$/(f_{yd} \times z) = 659$	<b>9</b> mm²/m			
Tension reinforcement provide	ed	16 dia.bars	@ 150 c/c				
Area of tension reinforcement	provided	$A_{sfM.prov} = \pi$	$\times \phi_{sfM^2} / (4 \times s_s)$	<sub>sfM</sub> ) = <b>1340</b> mm <sup>2</sup> /I	n		
Minimum area of reinforceme	nt - exp.9.1N	$A_{sfM.min} = m$	$ax(0.26 \times f_{ctm})$	f <sub>yk</sub> , 0.0013) × d =	= <b>467</b> mm²/m		
Maximum area of reinforceme	ent - cl.9.2.1.1(3)	$A_{sfM.max} = 0.$	.04 × h = <b>1400</b>	<b>0</b> mm²/m			
	DASS Area a	max(A <sub>sfM.rec</sub>	<sub>1</sub> , A <sub>sfM.min</sub> ) / A <sub>sfM</sub> t provided is c	.prov = <b>0.492</b>	a of roinforce	mont requires	
	PASS - Alea 0	reiniorcemeni	i provided is g	freater than are		ment required	
Deflection control - Section	7.4		( N1/ma ma <sup>2</sup> ) / 100	0.000			
Reference reinforcement ratio		$\rho_0 = \mathcal{N}(\mathbf{T_{ck}})$	1 IN/mm²) / 100	0 = 0.006			
Required tension reinforceme	nt ratio	$\rho = A_{sfM.req}$	d = 0.002				
Required compression reinfor	cement ratio	$\rho' = A_{sfM.2.red}$	q / d <sub>2</sub> = <b>0.000</b>				
Structural system factor - Tab	le 7.4N	K <sub>b</sub> = <b>1</b>					
Reinforcement factor - exp.7.	17	$K_s = min(50)$	00 N/mm² / (t <sub>yk</sub>	× AsfM.req / AsfM.pro	w), 1.5) = <b>1.5</b>		
Limiting span to depth ratio - e	exp.7.16.a	min(K <sub>s</sub> × K <sub>t</sub>	5 × [11 + 1.5 × 1	√(f <sub>ck</sub> / 1 N/mm²) >	< ρ <sub>0</sub> / ρ + 3.2 ×	√(f <sub>ck</sub> / 1	
		$N/mm^2) \times (p$	ρ <sub>0</sub> / ρ - 1) <sup>3/2</sup> ], 4(	$0 \times K_b) = 40$			
Actual span to depth ratio		$h_{prop} / d = 1$	4.1 Snon to don	th ratio is loss	han daflaatia	n control limit	
		PASS	- Span to dep	th ratio is less i	nan defiectio	n control limit	
Crack control - Section 7.3							
Limiting crack width	<b>T</b>	$W_{max} = 0.3$	mm				
Variable load factor - EN1990	– Table A1.1	$\Psi_2 = 0.6$					
Serviceability bending momer	nt .	$M_{sls} = 57.8$	kNm/m				
Lensile stress in reinforcemer	It	$\sigma_{\rm s} = M_{\rm sls} / (A_{\rm sls})$	$A_{sfM.prov} \times Z) = 1$	152.7 N/mm²			
Load duration factor	anaian	$K_t = 0.4$	0.E.v. (b. d.) (k	x) (2 b (2)	104000 mm <sup>2</sup>	<b>`</b> 22	
Ellective area of concrete in the	ension e etrepath	$A_{c.eff} = min($	$2.5 \times (11 - 0), (1$	(1 - x) / (3, 11 / 2) =	104292 mm <sup>-</sup> /	ſĦ	
Poinforcomont ratio	estiength	$I_{ct.eff} = I_{ctm} =$	3.0 N/IIIII- / A 0.0	12			
		$p_{p.eff} = A_{sfM,p}$	5 009	15			
Rend property coefficient		$\alpha_e = E_s / E_c$	m = <b>3.990</b>				
Strain distribution coefficient		$k_1 = 0.0$					
		$k_2 = 0.3$					
		k <sub>4</sub> = 0.425					
					007		
Maximum crack spacing - exp	Maximum crack spacing - exp.7.11		$s_{r.max} = k_3 \times c_{sf} + k_1 \times k_2 \times k_4 \times \phi_{sfM} / \rho_{p.eff} = 297 \text{ mm}$				
Maximum crack spacing - exp Maximum crack width - exp 7	0.7.11 8	$S_{r.max} = K_3 \times$	$C_{sf} + K_1 \times K_2 \times$	$K_4 \times \Phi_{sfM} / \rho_{p.eff} =$ (fet eff / $\Omega_{p.off} \times (1)$	<b>291</b> mm + α <sub>e</sub> × ο <sub>5 e</sub> μ) Ο	$6 \times \sigma_{c}$ / $F_{c}$	

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P&M	Calco for			Start page pg //				
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		w <sub>k</sub> / w <sub>max</sub> = <b>PASS</b>	0.453 <i>- Maximum c</i>	rack width is les	ss than limitin	g crack width		
Check stem design at bas	se of stem					-		
Depth of section		h = <b>350</b> mr	n					
Rectangular section in fle	xure - Section 6.1							
Design bending moment co	mbination 1	M = <b>166</b> kN	lm/m					
Depth to tension reinforcem	nent	$d = h - c_{sr} - c_{sr}$	$\phi_{sr} / 2 = 263 \text{ m}$	ım				
		$K = M / (d^2)$	$\times$ f <sub>ck</sub> ) = <b>0.075</b>					
		K' = <b>0.207</b>						
			K' > K -	No compressio	n reinforceme	ent is required		
Lever arm		z = min(0.5	$5 + 0.5 \times (1 - 3)$	$53 \times \text{K}$ ) <sup>0.5</sup> , 0.95)	× d = <b>244</b> mm			
Depth of neutral axis		$x = 2.5 \times (c$	l − z) = <b>47</b> mm					
Area of tension reinforceme	ent required	$A_{sr.req} = M /$	$(f_{yd} \times z) = 156$	<b>6</b> mm²/m				
Tension reinforcement prov	rided	25 dia.bars	@ 75 c/c					
Area of tension reinforceme	ent provided	$A_{sr.prov} = \pi >$	$A_{sr,prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = 6545 \text{ mm}^2/\text{m}$					
Minimum area of reinforcen	$A_{sr.min} = max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 413 \text{ mm}^2/\text{m}$							
Maximum area of reinforcer	ment - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h = 14000 \text{ mm}^2/\text{m}$						
		max(A <sub>sr.req</sub> ,	A <sub>sr.min</sub> ) / A <sub>sr.prov</sub>	<i>y</i> = <b>0.239</b>				
	PASS - Area o	f reinforcement	t provided is g	greater than area	a of reinforce	ment required		
Deflection control - Section	on 7.4							
Reference reinforcement ra	ıtio	$\rho_0 = \sqrt{f_{ck}} / T_{ck}$	1 N/mm <sup>2</sup> ) / 100	<b>00 = 0.006</b>				
Required tension reinforcen	nent ratio	$\rho = A_{sr.req}$ /	d = <b>0.006</b>					
Required compression reinf	forcement ratio	$\rho' = A_{sr.2.req}$	/ d <sub>2</sub> = <b>0.000</b>					
Structural system factor - Ta	able 7.4N	$K_b = 1$						
Reinforcement factor - exp.	7.17	K <sub>s</sub> = min(50	00 N/mm² / (f <sub>yk</sub>	imes A <sub>sr.req</sub> / A <sub>sr.prov</sub> ),	1.5) = <b>1.5</b>			
Limiting span to depth ratio	- exp.7.16.b	$min(K_s  imes K_t)$	5 × [11 + 1.5 ×	√(f <sub>ck</sub> / 1 N/mm²) >	< p <sub>0</sub> / (p - p') + -	√(f <sub>ck</sub> / 1		
		$N/mm^2) \times \sqrt{2}$	(ρ' / ρ₀) / 12], 4	40 × K <sub>b</sub> ) = <b>28.6</b>				
Actual span to depth ratio		$h_{prop} / d = 1$	6					
		PASS	- Span to dep	oth ratio is less t	han deflectio	n control limit		
Crack control - Section 7.	3							
Limiting crack width		Wmax = 0.3	mm					
Variable load factor - EN19	90 – Table A1.1	ψ <sub>2</sub> = <b>0.6</b>						
Serviceability bending mom	ient	$M_{sls} = 119.7$	<b>1</b> kNm/m					
Tensile stress in reinforcem	ient	$\sigma_s = M_{sls} / (a_s)$	$A_{sr.prov} \times z) = 7$	<b>4.7</b> N/mm²				
Load duration		Long term						
Load duration factor		$k_t = 0.4$						
Effective area of concrete in	n tension	A <sub>c.eff</sub> = min(	2.5 × (h - d), (l	h – x) / 3, h / 2) =	101015 mm <sup>2</sup> /	m		
Mean value of concrete ten	sile strength	$f_{ct.eff} = f_{ctm} =$	<b>3.0</b> N/mm <sup>2</sup>	_				
Reinforcement ratio		$\rho_{p.eff} = A_{sr.pr}$	$_{ov}$ / $A_{c.eff} = 0.06$	5				
Modular ratio		$\alpha_{e} = E_{s} / E_{c}$	m = <b>5.998</b>					
Bond property coefficient		k <sub>1</sub> = <b>0.8</b>						
Strain distribution coefficien	I	K <sub>2</sub> = <b>0.5</b>						
		K3 = 3.4						
Maximum areak anadian	vn 7 11	$r_4 = 0.425$	ب باب باب م	kixa /a a	<b>91</b> mm			
waximum crack spacing - e	xp./.11	$S_{r.max} = K_3 \times$	$U_{sr} + K_1 \times K_2 \times$	$\mathbf{r}_4 \times \psi_{sr} / \rho_{p.eff} = 3$				

Project Job							
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	Calcs for	Typical basem	1	Start page no./R	evision 7		
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Maximum crack width - exp.7	7.8	W <sub>k</sub> = S <sub>r.max</sub> >	$\times \max(\sigma_s - k_t \times (t))$	$f_{ct.eff} / \rho_{p.eff})  imes (1 +$	$- \alpha_{e} \times \rho_{p.eff}$ ), 0.6	$6 \times \sigma_s) / E_s$	
		Wk = <b>0.078</b>	mm				
		$w_k / w_{max} =$	0.26				
		PASS	- Maximum cra	ack width is les	s than limiting	g crack width	
Rectangular section in she	ear - Section 6.2						
Design shear force		V = <b>221.9</b>	kN/m				
		$C_{\text{Rd,c}} = 0.18$	8 / γ <sub>C</sub> = <b>0.120</b>				
		k = min(1 +	⊦ √(200 mm / d),	2) = <b>1.873</b>			
Longitudinal reinforcement ra	atio	$\rho_l = min(A_s$	<sub>r.prov</sub> / d, 0.02) =	0.020			
		v <sub>min</sub> = 0.03	$5 \text{ N}^{1/2}/\text{mm} \times \text{k}^{3/2}$	× f <sub>ck</sub> <sup>0.5</sup> = <b>0.507</b> N	/mm²		
Design shear resistance - ex	(p.6.2a & 6.2b	V <sub>Rd.c</sub> = max	$k(C_{Rd.c} \times k \times (100))$	$0 \text{ N}^2/\text{mm}^4  imes  ho_{\text{I}}  imes f_0$	$_{\rm ck})^{1/3}, v_{\rm min})  imes d$		
		V <sub>Rd.c</sub> = <b>236</b>	kN/m				
		$V / V_{Rd.c} = 0$	0.940				
		PAS	SS - Design she	ar resistance e	xceeds desig	n shear force	
Check stem design at prop	)						
Depth of section		h = <b>350</b> mr	n				
Rectangular section in she	ear - Section 6.2						
Design shear force		V = <b>83.5</b> kl	N/m				
		$C_{\text{Rd,c}} = 0.18$	8 / γ <sub>C</sub> = <b>0.120</b>				
		k = min(1 +	⊦ √(200 mm / d),	2) = <b>1.873</b>			
Longitudinal reinforcement ra	atio	$\rho_I = min(A_s$	r1.prov / d, 0.02) =	0.003			
		v <sub>min</sub> = 0.03	$5 \text{ N}^{1/2}/\text{mm} \times \text{k}^{3/2}$	× f <sub>ck</sub> <sup>0.5</sup> = <b>0.507</b> N	/mm²		
Design shear resistance - ex	(p.6.2a & 6.2b	V <sub>Rd.c</sub> = max	$(C_{Rd.c} \times k \times (100))$	$0 \text{ N}^2/\text{mm}^4 \times \rho_1 \times f_0$	$_{\rm ck})^{1/3}, v_{\rm min}) imes d$		
		V <sub>Rd.c</sub> = <b>133</b>	<b>.2</b> kN/m				
		$V / V_{Rd.c} = 0$	0.627				
Havizantal vainfavaamant n	arallal to face of a	PAS tom Section	SS - Design she	ar resistance e	xceeds desig	n shear force	
Minimum area of reinforcement p				$0.001 \times t$ ) - 1	1636 mm <sup>2</sup> /m		
Maximum spacing of reinforcem	$e_{11} = c_{1.9.0.3(1)}$	$A_{\text{sx.req}} = 112$	10  mm	$0.001 \times lstem) = 1$			
Transverse reinforcement pr	ovided	20 dia bar	≈ @ 150 c/c				
Area of transverse reinforcer	ment provided	As prov = $\pi$	$\times \phi_{ex}^2 / (4 \times s_{ex}) =$	= <b>2094</b> mm²/m			
	PASS - Area of	reinforcemen	t provided is ar	reater than area	of reinforcen	nent required	
Check base design at too			7				
Depth of section		h = <b>350</b> mr	n				
Rectangular section in flay	rura - Section 6 1						
Design bending moment con	mbination 1	M – <b>43 4</b> k	Nm/m				
Depth to tension reinforceme	ent	$d = h - C_{hh}$	- ohh / 2 = <b>292</b> m	m			
	•	$K = M / (d^2)$	$x f_{ck}$ = 0.016				
		K' = <b>0.207</b>					
			K' > K - N	lo compression	reinforceme	nt is required	
Lever arm		z = min(0.5	5 + 0.5 × (1 - 3.5	3 × K) <sup>0.5</sup> , 0.95) ×	d = <b>277</b> mm		
Depth of neutral axis		$x = 2.5 \times (0)$	d – z) = <b>37</b> mm	-			
Area of tension reinforcemer	nt required	$A_{bb,req} = M$	/ (f <sub>yd</sub> × z) = <b>360</b> r	mm²/m			
Tension reinforcement provid	ded	16 dia.bars	s @ 150 c/c				
Area of tension reinforcemer	nt provided	$A_{bb,prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb}) = 1340 \text{ mm}^2/\text{m}$					

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Minimum area of reinforceme	ent - exp.9.1N	A <sub>bb.min</sub> = m	ax(0.26 $\times$ f <sub>ctm</sub> /	f <sub>yk</sub> , 0.0013) × d =	<b>459</b> mm²/m				
Maximum area of reinforcem	ent - cl.9.2.1.1(3)	$A_{bb.max} = 0.$	04 × h = <b>1400</b>	<b>0</b> mm²/m					
		max(A <sub>bb.req</sub>	, A <sub>bb.min</sub> ) / A <sub>bb.pr</sub>	rov = <b>0.343</b>					
	PASS - Area of	reinforcemen	t provided is g	greater than are	a of reinforce	ment requirea			
Crack control - Section 7.3	i i i i i i i i i i i i i i i i i i i								
Limiting crack width		Wmax = <b>0.3</b>	mm						
Variable load factor - EN199	0 – Table A1.1	$\psi_2 = 0.6$							
Serviceability bending mome	ent	$M_{sls} = 32.1$	kNm/m						
Tensile stress in reinforceme	ent	$\sigma_{s} = M_{sls} / $	$(A_{bb.prov} \times z) = 8$	<b>86.4</b> N/mm <sup>2</sup>					
Load duration		Long term							
Load duration factor		$k_t = 0.4$							
Effective area of concrete in	tension	A <sub>c.eff</sub> = min	(2.5 × (h - d), (	h – x) / 3, h / 2) =	<b>104500</b> mm <sup>2</sup> /i	n			
Mean value of concrete tens	ile strength	$f_{ct.eff} = f_{ctm} =$	= <b>3.0</b> N/mm <sup>2</sup>						
Reinforcement ratio		$\rho_{\text{p.eff}} = A_{\text{bb.p}}$	$P_{\text{rov}} / A_{\text{c.eff}} = 0.0$	13					
Modular ratio		$\alpha_e = E_s / E$	$\alpha_e = E_s / E_{cm} = 5.998$						
Bond property coefficient		k <sub>1</sub> = <b>0.8</b>	k <sub>1</sub> = <b>0.8</b>						
Strain distribution coefficient		k <sub>2</sub> = <b>0.5</b>							
		k <sub>3</sub> = <b>3.4</b>							
		k4 = <b>0.425</b>							
Maximum crack spacing - ex	p.7.11	$s_{r.max} = k_3 >$	$\langle c_{bb} + k_1 \times k_2 \rangle$	$k_4 \times \phi_{bb} / \rho_{p.eff} = 1$	<b>382</b> mm				
Maximum crack width - exp.7	7.8	$W_k = S_{r.max}$	$\times \max(\sigma_s - k_t \times$	$(f_{\text{ct.eff}}  /  \rho_{\text{p.eff}}) \times (1$	+ $\alpha_e \times \rho_{p.eff}$ ), 0.	$6  imes \sigma_s$ ) / E <sub>s</sub>			
		w <sub>k</sub> = <b>0.099</b>	mm						
		$W_k / W_{max} =$	0.33						
		PASS	6 - Maximum c	rack width is le	ss than limitin	g crack width			
Rectangular section in she	ear - Section 6.2								
Design shear force		V = <b>86.8</b> k	N/m						
		$C_{\text{Rd,c}} = 0.1$	8 / γ <sub>C</sub> = <b>0.120</b>						
		k = min(1 -	+ √(200 mm / d	l), 2) = <b>1.828</b>					
Longitudinal reinforcement ra	atio	$\rho_1 = \min(A_t)$	ob.prov / d, 0.02)	= 0.005					
		V <sub>min</sub> = 0.03	$5 \text{ N}^{1/2}/\text{mm} \times \text{k}^{3/2}$	<sup>/2</sup> × f <sub>ck</sub> <sup>0.5</sup> = <b>0.489</b>	N/mm²				
Design shear resistance - ex	p.6.2a & 6.2b	V <sub>Rd.c</sub> = mat	$x(C_{Rd,c} \times k \times (1))$	00 N <sup>2</sup> /mm <sup>4</sup> × $\rho_l$ ×	$(f_{ck})^{1/3}, v_{min}) \times d$				
5		V <sub>Rd.c</sub> = 156	5.8 kN/m						
		$V / V_{Rd.c} =$	0.553						
		PAS	SS - Design sh	near resistance o	exceeds desig	In shear force			
Secondary transverse rein	forcement to base	Section 9.3							
Minimum area of reinforceme	ent – cl.9.3.1.1(2)	$A_{bx.req} = 0.2$	$2 \times A_{bt.prov} = 656$	<b>4</b> mm²/m					
Maximum spacing of reinford	cement - cl.9.3.1.1(3	6) S <sub>bx_max</sub> = <b>4</b>	50 mm						
Transverse reinforcement pr	ovided	16 dia.bar	s @ 150 c/c						
Area of transverse reinforcer	ment provided	$A_{bx.prov} = \pi$	$ imes \phi_{bx}^2$ / (4 $ imes$ s <sub>bx</sub>	) = <b>1340</b> mm²/m					

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**Reinforcement details**