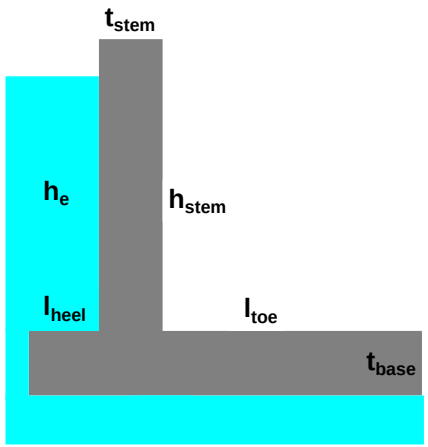
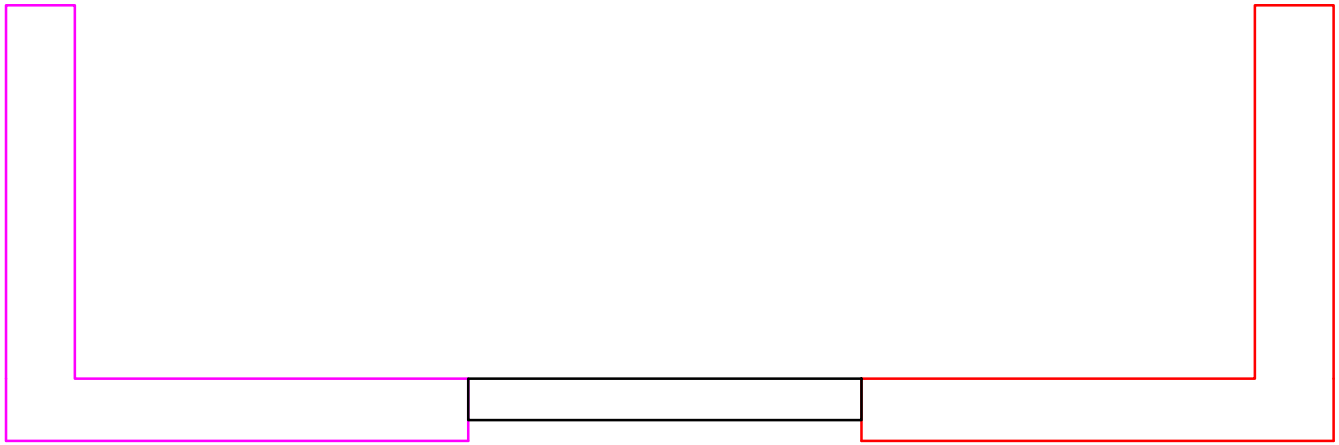
Design of RC Basement walls for Party Wall to No. 83 and Gable wall





Left hand side basement wall			Right hand side basement wall		
Position of stem :	Party wall with No. 83		Position of stem :	Gable wall	
Total height of wall including thickness of base (h) :	3.15	m	Total height of wall including thickness of base (h) :	3.15	m
Thickness of wall (t_{stem}) :	0.35	m	Thickness of wall (t_{stem}) :	0.40	m
Height of soil including thickness of base (h_e) :	2.88	m	Height of soil including thickness of base (h_e) :	3.15	m
Angle of backfill or slope (β) :	0	Degree	Angle of backfill or slope (β) :	0	Degree
Internal angle of friction for retained soil (ϕ) :	20	Degree	Internal angle of friction for retained soil (ϕ) :	20	Degree
Dead surcharge in SLS ($W_{d\,s}$) :	0.0	kN/m^2	Dead surcharge in SLS ($W_{d\,s}$) :	2.2	kN/m^2
Live surcharge in SLS ($W_{l\,s}$) :	0.0	kN/m^2	Live surcharge in SLS ($W_{l\,s}$) :	1.5	kN/m^2
Height of surcharge loads from underneath of base (h_s) :	0.00	m	Height of surcharge loads from underneath of base (h_s) :	1.90	m
Vertical dead load on stem under temporary work in SLS (W_{d2}) :	33.6	kN/m	Vertical dead load on stem under temporary work in SLS (W_{d2}) :	76.2	kN/m
Vertical live load on stem under temporary work in SLS (W_{l2}) :	5.2	kN/m	Vertical live load on stem under temporary work in SLS (W_{l2}) :	2.0	kN/m
Vertical dead load on stem after construction in SLS (W_{d3}) :	34.5	kN/m	Vertical dead load on stem after construction in SLS (W_{d3}) :	77.1	kN/m
Vertical live load on stem after construction in SLS (W_{l3}) :	10.3	kN/m	Vertical live load on stem after construction in SLS (W_{l3}) :	10.8	kN/m
Additional horizontal dead load to stem in SLS ($W_{d\,h}$) :	0.00	kN/m	Additional horizontal dead load to stem in SLS ($W_{d\,h}$) :	15.60	kN/m
Additional horizontal live load to stem in SLS ($W_{l\,h}$) :	0.00	kN/m	Additional horizontal live load to stem in SLS ($W_{l\,h}$) :	2.20	kN/m
Height of horizontal load from underneath of base (h_h) :	0.00	m	Height of horizontal load from underneath of base (h_h) :	0.43	m
Height of ground water from underneath of base (h_w) :	2.00	m	Height of ground water from underneath of base (h_w) :	2.00	m
Depth of base (t_{base}) :	0.45	m	Depth of base (t_{base}) :	0.45	m
Length of toe (l_{toe}) :	1.00	m	Length of toe (l_{toe}) :	1.00	m
Length of heel (l_{heel}) :	0.00	m	Length of heel (l_{heel}) :	0.00	m
Dead load by wall, screed or others on toe in SLS ($W_{d\,toe}$) :	0.00	kN/m^2	Dead load by wall, screed or others on toe in SLS ($W_{d\,toe}$) :	0.00	kN/m^2
Live load on toe in SLS ($W_{l\,toe}$) :	0.00	kN/m^2	Live load on toe in SLS ($W_{l\,toe}$) :	0.00	kN/m^2

General

Density of soil (W_e) :	19.0	kN/m^3	Density of saturated soil (W_{sat}) :	0.0	kN/m^3
Required ratio of resistance against sliding :	1.5		Required ratio of resistance against overturning :	1.5	
Strength of steel (f_y) :	500	N/mm^2	Strength of concrete (f_{cu}) :	40	N/mm^2
Allowable bearing pressure of ground (q) :	200	kN/m^2			

**** The design is based on cantilever retaining walls which considers 1m length. Each wall will be analysed for 3 cases and designed for the worst case ****

Left hand side loading in SLS			Right hand side loading in SLS		
Active pressure coefficient (K_a)	0.49		Active pressure coefficient (K_a)	0.49	
Passive pressure coefficient (K_p)	2.04		Passive pressure coefficient (K_p)	2.04	
Total height of soil behind retaining wall ($h_{e\ wall}$)	2.88	m	Total height of soil behind retaining wall ($h_{e\ wall}$)	3.15	m
Height of stem (h_{stem})	2.70	m	Height of stem (h_{stem})	2.70	m
Total height of soil behind stem ($h_{e\ stem}$)	2.70	m	Total height of soil behind stem ($h_{e\ stem}$)	2.70	m
Self weight of stem (SW_{stem})	22.7	kN/m	Self weight of stem (SW_{stem})	25.9	kN/m
Total additional horizontal load to stem (W_h)	0.0	kN/m	Total additional horizontal load to stem (W_h)	17.8	kN/m
Length of base (l_{base})	1.35	m	Length of base (l_{base})	1.40	m
Self weight of base (SW_{base})	14.6	kN/m	Self weight of base (SW_{base})	15.1	kN/m
Self weight of toe (SW_{toe})	10.8	kN/m	Self weight of toe (SW_{toe})	10.8	kN/m
Total dead load on toe ($W_{d\ toe\ tot}$)	0.0	kN/m	Total dead load on toe ($W_{d\ toe\ tot}$)	0.0	kN/m
Total live load on toe ($W_{l\ toe\ tot}$)	0.0	kN/m	Total live load on toe ($W_{l\ toe\ tot}$)	0.0	kN/m
Total surcharge on heel ($W_{s\ heel}$)	0.0	kN/m	Total surcharge on heel ($W_{s\ heel}$)	0.0	kN/m
Height of saturated soil above base (h_{satl})	1.55	m	Height of saturated soil above base (h_{satl})	1.55	m
Self weight of saturated soil on heel (SW_{sat})	0.0	kN/m	Self weight of saturated soil on heel (SW_{sat})	0.0	kN/m
Self weight of non saturated soil behind stem (SW_e)	0.0	kN/m	Self weight of non saturated soil behind stem (SW_e)	0.0	kN/m

CASE 1: ANALYSIS FOR EXISTING LOADING

Not applicable	Not applicable

Case 2: UNDER TEMPORARY WORK ANALYSIS

(Consider using only the existing vertical dead loads for stability against sliding and overturning without any pressure from ground water)

Left hand side wall			Right hand side wall		
Stability for sliding			**Stability for sliding**		
$\mu = 0.75 * Tan\phi$	0.27		$\mu = 0.75 * Tan\phi$	0.27	
Active force from soil ($P_{a\ e\ 2}$)	38.6	kN/m	Active force from soil ($P_{a\ e\ 2}$)	46.2	kN/m
Active force from surcharge ($P_{a\ s\ 2}$)	0.0	kN/m	Active force from surcharge ($P_{a\ s\ 2}$)	3.4	kN/m
Total sliding force (F_2)	38.6	kN/m	Total sliding force (F_2)	67.5	kN/m
Resistance by friction ($P_{f\ 2}$)	19.3	kN/m	Resistance by friction ($P_{f\ 2}$)	32.0	kN/m
Resistance by passive force ($P_{p\ 2}$)	3.9	kN/m	Resistance by passive force ($P_{p\ 2}$)	3.9	kN/m
Total resistance force ($F_{res\ 2}$)	23.3	kN/m	Sliding resistance force ($F_{res\ 2}$)	35.9	kN/m
Ratio of resistance against sliding = $F_{res\ 2} / F_2$	0.6		Ratio of resistance against sliding = $F_{res\ 2} / F_2$	0.5	
0.6 < 1.5 ** FAILS. Backfill of soil is required **			0.5 < 1.5 ** FAILS. Backfill of soil is required **		
Stability for overturning			**Stability for overturning**		
Soil ($M_{e\ 2}$)	37.1	kNm/m	Soil ($M_{e\ 2}$)	48.5	kNm/m
Surcharge ($M_{s\ 2}$)	0.0	kNm/m	Surcharge ($M_{s\ 2}$)	3.3	kNm/m
Additional horizontal load ($M_{h\ 2}$)	0.0	kNm/m	Additional horizontal load ($M_{h\ 2}$)	7.7	kNm/m
Total overturning moment (M_2)	37.1	kNm/m	Total overturning moment (M_2)	59.5	kNm/m
Resistance by stem & vertical DL ($M_{r\ stem\ 2}$)	66.1	kNm/m	Resistance by stem & vertical DL ($M_{r\ stem\ 2}$)	122.5	kNm/m
Resistance by base ($M_{r\ base\ 2}$)	9.8	kNm/m	Resistance by base ($M_{r\ base\ 2}$)	10.6	kNm/m
Resistance by surcharge on heel ($M_{r\ s\ heel\ 2}$)	0.0	kNm/m	Resistance by surcharge on heel ($M_{r\ s\ heel\ 2}$)	0.0	kNm/m
Total resistance moment ($M_{res\ 2}$)	76.0	kNm/m	Total resistance moment ($M_{res\ 2}$)	133.1	kNm/m
Ratio of resistance against overturning = $M_{res\ 2} / M_2$	2.0		Ratio of resistance against overturning = $M_{res\ 2} / M_2$	2.2	
2.0 >= 1.5 OK			2.2 >= 1.5 OK		
Bearing pressure in SLS			**Bearing pressure in SLS**		
Total vertical load on base ($N_{SLS\ base\ 2}$)	70.9	kN/m	Total vertical load on base ($N_{SLS\ base\ 2}$)	117.2	kN/m

Distance to reaction ($X_{SLS\ 2}$)			0.55	m	Distance to reaction ($X_{SLS\ 2}$)		0.63	m
Eccentricity of vertical load in SLS ($e_{SLS\ 2}$)			0.13	m	Eccentricity of vertical load in SLS ($e_{SLS\ 2}$)		0.07	m
l_{base} / 6 =	0.23	>= 0.13	Load resultant lies inside middle third		l_{base} / 6 =	0.23	>= 0.07	Load resultant lies inside middle third
Pressure under base (p_{SLS}) :			81.9	kN/m^2	Pressure under base (p_{SLS}) :		109.4	kN/m^2
81.9	<= 200	OK			109.4	<= 200	OK	
Moment for stem in ULS					**Moment for stem in ULS**			
Soil ($M_{e\ ULS\ stem\ 2}$)			49.2	kNm/m	Soil ($M_{e\ ULS\ stem\ 2}$)		53.5	kNm/m
Surcharge ($M_{s\ ULS\ stem\ 2}$)			0	kNm/m	Surcharge ($M_{s\ ULS\ stem\ 2}$)		3.7010566	kNm/m
Additional horizontal loads ($M_{h\ ULS\ stem\ 2}$)			0.0	kNm/m	Additional horizontal loads ($M_{h\ ULS\ stem\ 2}$)		5.2	kNm/m
Total moment for stem ($M_{ULS\ stem\ 2}$)			49.2	kNm/m	Total moment for stem ($M_{ULS\ stem\ 2}$)		62.4	kNm/m
Moment for base in ULS					**Moment for base in ULS**			
Total vertical load on base ($N_{ULS\ base\ 2}$)			107.5	kN/m	Total vertical load on base ($N_{ULS\ base\ 2}$)		167.3	kN/m
Total moment on base ($M_{ULS\ base\ 2}$)			51.9	kNm/m	Total moment on base ($M_{ULS\ base\ 2}$)		83.7	kNm/m
Total resistance moment on base ($M_{res\ ULS\ base\ 2}$)			106.4	kNm/m	Total resistance moment on base ($M_{res\ ULS\ base\ 2}$)		186.4	kNm/m
Distance to reaction ($X_{ULS\ 2}$)			0.51	m	Distance to reaction ($X_{ULS\ 2}$)		0.61	m
Eccentricity of vertical load in ULS ($e_{ULS\ 2}$)			0.17	m	Eccentricity of vertical load in ULS ($e_{ULS\ 2}$)		0.09	m
l_{base} / 6 =	0.23	>= 0.17	Load resultant lies inside middle third		l_{base} / 6 =	0.23	>= 0.09	Load resultant lies inside middle third
Maximum pressure under base ($p_{max\ ULS\ base\ 2}$)			139.4	kN/m^2	Maximum pressure under base ($p_{max\ ULS\ base\ 2}$)		163.8	kN/m^2
Minimum pressure under base ($p_{min\ ULS\ base\ 2}$)			19.9	kN/m^2	Minimum pressure under base ($p_{min\ ULS\ base\ 2}$)		75.3	kN/m^2
Bearing length of base ($L_{p\ base\ 2}$)			1.35	m	Bearing length of base ($L_{p\ base\ 2}$)		1.40	m
Bearing length of heel ($L_{p\ heel\ 2}$)			0.00	m	Bearing length of heel ($L_{p\ heel\ 2}$)		0.00	m
Pressure under heel/stem interface ($p_{ULS\ heel\ 2}$)			0.0	kN/m^2	Pressure under heel/stem interface ($p_{ULS\ heel\ 2}$)		0.0	kN/m^2
Pressure under toe/stem interface ($p_{ULS\ toe\ 2}$)			50.9	kN/m^2	Pressure under toe/stem interface ($p_{ULS\ toe\ 2}$)		100.6	kN/m^2
Total vertical load on heel ($N_{ULS\ heel\ 2}$)			0.0	kN/m^2	Total vertical load on heel ($N_{ULS\ heel\ 2}$)		0.0	kN/m^2
Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 2}$)			0.0	kNm/m	Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 2}$)		0.0	kNm/m
Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 2}$)			0.0	kNm/m	Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 2}$)		0.0	kNm/m
Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 2}$)			0.0	kNm/m	Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 2}$)		0.0	kNm/m
Moment for toe at wall centre ($M_{ULS\ toe\ 2}$)			61.4	kNm/m	Moment for toe at wall centre ($M_{ULS\ toe\ 2}$)		87.2	kNm/m
Max net moment for base at face of wall ($M_{ULS\ base\ net\ 2}$)			61.4	kNm/m	Max net moment for base at face of wall ($M_{ULS\ base\ net\ 2}$)		87.2	kNm/m

CASE 3: AFTER CONSTRUCTION ANALYSIS

(Consider using all loads but no check for stability against sliding is required)

Left hand side wall			Right hand side wall		
Stability for overturning			**Stability for overturning**		
Surcharge ($M_{s\ 3}$)	0.0	kNm/m	Surcharge ($M_{s\ 3}$)	3.3	kNm/m
Additional horizontal load ($M_{h\ 3}$)	0.0	kNm/m	Additional horizontal load ($M_{h\ 3}$)	7.7	kNm/m
Moist backfill above water table ($M_{mbaw\ 3}$)	8.3	kNm/m	Moist backfill above water table ($M_{mbaw\ 3}$)	14.7	kNm/m
Moist backfill below water table ($M_{mbbw\ 3}$)	16.4	kNm/m	Moist backfill below water table ($M_{mbbw\ 3}$)	21.4	kNm/m
Saturated backfill ($M_{sb\ 3}$)	-6.4	kNm/m	Saturated backfill ($M_{sb\ 3}$)	-6.4	kNm/m
Water ($M_{w\ 3}$)	13.1	kNm/m	Water ($M_{w\ 3}$)	13.1	kNm/m
Total overturning moment (M_3)	31.3	kNm/m	Total overturning moment (M_3)	53.7	kNm/m
Resistance by stem & vertical loads ($M_{r\ stem\ 3}$)	79.3	kNm/m	Resistance by stem & vertical loads ($M_{r\ stem\ 3}$)	136.6	kNm/m
Resistance by base ($M_{r\ base\ 3}$)	9.8	kNm/m	Resistance by base ($M_{r\ base\ 3}$)	10.6	kNm/m
Resistance by loads on toe ($M_{r\ toe\ 3}$)	0.0	kNm/m	Resistance by loads on toe ($M_{r\ toe\ 3}$)	0.0	kNm/m
Resistance by surcharge on heel ($M_{r\ s\ heel\ 3}$)	0.0	kNm/m	Resistance by surcharge on heel ($M_{r\ s\ heel\ 3}$)	0.0	kNm/m
Resistance by moist backfill ($M_{r\ mb\ 3}$)	0.0	kNm/m	Resistance by moist backfill ($M_{r\ mb\ 3}$)	0.0	kNm/m
Resistance by saturated backfill ($M_{r\ sb\ 3}$)	0.0	kNm/m	Resistance by saturated backfill ($M_{r\ sb\ 3}$)	0.0	kNm/m
Total resistance moment ($M_{res\ 3}$)	89.1	kNm/m	Total resistance moment ($M_{res\ 3}$)	147.2	kNm/m

Ratio of resistance against overturning = $M_{res\ 3}$ / M_3			2.8		Ratio of resistance against overturning = $M_{res\ 3}$ / M_3		2.7	
2.8	>=	1.5	OK		2.7	>=	1.5	OK
Bearing pressure in SLS					**Bearing pressure in SLS**			
Total vertical load on base ($N_{SLS\ base\ 3}$)			82.1	kN/m	Total vertical load on base ($N_{SLS\ base\ 3}$)		128.9	kN/m
Distance to reaction ($X_{SLS\ 3}$)			0.70	m	Distance to reaction ($X_{SLS\ 3}$)		0.72	m
Eccentricity of vertical load in SLS ($e_{SLS\ 3}$)			0.03	m	Eccentricity of vertical load in SLS ($e_{SLS\ 3}$)		0.02	m
l_{base} / 6 =	0.23	>=	0.03	Load resultant lies inside middle third	l_{base} / 6 =	0.23	>=	0.02	Load resultant lies inside middle third
Pressure under base (p_{SLS}) :			68.7	kN/m^2	Pressure under base (p_{SLS}) :		101.9	kN/m^2
68.7	<=	200	OK		101.9	<=	200	OK
Moment for stem in ULS					**Moment for stem in ULS**			
Surcharge ($M_{s\ ULS\ stem\ 3}$)			0	kNm/m	Surcharge ($M_{s\ ULS\ stem\ 3}$)		3.7010566	kNm/m
Additional horizontal loads ($M_{h\ ULS\ stem\ 3}$)			0.0	kNm/m	Additional horizontal loads ($M_{h\ ULS\ stem\ 3}$)		5.1988	kNm/m
Moist backfill above water table ($M_{mbaw\ ULS\ stem\ 3}$)			17.8	kNm/m	Moist backfill above water table ($M_{mbaw\ ULS\ stem\ 3}$)		18.6	kNm/m
Moist backfill below water table ($M_{mbbw\ ULS\ stem\ 3}$)			18.0	kNm/m	Moist backfill below water table ($M_{mbbw\ ULS\ stem\ 3}$)		18.0	kNm/m
Saturated backfill ($M_{sb\ ULS\ stem\ 3}$)			-4.2	kNm/m	Saturated backfill ($M_{sb\ ULS\ stem\ 3}$)		-4.2	kNm/m
Water ($M_{w\ ULS\ stem\ 3}$)			8.5	kNm/m	Water ($M_{w\ ULS\ stem\ 3}$)		8.5	kNm/m
Total moment for stem ($M_{ULS\ stem\ 3}$)			40.2	kNm/m	Total moment for stem ($M_{ULS\ stem\ 3}$)		49.9	kNm/m
Moment for base in ULS					**Moment for base in ULS**			
Total vertical load on base ($N_{ULS\ base\ 3}$)			116.9	kN/m	Total vertical load on base ($N_{ULS\ base\ 3}$)		182.7	kN/m
Total moment on base ($M_{ULS\ base\ 3}$)			43.9	kNm/m	Total moment on base ($M_{ULS\ base\ 3}$)		75.6	kNm/m
Total resistance moment on base ($M_{res\ ULS\ base\ 3}$)			127.2	kNm/m	Total resistance moment on base ($M_{res\ ULS\ base\ 3}$)		208.6	kNm/m
Distance to reaction ($X_{ULS\ 3}$)			0.71	m	Distance to reaction ($X_{ULS\ 3}$)		0.73	m
Eccentricity of vertical load in ULS ($e_{ULS\ 3}$)			0.04	m	Eccentricity of vertical load in ULS ($e_{ULS\ 3}$)		0.03	
l_{base} / 6 =	0.23	<	0.71	Load resultant lies outside middle third	l_{base} / 6 =	0.23	<	0.73	Load resultant lies outside middle third
Maximum pressure under base ($p_{max\ ULS\ base\ 3}$)			109.4	kN/m^2	Maximum pressure under base ($p_{max\ ULS\ base\ 3}$)		167.3	kN/m^2
Minimum pressure under base ($p_{min\ ULS\ base\ 3}$)			0.0	kN/m^2	Minimum pressure under base ($p_{min\ ULS\ base\ 3}$)		0.0	kN/m^2
Bearing length of base ($L_{p\ base\ 3}$)			1.35	m	Bearing length of base ($L_{p\ base\ 3}$)		1.40	m
Bearing length of heel ($L_{p\ heel\ 3}$)			0.00	m	Bearing length of heel ($L_{p\ heel\ 3}$)		0.00	m
Pressure under heel/stem interface ($p_{ULS\ heel\ 3}$)			0.0	kN/m^2	Pressure under heel/stem interface ($p_{ULS\ heel\ 3}$)		0.0	kN/m^2
Pressure under toe/stem interface ($p_{ULS\ toe\ 3}$)			28.4	kN/m^2	Pressure under toe/stem interface ($p_{ULS\ toe\ 3}$)		47.8	kN/m^2
Total vertical load on heel ($N_{ULS\ heel\ 3}$)			0.0	kN/m^2	Total vertical load on heel ($N_{ULS\ heel\ 3}$)		0.0	kN/m^2
Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 3}$)			0.0	kNm/m	Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 3}$)		0.0	kNm/m
Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 3}$)			0.0	kNm/m	Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 3}$)		0.0	kNm/m
Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 3}$)			0.0	kNm/m	Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 3}$)		0.0	kNm/m
Moment for toe at wall centre ($M_{ULS\ toe\ 3}$)			43.0	kNm/m	Moment for toe at wall centre ($M_{ULS\ toe\ 3}$)		74.6	kNm/m
Max net moment for base at face of wall ($M_{ULS\ base\ net\ 3}$)			43.0	kNm/m	Max net moment for base at face of wall ($M_{ULS\ base\ net\ 3}$)		74.6	kNm/m

DESIGN OF STEMS

Left hand side stem			Right hand side stem			
Cover for reinforcement (c_w) :	75	mm	Cover for reinforcement (c_w) :		75	mm
Diameter of tension bars ($\phi_{t\ w}$) :	16	mm	Tension bars ($\phi_{t\ w}$) :	3 No. Layers Mesh A393	10	mm
C/C spacing for tension reinforcement ($S_{t\ wall}$) :	200	mm	C/C spacing for tension reinforcement ($S_{t\ wall}$) :		200	mm
Diameter of distribution bars ($\phi_{d\ w}$) :	12	mm	Distribution bars ($\phi_{d\ w}$) :	3 No. Layers Mesh A393	10	mm
C/C spacing for distribution reinforcement ($S_{d\ wall}$) :	200	mm	C/C spacing for distribution reinforcement ($S_{d\ wall}$) :		200	mm
Design moment (M_{wall}) = Max ($M_{ULS\ stem\ 2}$, $M_{ULS\ stem\ 3}$)	49.2	kNm/m	Design moment (M_{wall}) = Max ($M_{ULS\ stem\ 2}$, $M_{ULS\ stem\ 3}$)		62.4	kNm/m
Depth for tension reinforcement (d_{wall})	267.0	mm	Depth for tension reinforcement (d_{wall})		300.0	mm

$K_{wall} = M_{wall} / (f_{cu} * 1000 * d_{wall}^2)$				0.017		$K_{wall} = M_{wall} / (f_{cu} * 1000 * d_{wall}^2)$	0.017
0.017	<=	0.156	then only tension reinforcement is required.			0.017 <= 0.156 then only tension reinforcement is required.	
Lever arm (Z_{wall})				253.7	mm	Lever arm (Z_{wall})	285.0 mm
Required tension reinforcement ($A_{st\ req\ wall}$)				446	mm^2/m	Required tension reinforcement ($A_{st\ req\ wall}$)	503 mm^2/m
Minimum required tension reinforcement ($A_{st\ min\ wall}$)				455	mm^2/m	Minimum required tension reinforcement ($A_{st\ min\ wall}$)	520 mm^2/m
Tension reinforcement ($A_{st\ wall}$) = Max ($A_{st\ req\ wall}$, $A_{st\ min\ wall}$)				455	mm^2/m	Tension reinforcement ($A_{st\ wall}$) = Max ($A_{st\ req\ wall}$, $A_{st\ min\ wall}$)	520 mm^2/m
Provided tension reinforcement ($A_{st\ pro\ wall}$)				1005	mm^2/m	Provided tension reinforcement ($A_{st\ pro\ in\ wall}$)	1178 mm^2/m
1005	>	455	OK			1178 > 520 OK	
Minimum required distribution reinforcement ($A_{s\ min\ dis\ wall}$) = $A_{st\ min\ wall}$						Minimum required distribution reinforcement ($A_{s\ min\ dis\ wall}$) = $A_{st\ min\ wall}$	
Provided distribution reinforcement ($A_{s\ pro\ dis\ wall}$)				565	mm^2/m	Provided distribution reinforcement ($A_{s\ pro\ dis\ wall}$)	1178 mm^2/m
565	>=	455	OK			1178 >= 520 OK	
Total horizontal force to wall in ULS ($F_{ULS\ wall}$)				47.5	kN/m	Total horizontal force to wall in ULS ($F_{ULS\ wall}$)	75.4 kN/m
Applied shear stress to wall ($v_{ULS\ wall}$)				0.18	N/mm^2	Applied shear stress to wall ($v_{ULS\ wall}$)	0.25 N/mm^2
0.18	<=	5.0	OK			0.25 <= 5.0 OK	
$A_{st\ pro\ in\ wall} / (d_{wall} * 10)$				0.38		$A_{st\ pro\ in\ wall} / (d_{wall} * 10)$	0.39
Design concrete shear stress $\mathbf{v_{c\ wall}}$ from Table 3.8 – BS 8110:				0.57	N/mm^2	Design concrete shear stress $\mathbf{v_{c\ wall}}$ from Table 3.8 – BS 8110:	0.57 N/mm^2
0.57	>=	0.18	No shear reinforcement required.			0.57 >= 0.25 No shear reinforcement required.	
Design service stress ($f_{s\ wall}$)				150.9	N/mm^2	Design service stress ($f_{s\ wall}$)	147.1 N/mm^2
Modification factor for tension				2.0		Modification factor for tension	2.0
Permissible span to depth ration				14.0		Permissible span to depth ration	14.0
Actual span to depth ration = h_{stem} / d_{wall}				10.1		Actual span to depth ration = h_{stem} / d_{wall}	9.0
14.0	>=	10.1	OK			14.0 >= 9.0 OK	

DESIGN OF BASES

Left hand side base			Right hand side base		
Cover for reinforcement (c_b) :	75	mm	Cover for reinforcement (c_b) :	75	mm
Diameter of tension bars ($\phi_{t\ b}$) :	16	mm	Tension bars ($\phi_{t\ b}$) : 4 No. Layers Mesh A393	10	mm
C/C spacing for tension reinforcement ($S_{t\ base}$) :	200	mm	C/C spacing for tension reinforcement ($S_{t\ base}$) :	200	mm
Diameter of distribution bars ($\phi_{d\ b}$) :	16	mm	Distribution bars ($\phi_{d\ b}$) : 4 No. Layers Mesh A393	10	mm
C/C spacing for distribution reinforcement ($S_{d\ base}$) :	200	mm	C/C spacing for distribution reinforcement ($S_{d\ base}$) :	200	mm
Moment for base ($M_{ULS\ base\ net}$) = Max ($M_{ULS\ base\ net\ 2}$, $M_{ULS\ base\ net\ 3}$)	61.4	kNm/m	Moment for base ($M_{ULS\ base\ net}$) = Max ($M_{ULS\ base\ net\ 2}$, $M_{ULS\ base\ net\ 3}$)	87.2	kNm/m
Depth for tension reinforcement in base (d_{base})	367.0	mm	Depth for tension reinforcement in base (d_{base})	340.0	mm
$K_{base} = M_{ULS\ base\ net} / (f_{cu} * 1000 * d_{base}^2)$	0.011		$K_{base} = M_{ULS\ base\ net} / (f_{cu} * 1000 * d_{base}^2)$	0.019	
0.011 <= 0.156 then only tension reinforcement is required.			0.019 <= 0.156 then only tension reinforcement is required.		
Lever arm (Z_{base})	348.7	mm	Lever arm (Z_{base})	323.0	mm
Required tension reinforcement ($A_{st\ req\ base}$)	405	mm^2/m	Required tension reinforcement ($A_{st\ req\ base}$)	621	mm^2/m
Minimum required tension reinforcement ($A_{st\ min\ base}$)	585	mm^2/m	Minimum required tension reinforcement ($A_{st\ min\ base}$)	585	mm^2/m
Tension reinforcement ($A_{st\ base}$) = Max($A_{st\ req\ base}$, $A_{st\ min\ base}$)	585	mm^2/m	Tension reinforcement ($A_{st\ base}$) = Max($A_{st\ req\ base}$, $A_{st\ min\ base}$)	621	mm^2/m
Provided tension reinforcement ($A_{st\ pro\ base}$)	1005	mm^2/m	Provided tension reinforcement ($A_{st\ pro\ base}$)	1571	mm^2/m
1005 > 585 OK			1571 > 621 OK		
Minimum required distribution reinforcement ($A_{s\ min\ dis\ base}$) = $A_{st\ min\ base}$			Minimum required distribution reinforcement ($A_{s\ min\ dis\ base}$) = $A_{st\ min\ base}$		
Provided distribution reinforcement ($A_{s\ pro\ dis\ base}$)	1005	mm^2/m	Provided distribution reinforcement ($A_{s\ pro\ dis\ base}$)	1571	mm^2/m
1005 >= 585 OK			1571 >= 585 OK		
Shear for heel at face of wall ($V_{ULS\ heel}$)	0.0	kN/m	Shear for heel at face of wall ($V_{ULS\ heel}$)	0.0	kN/m
Shear for toe at face of wall ($V_{ULS\ toe}$)	101.8	kN/m	Shear for toe at face of wall ($V_{ULS\ toe}$)	167.6	kN/m
Applied shear stress to base ($v_{ULS\ base}$)	0.28	N/mm^2	Applied shear stress to base ($v_{ULS\ base}$)	0.60	N/mm^2
0.28 <= 5.0 OK			0.60 <= 5.0 OK		
$A_{st\ pro\ base} / (d_{base} * 10)$	0.27		$A_{st\ pro\ base} / (d_{base} * 10)$	0.46	

Design concrete shear stress $v_{c\ base}$ from Table 3.8 – BS 8110: 0.50 N/mm^2

0.50 >= 0.28 No shear reinforcement required

Tension reinforcement for each face of stem: **T16 @ 200 mm**
Distribution reinforcement for each face of stem: **T12 @ 200 mm**
Tension reinforcement in top & bottom of base: **T16 @ 200 mm**
Distribution reinforcement in top & bottom of base: **T16 @ 200 mm**
Provide T8 @ 200 mm U-bars for top of stem

Design concrete shear stress $v_{c\ base}$ from Table 3.8 – BS 8110: 0.61 N/mm^2

0.61 >= 0.60 No shear reinforcement required

Reinforcement for each face of stem: **3 No. Layers Mesh A393**

Reinforcement in top & bottom of base: **4 No. Layers Mesh A393**

Provide T10 @ 200 mm U-bars for top of stem

DESIGN OF SLABS IN BASEMENT

Thickness of slab (t_{slab}) :	0.30	m	Span of slab (l_{slab}) :	4.30	m
Diameter of tension bars ($\phi_{t\ slab}$) :	16	mm	C/C of reinforcements ($S_{t\ slab}$) :	200	mm
Diameter of distribution bars ($\phi_{d\ slab}$) :	16	mm	Top cover for reinforcement (c_{slab}) :	25	mm
Diameter of dowel bars (ϕ_{dowel}) :	16	mm	C/C of dowel bars (S_{dowel}) :	200	mm

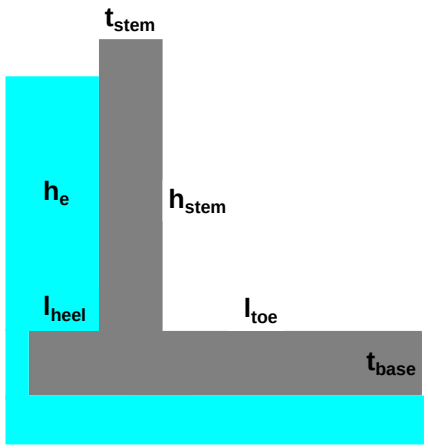
Design slab for heave as worst case loading than water pressure as a simply supported slab connected between base of retaining walls with dowels

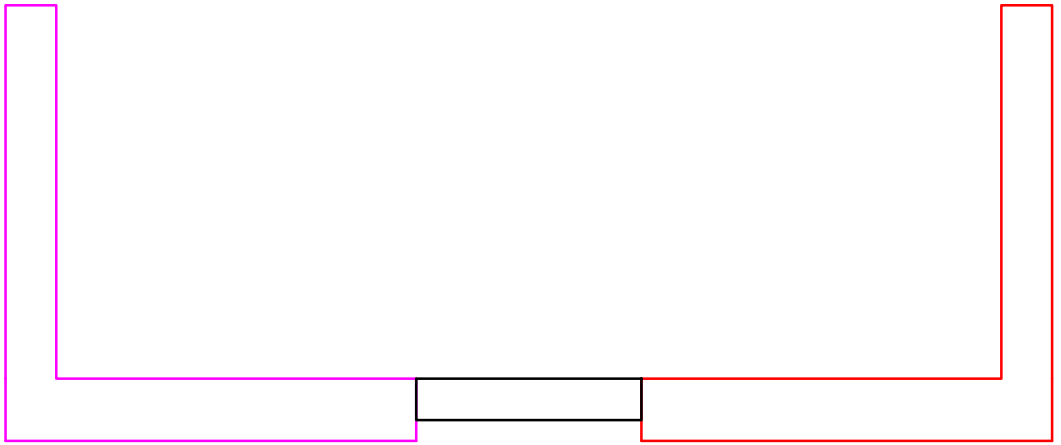
Pressure from heave (P_{heave}) = (h_e * W_e) - (20% * (h_e * W_e))	P_{heave} =	43.8	kN/m^2		
Net uplift pressure (P_{up}) = P_{heave} - (24 * t_{slab}) - (Min ($W_{d\ toe\ left}$, $W_{d\ toe\ right}$))	P_{up} =	36.6	kN/m^2		
Moment by uplift (M_{up}) = (1.5 * P_{up} * l_{slab}^2) / 8	M_{up} =	110.2	kNm/m		
Shear by uplift (V_{up}) = (1.5 * P_{up} * l_{slab}) / 2	V_{up} =	118.0	kN/m		
Depth for tension reinforcement in base (d_{slab})	d_{slab} =	267.0	mm		
K_{slab} = M_{up} / (f_{cu} * 1000 * d_{slab}^2)	K_{slab} =	0.039			
	0.039	<=	0.156	Only tension reinforcement is required	
Lever arm (Z_{slab}) = Min ((d_{slab} * (0.5 + sqrt(0.25 - (K_{slab} / 0.9)))) , (0.95 * d_{slab}))	Z_{slab} =	253.7	mm		
Required tension reinforcement ($A_{st\ req\ slab}$) = M_{up} / (0.87 * f_y * Z_{slab})	$A_{st\ req\ slab}$ =	999	mm^2/m		
Minimum required tension reinforcement ($A_{st\ min\ slab}$) = 0.13 * t_{slab} * 10^4	$A_{st\ min\ slab}$ =	390	mm^2/m		
Tension reinforcement ($A_{st\ slab}$) = Max($A_{st\ req\ slab}$, $A_{st\ min\ slab}$)	$A_{st\ slab}$ =	999	mm^2/m		
Provided tension reinforcement ($A_{st\ pro\ slab}$) = (1000 * π * $\phi_{t\ slab}^2$) / (4 * $S_{t\ slab}$)	$A_{st\ pro\ slab}$ =	1005	mm^2/m		
	1005	>	999	OK	
Minimum required distribution reinforcement ($A_{s\ min\ dis\ slab}$) = $A_{st\ min\ slab}$	$A_{s\ min\ dis\ slab}$ =	390	mm^2/m		
Provided distribution reinforcement ($A_{s\ pro\ dis\ slab}$) = (1000 * π * $\phi_{d\ slab}^2$) / (4 * $S_{t\ slab}$)	$A_{s\ pro\ dis\ slab}$ =	1005	mm^2/m		
	1005	>=	390	OK	
Design service stress ($f_{s\ slab}$) = (2 * f_y * $A_{st\ slab}$ / (3 * $A_{st\ pro\ slab}$)	$f_{s\ slab}$ =	331.2	N/mm^2		
Modification factor for tension = 0.55 + ((477 - $f_{s\ slab}$) / (120 * (0.9 + (M_{up} / (1000 * d_{slab}^2)))))		1.0			
Permissible span to depth ration = Basic span to effective depth ratio * Modification factor for tension * 1		20.9			
Actual span to depth ration = l_{slab} / d_{slab}		16.1			
	20.9	>=	16.1	OK	
Provided reinforcement by dowels ($A_{s\ dowel}$) = (1000 * π * ϕ_{dowel}^2) / (4 * S_{dowel})	$A_{s\ dowel}$ =	1005	mm^2/m		
Shear capacity of dowels ($V_{res\ dowel}$) = (0.6 * f_y * $A_{s\ dowel}$) / 1000	$V_{res\ dowel}$ =	301.6	kN/m		
	301.6	>	118.0	OK	

Tension reinforcement in top & bottom of slab: **T16 @ 200 mm**
Distribution reinforcement in top & bottom of slab: **T16 @ 200 mm**
Connect slab to the base of retaining walls with T16 dowels @ 200 mm

Design of RC Basement walls for Rear Extension Wall to No. 83 and Rear Extension right hand side wall

Page:	7
Job Ref:	MDM406





Left hand side basement wall			Right hand side basement wall		
Position of stem :	Rear extension wall to No. 83		Position of stem :	Rear Extension right hand side wall	
Total height of wall including thickness of base (h) :	3.15	m	Total height of wall including thickness of base (h) :	3.15	m
Thickness of wall (t_{stem}) :	0.45	m	Thickness of wall (t_{stem}) :	0.45	m
Height of soil including thickness of base (h_e) :	3.15	m	Height of soil including thickness of base (h_e) :	3.15	m
Angle of backfill or slope (β) :	0	Degree	Angle of backfill or slope (β) :	0	Degree
Internal angle of friction for retained soil (ϕ) :	20	Degree	Internal angle of friction for retained soil (ϕ) :	20	Degree
Dead surcharge in SLS ($W_{d\,s}$) :	0.0	kN/m^2	Dead surcharge in SLS ($W_{d\,s}$) :	0.0	kN/m^2
Live surcharge in SLS ($W_{l\,s}$) :	1.5	kN/m^2	Live surcharge in SLS ($W_{l\,s}$) :	1.5	kN/m^2
Height of surcharge loads from underneath of base (h_s) :	3.15	m	Height of surcharge loads from underneath of base (h_s) :	3.15	m
Vertical dead load on stem under temporary work in SLS (W_{d2}) :	0.0	kN/m	Vertical dead load on stem under temporary work in SLS (W_{d2}) :	0.0	kN/m
Vertical live load on stem under temporary work in SLS (W_{l2}) :	0.0	kN/m	Vertical live load on stem under temporary work in SLS (W_{l2}) :	0.0	kN/m
Vertical dead load on stem after construction in SLS (W_{d3}) :	14.5	kN/m	Vertical dead load on stem after construction in SLS (W_{d3}) :	13.8	kN/m
Vertical live load on stem after construction in SLS (W_{l3}) :	5.0	kN/m	Vertical live load on stem after construction in SLS (W_{l3}) :	3.6	kN/m
Additional horizontal dead load to stem in SLS ($W_{d\,h}$) :	0.00	kN/m	Additional horizontal dead load to stem in SLS ($W_{d\,h}$) :	0.00	kN/m
Additional horizontal live load to stem in SLS ($W_{l\,h}$) :	0.00	kN/m	Additional horizontal live load to stem in SLS ($W_{l\,h}$) :	0.00	kN/m
Height of horizontal load from underneath of base (h_h) :	0.00	m	Height of horizontal load from underneath of base (h_h) :	0.00	m
Height of ground water from underneath of base (h_w) :	2.00	m	Height of ground water from underneath of base (h_w) :	2.00	m
Depth of base (t_{base}) :	0.45	m	Depth of base (t_{base}) :	0.45	m
Length of toe (l_{toe}) :	1.60	m	Length of toe (l_{toe}) :	1.60	m
Length of heel (l_{heel}) :	0.00	m	Length of heel (l_{heel}) :	0.00	m
Dead load by wall, screed or others on toe in SLS ($W_{d\,toe}$) :	0.00	kN/m^2	Dead load by wall, screed or others on toe in SLS ($W_{d\,toe}$) :	0.00	kN/m^2
Live load on toe in SLS ($W_{l\,toe}$) :	0.00	kN/m^2	Live load on toe in SLS ($W_{l\,toe}$) :	0.00	kN/m^2

General

Density of soil (W_e) :	19.0	kN/m^3	Density of saturated soil (W_{sat}) :	0.0	kN/m^3
Required ratio of resistance against sliding :	1.5		Required ratio of resistance against overturning :	1.5	
Strength of steel (f_y) :	500	N/mm^2	Strength of concrete (f_{cu}) :	40	N/mm^2
Allowable bearing pressure of ground (q) :	200	kN/m^2			

**** The design is based on cantilever retaining walls which considers 1m length. Each wall will be analysed for 3 cases and designed for the worst case ****

Left hand side loading in SLS			Right hand side loading in SLS		
Active pressure coefficient (K_a)	0.49		Active pressure coefficient (K_a)	0.49	
Passive pressure coefficient (K_p)	2.04		Passive pressure coefficient (K_p)	2.04	
Total height of soil behind retaining wall ($h_{e\ wall}$)	3.15	m	Total height of soil behind retaining wall ($h_{e\ wall}$)	3.15	m
Height of stem (h_{stem})	2.70	m	Height of stem (h_{stem})	2.70	m
Total height of soil behind stem ($h_{e\ stem}$)	2.70	m	Total height of soil behind stem ($h_{e\ stem}$)	2.70	m
Self weight of stem (SW_{stem})	29.2	kN/m	Self weight of stem (SW_{stem})	29.2	kN/m
Total additional horizontal load to stem (W_h)	0.0	kN/m	Total additional horizontal load to stem (W_h)	0.0	kN/m
Length of base (l_{base})	2.05	m	Length of base (l_{base})	2.05	m
Self weight of base (SW_{base})	22.1	kN/m	Self weight of base (SW_{base})	22.1	kN/m
Self weight of toe (SW_{toe})	17.3	kN/m	Self weight of toe (SW_{toe})	17.3	kN/m
Total dead load on toe ($W_{d\ toe\ tot}$)	0.0	kN/m	Total dead load on toe ($W_{d\ toe\ tot}$)	0.0	kN/m
Total live load on toe ($W_{l\ toe\ tot}$)	0.0	kN/m	Total live load on toe ($W_{l\ toe\ tot}$)	0.0	kN/m
Total surcharge on heel ($W_{s\ heel}$)	0.0	kN/m	Total surcharge on heel ($W_{s\ heel}$)	0.0	kN/m
Height of saturated soil above base (h_{satl})	1.55	m	Height of saturated soil above base (h_{satl})	1.55	m
Self weight of saturated soil on heel (SW_{sat})	0.0	kN/m	Self weight of saturated soil on heel (SW_{sat})	0.0	kN/m
Self weight of non saturated soil behind stem (SW_e)	0.0	kN/m	Self weight of non saturated soil behind stem (SW_e)	0.0	kN/m

CASE 1: ANALYSIS FOR EXISTING LOADING

Not applicable	Not applicable

Case 2: UNDER TEMPORARY WORK ANALYSIS

(Consider using only the existing vertical dead loads for stability against sliding and overturning without any pressure from ground water)

Left hand side wall			Right hand side wall		
Stability for sliding			**Stability for sliding**		
$\mu = 0.75 * Tan\phi$	0.27		$\mu = 0.75 * Tan\phi$	0.27	
Active force from soil ($P_{a\ e\ 2}$)	46.2	kN/m	Active force from soil ($P_{a\ e\ 2}$)	46.2	kN/m
Active force from surcharge ($P_{a\ s\ 2}$)	2.3	kN/m	Active force from surcharge ($P_{a\ s\ 2}$)	2.3	kN/m
Total sliding force (F_2)	48.5	kN/m	Total sliding force (F_2)	48.5	kN/m
Resistance by friction ($P_{f\ 2}$)	14.0	kN/m	Resistance by friction ($P_{f\ 2}$)	14.0	kN/m
Resistance by passive force ($P_{p\ 2}$)	3.9	kN/m	Resistance by passive force ($P_{p\ 2}$)	3.9	kN/m
Total resistance force ($F_{res\ 2}$)	17.9	kN/m	Sliding resistance force ($F_{res\ 2}$)	17.9	kN/m
Ratio of resistance against sliding = $F_{res\ 2} / F_2$	0.4		Ratio of resistance against sliding = $F_{res\ 2} / F_2$	0.4	
0.4 < 1.5 ** FAILS. Backfill of soil is required **			0.4 < 1.5 ** FAILS. Backfill of soil is required **		
Stability for overturning			**Stability for overturning**		
Soil ($M_{e\ 2}$)	48.5	kNm/m	Soil ($M_{e\ 2}$)	48.5	kNm/m
Surcharge ($M_{s\ 2}$)	3.6	kNm/m	Surcharge ($M_{s\ 2}$)	3.6	kNm/m
Additional horizontal load ($M_{h\ 2}$)	0.0	kNm/m	Additional horizontal load ($M_{h\ 2}$)	0.0	kNm/m
Total overturning moment (M_2)	52.2	kNm/m	Total overturning moment (M_2)	52.2	kNm/m
Resistance by stem & vertical DL ($M_{r\ stem\ 2}$)	53.2	kNm/m	Resistance by stem & vertical DL ($M_{r\ stem\ 2}$)	53.2	kNm/m
Resistance by base ($M_{r\ base\ 2}$)	22.7	kNm/m	Resistance by base ($M_{r\ base\ 2}$)	22.7	kNm/m
Resistance by surcharge on heel ($M_{r\ s\ heel\ 2}$)	0.0	kNm/m	Resistance by surcharge on heel ($M_{r\ s\ heel\ 2}$)	0.0	kNm/m
Total resistance moment ($M_{res\ 2}$)	75.9	kNm/m	Total resistance moment ($M_{res\ 2}$)	75.9	kNm/m
Ratio of resistance against overturning = $M_{res\ 2} / M_2$	1.5		Ratio of resistance against overturning = $M_{res\ 2} / M_2$	1.5	
1.5 <= 1.5 OK			1.5 <= 1.5		
Bearing pressure in SLS			**Bearing pressure in SLS**		
Total vertical load on base ($N_{SLS\ base\ 2}$)	51.3	kN/m	Total vertical load on base ($N_{SLS\ base\ 2}$)	51.3	kN/m

Distance to reaction ($X_{SLS\ 2}$)	0.46	m
Eccentricity of vertical load in SLS ($e_{SLS\ 2}$)	0.56	m
l_{base} / 6 = 0.34 < 0.56 Load resultant lies outside middle third		
Pressure under base (p_{SLS}) :	73.9	kN/m^2
73.9 <= 200 OK		

Moment for stem in ULS

Soil ($M_{e\ ULS\ stem\ 2}$)	53.5	kNm/m
Surcharge ($M_{s\ ULS\ stem\ 2}$)	5.0039058	kNm/m
Additional horizontal loads ($M_{h\ ULS\ stem\ 2}$)	0.0	kNm/m
Total moment for stem ($M_{ULS\ stem\ 2}$)	58.5	kNm/m

Moment for base in ULS

Total vertical load on base ($N_{ULS\ base\ 2}$)	71.8	kN/m
Total moment on base ($M_{ULS\ base\ 2}$)	73.8	kNm/m
Total resistance moment on base ($M_{res\ ULS\ base\ 2}$)	106.3	kNm/m
Distance to reaction ($X_{ULS\ 2}$)	0.45	m
Eccentricity of vertical load in ULS ($e_{ULS\ 2}$)	0.57	m
l_{base} / 6 = 0.34 < 0.57 Load resultant lies outside middle third		
Maximum pressure under base ($p_{max\ ULS\ base\ 2}$)	105.8	kN/m^2
Minimum pressure under base ($p_{min\ ULS\ base\ 2}$)	0.0	kN/m^2
Bearing length of base ($L_{p\ base\ 2}$)	1.36	m
Bearing length of heel ($L_{p\ heel\ 2}$)	-0.69	m
Pressure under heel/stem interface ($p_{ULS\ heel\ 2}$)	0.0	kN/m^2
Pressure under toe/stem interface ($p_{ULS\ toe\ 2}$)	-18.9	kN/m^2
Total vertical load on heel ($N_{ULS\ heel\ 2}$)	0.0	kN/m^2
Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 2}$)	0.0	kNm/m
Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 2}$)	0.0	kNm/m
Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 2}$)	0.0	kNm/m
Moment for toe at wall centre ($M_{ULS\ toe\ 2}$)	73.1	kNm/m
Max net moment for base at face of wall ($M_{ULS\ base\ net\ 2}$)	73.1	kNm/m

Distance to reaction ($X_{SLS\ 2}$)	0.46	m
Eccentricity of vertical load in SLS ($e_{SLS\ 2}$)	0.56	m
l_{base} / 6 = 0.34 < 0.56 Load resultant lies outside middle third		
Pressure under base (p_{SLS}) :	73.9	kN/m^2
73.9 <= 200 OK		

Moment for stem in ULS

Soil ($M_{e\ ULS\ stem\ 2}$)	53.5	kNm/m
Surcharge ($M_{s\ ULS\ stem\ 2}$)	5.0039058	kNm/m
Additional horizontal loads ($M_{h\ ULS\ stem\ 2}$)	0.0	kNm/m
Total moment for stem ($M_{ULS\ stem\ 2}$)	58.5	kNm/m

Moment for base in ULS

Total vertical load on base ($N_{ULS\ base\ 2}$)	71.8	kN/m
Total moment on base ($M_{ULS\ base\ 2}$)	73.8	kNm/m
Total resistance moment on base ($M_{res\ ULS\ base\ 2}$)	106.3	kNm/m
Distance to reaction ($X_{ULS\ 2}$)	0.45	m
Eccentricity of vertical load in ULS ($e_{ULS\ 2}$)	0.57	m
l_{base} / 6 = 0.34 < 0.57 Load resultant lies outside middle third		
Maximum pressure under base ($p_{max\ ULS\ base\ 2}$)	105.8	kN/m^2
Minimum pressure under base ($p_{min\ ULS\ base\ 2}$)	0.0	kN/m^2
Bearing length of base ($L_{p\ base\ 2}$)	1.36	m
Bearing length of heel ($L_{p\ heel\ 2}$)	-0.69	m
Pressure under heel/stem interface ($p_{ULS\ heel\ 2}$)	0.0	kN/m^2
Pressure under toe/stem interface ($p_{ULS\ toe\ 2}$)	-18.9	kN/m^2
Total vertical load on heel ($N_{ULS\ heel\ 2}$)	0.0	kN/m^2
Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 2}$)	0.0	kNm/m
Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 2}$)	0.0	kNm/m
Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 2}$)	0.0	kNm/m
Moment for toe at wall centre ($M_{ULS\ toe\ 2}$)	73.1	kNm/m
Max net moment for base at face of wall ($M_{ULS\ base\ net\ 2}$)	73.1	kNm/m

CASE 3: AFTER CONSTRUCTION ANALYSIS

(Consider using all loads but no check for stability against sliding is required)

Left hand side wall

Stability for overturning

Surcharge ($M_{s\ 3}$)	3.6	kNm/m
Additional horizontal load ($M_{h\ 3}$)	0.0	kNm/m
Moist backfill above water table ($M_{mbaw\ 3}$)	14.7	kNm/m
Moist backfill below water table ($M_{mbbw\ 3}$)	21.4	kNm/m
Saturated backfill ($M_{sb\ 3}$)	-6.4	kNm/m
Water ($M_{w\ 3}$)	13.1	kNm/m
Total overturning moment (M_3)	46.4	kNm/m
Resistance by stem & vertical loads ($M_{r\ stem\ 3}$)	88.8	kNm/m
Resistance by base ($M_{r\ base\ 3}$)	22.7	kNm/m
Resistance by loads on toe ($M_{r\ toe\ 3}$)	0.0	kNm/m
Resistance by surcharge on heel ($M_{r\ s\ heel\ 3}$)	0.0	kNm/m
Resistance by moist backfill ($M_{r\ mb\ 3}$)	0.0	kNm/m
Resistance by saturated backfill ($M_{r\ sb\ 3}$)	0.0	kNm/m
Total resistance moment ($M_{res\ 3}$)	111.5	kNm/m

Right hand side wall

Stability for overturning

Surcharge ($M_{s\ 3}$)	3.6	kNm/m
Additional horizontal load ($M_{h\ 3}$)	0.0	kNm/m
Moist backfill above water table ($M_{mbaw\ 3}$)	14.7	kNm/m
Moist backfill below water table ($M_{mbbw\ 3}$)	21.4	kNm/m
Saturated backfill ($M_{sb\ 3}$)	-6.4	kNm/m
Water ($M_{w\ 3}$)	13.1	kNm/m
Total overturning moment (M_3)	46.4	kNm/m
Resistance by stem & vertical loads ($M_{r\ stem\ 3}$)	85.0	kNm/m
Resistance by base ($M_{r\ base\ 3}$)	22.7	kNm/m
Resistance by loads on toe ($M_{r\ toe\ 3}$)	0.0	kNm/m
Resistance by surcharge on heel ($M_{r\ s\ heel\ 3}$)	0.0	kNm/m
Resistance by moist backfill ($M_{r\ mb\ 3}$)	0.0	kNm/m
Resistance by saturated backfill ($M_{r\ sb\ 3}$)	0.0	kNm/m
Total resistance moment ($M_{res\ 3}$)	107.7	kNm/m

Ratio of resistance against overturning = $M_{res\ 3}$ / M_3			2.4		Ratio of resistance against overturning = $M_{res\ 3}$ / M_3		2.3	
2.4	>=	1.5	OK		2.3	>=	1.5	OK
Bearing pressure in SLS					**Bearing pressure in SLS**			
Total vertical load on base ($N_{SLS\ base\ 3}$)			70.8	kN/m	Total vertical load on base ($N_{SLS\ base\ 3}$)		68.7	kN/m
Distance to reaction ($X_{SLS\ 3}$)			0.92	m	Distance to reaction ($X_{SLS\ 3}$)		0.89	m
Eccentricity of vertical load in SLS ($e_{SLS\ 3}$)			0.11	m	Eccentricity of vertical load in SLS ($e_{SLS\ 3}$)		0.13	m
l_{base} / 6 =	0.34	>=	0.11	Load resultant lies inside middle third	l_{base} / 6 =	0.34	>=	0.13	Load resultant lies inside middle third
Pressure under base (p_{SLS}) :			45.2	kN/m^2	Pressure under base (p_{SLS}) :		46.6	kN/m^2
45.2	<=	200	OK		46.6	<=	200	OK
Moment for stem in ULS					**Moment for stem in ULS**			
Surcharge ($M_{s\ ULS\ stem\ 3}$)			5.0039058	kNm/m	Surcharge ($M_{s\ ULS\ stem\ 3}$)		5.0039058	kNm/m
Additional horizontal loads ($M_{h\ ULS\ stem\ 3}$)			0.0	kNm/m	Additional horizontal loads ($M_{h\ ULS\ stem\ 3}$)		0	kNm/m
Moist backfill above water table ($M_{mbaw\ ULS\ stem\ 3}$)			18.6	kNm/m	Moist backfill above water table ($M_{mbaw\ ULS\ stem\ 3}$)		18.6	kNm/m
Moist backfill below water table ($M_{mbbw\ ULS\ stem\ 3}$)			18.0	kNm/m	Moist backfill below water table ($M_{mbbw\ ULS\ stem\ 3}$)		18.0	kNm/m
Saturated backfill ($M_{sb\ ULS\ stem\ 3}$)			-4.2	kNm/m	Saturated backfill ($M_{sb\ ULS\ stem\ 3}$)		-4.2	kNm/m
Water ($M_{w\ ULS\ stem\ 3}$)			8.5	kNm/m	Water ($M_{w\ ULS\ stem\ 3}$)		8.5	kNm/m
Total moment for stem ($M_{ULS\ stem\ 3}$)			46.0	kNm/m	Total moment for stem ($M_{ULS\ stem\ 3}$)		46.0	kNm/m
Moment for base in ULS					**Moment for base in ULS**			
Total vertical load on base ($N_{ULS\ base\ 3}$)			100.1	kN/m	Total vertical load on base ($N_{ULS\ base\ 3}$)		96.9	kN/m
Total moment on base ($M_{ULS\ base\ 3}$)			65.7	kNm/m	Total moment on base ($M_{ULS\ base\ 3}$)		65.7	kNm/m
Total resistance moment on base ($M_{res\ ULS\ base\ 3}$)			157.9	kNm/m	Total resistance moment on base ($M_{res\ ULS\ base\ 3}$)		152.0	kNm/m
Distance to reaction ($X_{ULS\ 3}$)			0.92	m	Distance to reaction ($X_{ULS\ 3}$)		0.89	m
Eccentricity of vertical load in ULS ($e_{ULS\ 3}$)			0.10	m	Eccentricity of vertical load in ULS ($e_{ULS\ 3}$)		0.13	
l_{base} / 6 =	0.34	<	0.92	Load resultant lies outside middle third	l_{base} / 6 =	0.34	<	0.89	Load resultant lies outside middle third
Maximum pressure under base ($p_{max\ ULS\ base\ 3}$)			72.5	kN/m^2	Maximum pressure under base ($p_{max\ ULS\ base\ 3}$)		72.5	kN/m^2
Minimum pressure under base ($p_{min\ ULS\ base\ 3}$)			0.0	kN/m^2	Minimum pressure under base ($p_{min\ ULS\ base\ 3}$)		0.0	kN/m^2
Bearing length of base ($L_{p\ base\ 3}$)			2.05	m	Bearing length of base ($L_{p\ base\ 3}$)		2.05	m
Bearing length of heel ($L_{p\ heel\ 3}$)			0.00	m	Bearing length of heel ($L_{p\ heel\ 3}$)		0.00	m
Pressure under heel/stem interface ($p_{ULS\ heel\ 3}$)			0.0	kN/m^2	Pressure under heel/stem interface ($p_{ULS\ heel\ 3}$)		0.0	kN/m^2
Pressure under toe/stem interface ($p_{ULS\ toe\ 3}$)			15.9	kN/m^2	Pressure under toe/stem interface ($p_{ULS\ toe\ 3}$)		15.9	kN/m^2
Total vertical load on heel ($N_{ULS\ heel\ 3}$)			0.0	kN/m^2	Total vertical load on heel ($N_{ULS\ heel\ 3}$)		0.0	kN/m^2
Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 3}$)			0.0	kNm/m	Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 3}$)		0.0	kNm/m
Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 3}$)			0.0	kNm/m	Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 3}$)		0.0	kNm/m
Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 3}$)			0.0	kNm/m	Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 3}$)		0.0	kNm/m
Moment for toe at wall centre ($M_{ULS\ toe\ 3}$)			59.7	kNm/m	Moment for toe at wall centre ($M_{ULS\ toe\ 3}$)		59.8	kNm/m
Max net moment for base at face of wall ($M_{ULS\ base\ net\ 3}$)			59.7	kNm/m	Max net moment for base at face of wall ($M_{ULS\ base\ net\ 3}$)		59.8	kNm/m

DESIGN OF STEMS

Left hand side stem				Right hand side stem			
Cover for reinforcement (c_w) :		75	mm	Cover for reinforcement (c_w) :		75	mm
Tension bars ($\phi_{t\ w}$) :	3 No. Layers Mesh A393	10	mm	Tension bars ($\phi_{t\ w}$) :	3 No. Layers Mesh A393	10	mm
C/C spacing for tension reinforcement ($S_{t\ wall}$) :		200	mm	C/C spacing for tension reinforcement ($S_{t\ wall}$) :		200	mm
Distribution bars ($\phi_{d\ w}$) :	3 No. Layers Mesh A393	10	mm	Distribution bars ($\phi_{d\ w}$) :	3 No. Layers Mesh A393	10	mm
C/C spacing for distribution reinforcement ($S_{d\ wall}$) :		200	mm	C/C spacing for distribution reinforcement ($S_{d\ wall}$) :		200	mm
Design moment (M_{wall}) = Max ($M_{ULS\ stem\ 2}$, $M_{ULS\ stem\ 3}$)		58.5	kNm/m	Design moment (M_{wall}) = Max ($M_{ULS\ stem\ 2}$, $M_{ULS\ stem\ 3}$)		58.5	kNm/m
Depth for tension reinforcement (d_{wall})		350.0	mm	Depth for tension reinforcement (d_{wall})		350.0	mm

$K_{wall} = M_{wall} / (f_{cu} * 1000 * d_{wall}^2)$				0.012		$K_{wall} = M_{wall} / (f_{cu} * 1000 * d_{wall}^2)$	0.012
0.012	<=	0.156	then only tension reinforcement is required.			0.012 <= 0.156 then only tension reinforcement is required.	
Lever arm (Z_{wall})				332.5	mm	Lever arm (Z_{wall})	332.5 mm
Required tension reinforcement ($A_{st\ req\ wall}$)				404	mm^2/m	Required tension reinforcement ($A_{st\ req\ wall}$)	404 mm^2/m
Minimum required tension reinforcement ($A_{st\ min\ wall}$)				585	mm^2/m	Minimum required tension reinforcement ($A_{st\ min\ wall}$)	585 mm^2/m
Tension reinforcement ($A_{st\ wall}$) = Max ($A_{st\ req\ wall}$, $A_{st\ min\ wall}$)				585	mm^2/m	Tension reinforcement ($A_{st\ wall}$) = Max ($A_{st\ req\ wall}$, $A_{st\ min\ wall}$)	585 mm^2/m
Provided tension reinforcement ($A_{st\ pro\ wall}$)				1178	mm^2/m	Provided tension reinforcement ($A_{st\ pro\ in\ wall}$)	1178 mm^2/m
1178	>	585	OK			1178 > 585 OK	
Minimum required distribution reinforcement ($A_{s\ min\ dis\ wall}$) = $A_{st\ min\ wall}$						Minimum required distribution reinforcement ($A_{s\ min\ dis\ wall}$) = $A_{st\ min\ wall}$	
Provided distribution reinforcement ($A_{s\ pro\ dis\ wall}$)				1178	mm^2/m	Provided distribution reinforcement ($A_{s\ pro\ dis\ wall}$)	1178 mm^2/m
1178	>=	585	OK			1178 >= 585 OK	
Total horizontal force to wall in ULS ($F_{ULS\ wall}$)				49.4	kN/m	Total horizontal force to wall in ULS ($F_{ULS\ wall}$)	49.4 kN/m
Applied shear stress to wall ($v_{ULS\ wall}$)				0.14	N/mm^2	Applied shear stress to wall ($v_{ULS\ wall}$)	0.14 N/mm^2
0.14	<=	5.0	OK			0.14 <= 5.0 OK	
$A_{st\ pro\ in\ wall} / (d_{wall} * 10)$				0.34		$A_{st\ pro\ in\ wall} / (d_{wall} * 10)$	0.34
Design concrete shear stress $\mathbf{v_{c\ wall}}$ from Table 3.8 – BS 8110:				0.57	N/mm^2	Design concrete shear stress $\mathbf{v_{c\ wall}}$ from Table 3.8 – BS 8110:	0.57 N/mm^2
0.57	>=	0.14	No shear reinforcement required.			0.57 >= 0.14 No shear reinforcement required.	
Design service stress ($f_{s\ wall}$)				165.5	N/mm^2	Design service stress ($f_{s\ wall}$)	165.5 N/mm^2
Modification factor for tension				2.0		Modification factor for tension	2.0
Permissible span to depth ration				14.0		Permissible span to depth ration	14.0
Actual span to depth ration = h_{stem} / d_{wall}				7.7		Actual span to depth ration = h_{stem} / d_{wall}	7.7
14.0	>=	7.7	OK			14.0 >= 7.7 OK	

DESIGN OF BASES

Left hand side base				Right hand side base			
Cover for reinforcement (c_b) :		75	mm	Cover for reinforcement (c_b) :		75	mm
Tension bars ($\phi_{t\ b}$) :	4 No. Layers Mesh A393	10	mm	Tension bars ($\phi_{t\ b}$) :	4 No. Layers Mesh A393	10	mm
C/C spacing for tension reinforcement ($S_{t\ base}$) :		200	mm	C/C spacing for tension reinforcement ($S_{t\ base}$) :		200	mm
Distribution bars ($\phi_{d\ b}$) :	4 No. Layers Mesh A393	10	mm	Distribution bars ($\phi_{d\ b}$) :	4 No. Layers Mesh A393	10	mm
C/C spacing for distribution reinforcement ($S_{d\ base}$) :		200	mm	C/C spacing for distribution reinforcement ($S_{d\ base}$) :		200	mm
Moment for base ($M_{ULS\ base\ net}$) = Max ($M_{ULS\ base\ net\ 2}$, $M_{ULS\ base\ net\ 3}$)		73.1	kNm/m	Moment for base ($M_{ULS\ base\ net}$) = Max ($M_{ULS\ base\ net\ 2}$, $M_{ULS\ base\ net\ 3}$)		73.1	kNm/m
Depth for tension reinforcement in base (d_{base})		340.0	mm	Depth for tension reinforcement in base (d_{base})		340.0	mm
$K_{base} = M_{ULS\ base\ net} / (f_{cu} * 1000 * d_{base}^2)$		0.016		$K_{base} = M_{ULS\ base\ net} / (f_{cu} * 1000 * d_{base}^2)$		0.016	
0.016 <= 0.156	then only tension reinforcement is required.			0.016 <= 0.156	then only tension reinforcement is required.		
Lever arm (Z_{base})		323.0	mm	Lever arm (Z_{base})		323.0	mm
Required tension reinforcement ($A_{st\ req\ base}$)		520	mm^2/m	Required tension reinforcement ($A_{st\ req\ base}$)		520	mm^2/m
Minimum required tension reinforcement ($A_{st\ min\ base}$)		585	mm^2/m	Minimum required tension reinforcement ($A_{st\ min\ base}$)		585	mm^2/m
Tension reinforcement ($A_{st\ base}$) = Max($A_{st\ req\ base}$, $A_{st\ min\ base}$)		585	mm^2/m	Tension reinforcement ($A_{st\ base}$) = Max($A_{st\ req\ base}$, $A_{st\ min\ base}$)		585	mm^2/m
Provided tension reinforcement ($A_{st\ pro\ base}$)		1571	mm^2/m	Provided tension reinforcement ($A_{st\ pro\ base}$)		1571	mm^2/m
1571 > 585	OK			1571 > 585	OK		
Minimum required distribution reinforcement ($A_{s\ min\ dis\ base}$) = $A_{st\ min\ base}$				Minimum required distribution reinforcement ($A_{s\ min\ dis\ base}$) = $A_{st\ min\ base}$			
Provided distribution reinforcement ($A_{s\ pro\ dis\ base}$)		1571	mm^2/m	Provided distribution reinforcement ($A_{s\ pro\ dis\ base}$)		1571	mm^2/m
1571 >= 585	OK			1571 >= 585	OK		
Shear for heel at face of wall ($V_{ULS\ heel}$)		0.0	kN/m	Shear for heel at face of wall ($V_{ULS\ heel}$)		0.0	kN/m
Shear for toe at face of wall ($V_{ULS\ toe}$)		75.9	kN/m	Shear for toe at face of wall ($V_{ULS\ toe}$)		72.7	kN/m
Applied shear stress to base ($v_{ULS\ base}$)		0.22	N/mm^2	Applied shear stress to base ($v_{ULS\ base}$)		0.21	N/mm^2
0.22 <= 5.0	OK			0.21 <= 5.0	OK		
$A_{st\ pro\ base} / (d_{base} * 10)$		0.46		$A_{st\ pro\ base} / (d_{base} * 10)$		0.46	

Design concrete shear stress $v_{c\ base}$ from Table 3.8 – BS 8110: 0.50 N/mm^2

0.50 >= 0.22 No shear reinforcement required

Tension reinforcement for each face of stem: **3 No. Layers Mesh A393**

Tension reinforcement in top & bottom of base: **4 No. Layers Mesh A393**

Provide T10 @ 200 mm U-bars for top of stem

Design concrete shear stress $v_{c\ base}$ from Table 3.8 – BS 8110: 0.61 N/mm^2

0.61 >= 0.21 No shear reinforcement required

Reinforcement for each face of stem: **3 No. Layers Mesh A393**

Reinforcement in top & bottom of base: **4 No. Layers Mesh A393**

Provide T10 @ 200 mm U-bars for top of stem

DESIGN OF SLABS IN BASEMENT

Thickness of slab (t_{slab}) :	0.30	m	Span of slab (l_{slab}) :	3.90	m
Diameter of tension bars ($\phi_{t\ slab}$) :	16	mm	C/C of reinforcements ($S_{t\ slab}$) :	200	mm
Diameter of distribution bars ($\phi_{d\ slab}$) :	16	mm	Top cover for reinforcement (c_{slab}) :	25	mm
Diameter of dowel bars (ϕ_{dowel}) :	16	mm	C/C of dowel bars (S_{dowel}) :	200	mm

Design slab for heave as worst case loading than water pressure as a simply supported slab connected between base of retaining walls with dowels

Pressure from heave (P_{heave}) = (h_e * W_e) - (20% * (h_e * W_e))	P_{heave} =	47.9	kN/m^2	
Net uplift pressure (P_{up}) = P_{heave} - (24 * t_{slab}) - (Min ($W_{d\ toe\ left}$, $W_{d\ toe\ right}$))	P_{up} =	40.7	kN/m^2	
Moment by uplift (M_{up}) = (1.5 * P_{up} * l_{slab}^2) / 8	M_{up} =	105.3	kNm/m	
Shear by uplift (V_{up}) = (1.5 * P_{up} * l_{slab}) / 2	V_{up} =	119.0	kN/m	
Depth for tension reinforcement in base (d_{slab})	d_{slab} =	267.0	mm	
K_{slab} = M_{up} / (f_{cu} * 1000 * d_{slab}^2)	K_{slab} =	0.037		
	0.037	<=	0.156	Only tension reinforcement is required
Lever arm (Z_{slab}) = Min ((d_{slab} * (0.5 + sqrt(0.25 - (K_{slab} / 0.9)))) , (0.95 * d_{slab}))	Z_{slab} =	253.7	mm	
Required tension reinforcement ($A_{st\ req\ slab}$) = M_{up} / (0.87 * f_y * Z_{slab})	$A_{st\ req\ slab}$ =	954	mm^2/m	
Minimum required tension reinforcement ($A_{st\ min\ slab}$) = 0.13 * t_{slab} * 10^4	$A_{st\ min\ slab}$ =	390	mm^2/m	
Tension reinforcement ($A_{st\ slab}$) = Max($A_{st\ req\ slab}$, $A_{st\ min\ slab}$)	$A_{st\ slab}$ =	954	mm^2/m	
Provided tension reinforcement ($A_{st\ pro\ slab}$) = (1000 * π * $\phi_{t\ slab}^2$) / (4 * $S_{t\ slab}$)	$A_{st\ pro\ slab}$ =	1005	mm^2/m	
	1005	>	954	OK
Minimum required distribution reinforcement ($A_{s\ min\ dis\ slab}$) = $A_{st\ min\ slab}$	$A_{s\ min\ dis\ slab}$ =	390	mm^2/m	
Provided distribution reinforcement ($A_{s\ pro\ dis\ slab}$) = (1000 * π * $\phi_{d\ slab}^2$) / (4 * $S_{t\ slab}$)	$A_{s\ pro\ dis\ slab}$ =	1005	mm^2/m	
	1005	>=	390	OK
Design service stress ($f_{s\ slab}$) = (2 * f_y * $A_{st\ slab}$ / (3 * $A_{st\ pro\ slab}$)	$f_{s\ slab}$ =	316.4	N/mm^2	
Modification factor for tension = 0.55 + ((477 - $f_{s\ slab}$) / (120 * (0.9 + (M_{up} / (1000 * d_{slab}^2)))))		1.1		
Permissible span to depth ration = Basic span to effective depth ratio * Modification factor for tension * 1		22.3		
Actual span to depth ration = l_{slab} / d_{slab}		14.6		
	22.3	>=	14.6	OK
Provided reinforcement by dowels ($A_{s\ dowel}$) = (1000 * π * ϕ_{dowel}^2) / (4 * S_{dowel})	$A_{s\ dowel}$ =	1005	mm^2/m	
Shear capacity of dowels ($V_{res\ dowel}$) = (0.6 * f_y * $A_{s\ dowel}$) / 1000	$V_{res\ dowel}$ =	301.6	kN/m	
	301.6	>	119.0	OK

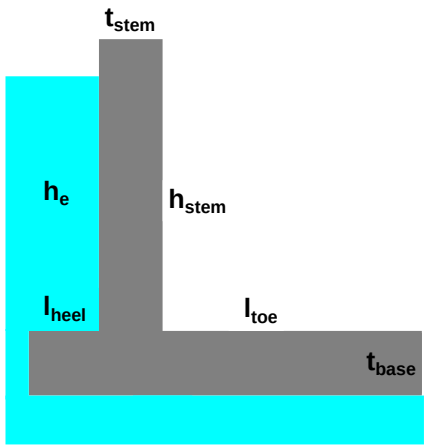
Tension reinforcement in top & bottom of slab: **T16 @ 200 mm**

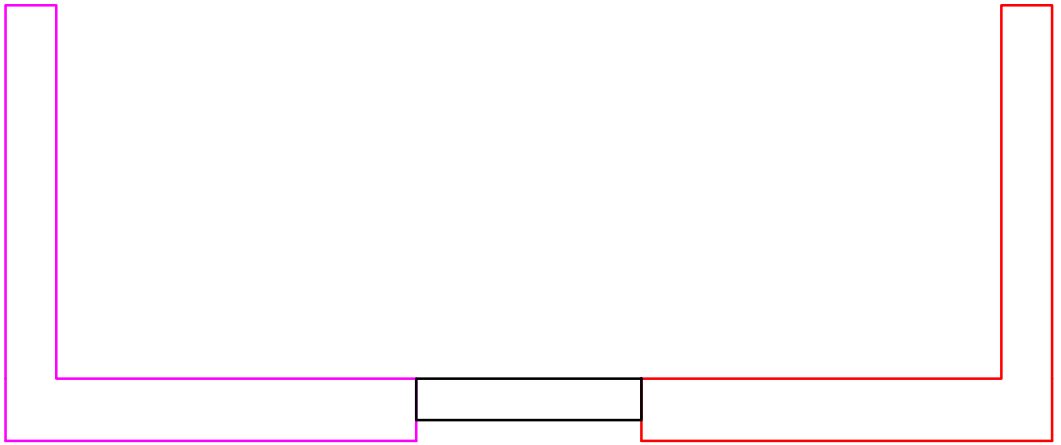
Distribution reinforcement in top & bottom of slab: **T16 @ 200 mm**

Connect slab to the base of retaining walls with T16 dowels @ 200 mm

Design of RC Basement walls for Rear Extension Wall to No. 83 and Rear Extension right hand side wall

Page:	13
Job Ref:	MDM406





Left hand side basement wall			Right hand side basement wall		
Position of stem :	Rear extension wall to No. 83		Position of stem :	Rear Extension right hand side wall	
Total height of wall including thickness of base (h) :	3.15	m	Total height of wall including thickness of base (h) :	3.15	m
Thickness of wall (t_{stem}) :	0.45	m	Thickness of wall (t_{stem}) :	0.45	m
Height of soil including thickness of base (h_e) :	3.15	m	Height of soil including thickness of base (h_e) :	3.15	m
Angle of backfill or slope (β) :	0	Degree	Angle of backfill or slope (β) :	0	Degree
Internal angle of friction for retained soil (ϕ) :	20	Degree	Internal angle of friction for retained soil (ϕ) :	20	Degree
Dead surcharge in SLS ($W_{d\,s}$) :	0.0	kN/m^2	Dead surcharge in SLS ($W_{d\,s}$) :	0.0	kN/m^2
Live surcharge in SLS ($W_{l\,s}$) :	1.5	kN/m^2	Live surcharge in SLS ($W_{l\,s}$) :	1.5	kN/m^2
Height of surcharge loads from underneath of base (h_s) :	3.15	m	Height of surcharge loads from underneath of base (h_s) :	3.15	m
Vertical dead load on stem under temporary work in SLS (W_{d2}) :	0.0	kN/m	Vertical dead load on stem under temporary work in SLS (W_{d2}) :	0.0	kN/m
Vertical live load on stem under temporary work in SLS (W_{l2}) :	0.0	kN/m	Vertical live load on stem under temporary work in SLS (W_{l2}) :	0.0	kN/m
Vertical dead load on stem after construction in SLS (W_{d3}) :	14.5	kN/m	Vertical dead load on stem after construction in SLS (W_{d3}) :	13.8	kN/m
Vertical live load on stem after construction in SLS (W_{l3}) :	5.0	kN/m	Vertical live load on stem after construction in SLS (W_{l3}) :	3.6	kN/m
Additional horizontal dead load to stem in SLS ($W_{d\,h}$) :	0.00	kN/m	Additional horizontal dead load to stem in SLS ($W_{d\,h}$) :	0.00	kN/m
Additional horizontal live load to stem in SLS ($W_{l\,h}$) :	0.00	kN/m	Additional horizontal live load to stem in SLS ($W_{l\,h}$) :	0.00	kN/m
Height of horizontal load from underneath of base (h_h) :	0.00	m	Height of horizontal load from underneath of base (h_h) :	0.00	m
Height of ground water from underneath of base (h_w) :	2.00	m	Height of ground water from underneath of base (h_w) :	2.00	m
Depth of base (t_{base}) :	0.45	m	Depth of base (t_{base}) :	0.45	m
Length of toe (l_{toe}) :	1.60	m	Length of toe (l_{toe}) :	1.60	m
Length of heel (l_{heel}) :	0.00	m	Length of heel (l_{heel}) :	0.00	m
Dead load by wall, screed or others on toe in SLS ($W_{d\,toe}$) :	0.00	kN/m^2	Dead load by wall, screed or others on toe in SLS ($W_{d\,toe}$) :	0.00	kN/m^2
Live load on toe in SLS ($W_{l\,toe}$) :	0.00	kN/m^2	Live load on toe in SLS ($W_{l\,toe}$) :	0.00	kN/m^2

General

Density of soil (W_e) :	19.0	kN/m^3	Density of saturated soil (W_{sat}) :	0.0	kN/m^3
Required ratio of resistance against sliding :	1.5		Required ratio of resistance against overturning :	1.5	
Strength of steel (f_y) :	500	N/mm^2	Strength of concrete (f_{cu}) :	40	N/mm^2
Allowable bearing pressure of ground (q) :	200	kN/m^2			

**** The design is based on cantilever retaining walls which considers 1m length. Each wall will be analysed for 3 cases and designed for the worst case ****

Left hand side loading in SLS			Right hand side loading in SLS		
Active pressure coefficient (K_a)	0.49		Active pressure coefficient (K_a)	0.49	
Passive pressure coefficient (K_p)	2.04		Passive pressure coefficient (K_p)	2.04	
Total height of soil behind retaining wall ($h_{e\ wall}$)	3.15	m	Total height of soil behind retaining wall ($h_{e\ wall}$)	3.15	m
Height of stem (h_{stem})	2.70	m	Height of stem (h_{stem})	2.70	m
Total height of soil behind stem ($h_{e\ stem}$)	2.70	m	Total height of soil behind stem ($h_{e\ stem}$)	2.70	m
Self weight of stem (SW_{stem})	29.2	kN/m	Self weight of stem (SW_{stem})	29.2	kN/m
Total additional horizontal load to stem (W_h)	0.0	kN/m	Total additional horizontal load to stem (W_h)	0.0	kN/m
Length of base (l_{base})	2.05	m	Length of base (l_{base})	2.05	m
Self weight of base (SW_{base})	22.1	kN/m	Self weight of base (SW_{base})	22.1	kN/m
Self weight of toe (SW_{toe})	17.3	kN/m	Self weight of toe (SW_{toe})	17.3	kN/m
Total dead load on toe ($W_{d\ toe\ tot}$)	0.0	kN/m	Total dead load on toe ($W_{d\ toe\ tot}$)	0.0	kN/m
Total live load on toe ($W_{l\ toe\ tot}$)	0.0	kN/m	Total live load on toe ($W_{l\ toe\ tot}$)	0.0	kN/m
Total surcharge on heel ($W_{s\ heel}$)	0.0	kN/m	Total surcharge on heel ($W_{s\ heel}$)	0.0	kN/m
Height of saturated soil above base (h_{satl})	1.55	m	Height of saturated soil above base (h_{satl})	1.55	m
Self weight of saturated soil on heel (SW_{sat})	0.0	kN/m	Self weight of saturated soil on heel (SW_{sat})	0.0	kN/m
Self weight of non saturated soil behind stem (SW_e)	0.0	kN/m	Self weight of non saturated soil behind stem (SW_e)	0.0	kN/m

CASE 1: ANALYSIS FOR EXISTING LOADING

Not applicable	Not applicable

Case 2: UNDER TEMPORARY WORK ANALYSIS

(Consider using only the existing vertical dead loads for stability against sliding and overturning without any pressure from ground water)

Left hand side wall			Right hand side wall		
Stability for sliding			**Stability for sliding**		
$\mu = 0.75 * Tan\phi$	0.27		$\mu = 0.75 * Tan\phi$	0.27	
Active force from soil ($P_{a\ e\ 2}$)	46.2	kN/m	Active force from soil ($P_{a\ e\ 2}$)	46.2	kN/m
Active force from surcharge ($P_{a\ s\ 2}$)	2.3	kN/m	Active force from surcharge ($P_{a\ s\ 2}$)	2.3	kN/m
Total sliding force (F_2)	48.5	kN/m	Total sliding force (F_2)	48.5	kN/m
Resistance by friction ($P_{f\ 2}$)	14.0	kN/m	Resistance by friction ($P_{f\ 2}$)	14.0	kN/m
Resistance by passive force ($P_{p\ 2}$)	3.9	kN/m	Resistance by passive force ($P_{p\ 2}$)	3.9	kN/m
Total resistance force ($F_{res\ 2}$)	17.9	kN/m	Sliding resistance force ($F_{res\ 2}$)	17.9	kN/m
Ratio of resistance against sliding = $F_{res\ 2} / F_2$	0.4		Ratio of resistance against sliding = $F_{res\ 2} / F_2$	0.4	
0.4 < 1.5 ** FAILS. Backfill of soil is required **			0.4 < 1.5 ** FAILS. Backfill of soil is required **		
Stability for overturning			**Stability for overturning**		
Soil ($M_{e\ 2}$)	48.5	kNm/m	Soil ($M_{e\ 2}$)	48.5	kNm/m
Surcharge ($M_{s\ 2}$)	3.6	kNm/m	Surcharge ($M_{s\ 2}$)	3.6	kNm/m
Additional horizontal load ($M_{h\ 2}$)	0.0	kNm/m	Additional horizontal load ($M_{h\ 2}$)	0.0	kNm/m
Total overturning moment (M_2)	52.2	kNm/m	Total overturning moment (M_2)	52.2	kNm/m
Resistance by stem & vertical DL ($M_{r\ stem\ 2}$)	53.2	kNm/m	Resistance by stem & vertical DL ($M_{r\ stem\ 2}$)	53.2	kNm/m
Resistance by base ($M_{r\ base\ 2}$)	22.7	kNm/m	Resistance by base ($M_{r\ base\ 2}$)	22.7	kNm/m
Resistance by surcharge on heel ($M_{r\ s\ heel\ 2}$)	0.0	kNm/m	Resistance by surcharge on heel ($M_{r\ s\ heel\ 2}$)	0.0	kNm/m
Total resistance moment ($M_{res\ 2}$)	75.9	kNm/m	Total resistance moment ($M_{res\ 2}$)	75.9	kNm/m
Ratio of resistance against overturning = $M_{res\ 2} / M_2$	1.5		Ratio of resistance against overturning = $M_{res\ 2} / M_2$	1.5	
1.5 <= 1.5 OK			1.5 <= 1.5		
Bearing pressure in SLS			**Bearing pressure in SLS**		
Total vertical load on base ($N_{SLS\ base\ 2}$)	51.3	kN/m	Total vertical load on base ($N_{SLS\ base\ 2}$)	51.3	kN/m

Distance to reaction ($X_{SLS\ 2}$)	0.46	m
Eccentricity of vertical load in SLS ($e_{SLS\ 2}$)	0.56	m
l_{base} / 6 = 0.34 < 0.56 Load resultant lies outside middle third		
Pressure under base (p_{SLS}) :	73.9	kN/m^2
73.9 <= 200 OK		

Moment for stem in ULS

Soil ($M_{e\ ULS\ stem\ 2}$)	53.5	kNm/m
Surcharge ($M_{s\ ULS\ stem\ 2}$)	5.0039058	kNm/m
Additional horizontal loads ($M_{h\ ULS\ stem\ 2}$)	0.0	kNm/m
Total moment for stem ($M_{ULS\ stem\ 2}$)	58.5	kNm/m

Moment for base in ULS

Total vertical load on base ($N_{ULS\ base\ 2}$)	71.8	kN/m
Total moment on base ($M_{ULS\ base\ 2}$)	73.8	kNm/m
Total resistance moment on base ($M_{res\ ULS\ base\ 2}$)	106.3	kNm/m
Distance to reaction ($X_{ULS\ 2}$)	0.45	m
Eccentricity of vertical load in ULS ($e_{ULS\ 2}$)	0.57	m
l_{base} / 6 = 0.34 < 0.57 Load resultant lies outside middle third		
Maximum pressure under base ($p_{max\ ULS\ base\ 2}$)	105.8	kN/m^2
Minimum pressure under base ($p_{min\ ULS\ base\ 2}$)	0.0	kN/m^2
Bearing length of base ($L_{p\ base\ 2}$)	1.36	m
Bearing length of heel ($L_{p\ heel\ 2}$)	-0.69	m
Pressure under heel/stem interface ($p_{ULS\ heel\ 2}$)	0.0	kN/m^2
Pressure under toe/stem interface ($p_{ULS\ toe\ 2}$)	-18.9	kN/m^2
Total vertical load on heel ($N_{ULS\ heel\ 2}$)	0.0	kN/m^2
Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 2}$)	0.0	kNm/m
Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 2}$)	0.0	kNm/m
Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 2}$)	0.0	kNm/m
Moment for toe at wall centre ($M_{ULS\ toe\ 2}$)	73.1	kNm/m
Max net moment for base at face of wall ($M_{ULS\ base\ net\ 2}$)	73.1	kNm/m

Distance to reaction ($X_{SLS\ 2}$)	0.46	m
Eccentricity of vertical load in SLS ($e_{SLS\ 2}$)	0.56	m
l_{base} / 6 = 0.34 < 0.56 Load resultant lies outside middle third		
Pressure under base (p_{SLS}) :	73.9	kN/m^2
73.9 <= 200 OK		

Moment for stem in ULS

Soil ($M_{e\ ULS\ stem\ 2}$)	53.5	kNm/m
Surcharge ($M_{s\ ULS\ stem\ 2}$)	5.0039058	kNm/m
Additional horizontal loads ($M_{h\ ULS\ stem\ 2}$)	0.0	kNm/m
Total moment for stem ($M_{ULS\ stem\ 2}$)	58.5	kNm/m

Moment for base in ULS

Total vertical load on base ($N_{ULS\ base\ 2}$)	71.8	kN/m
Total moment on base ($M_{ULS\ base\ 2}$)	73.8	kNm/m
Total resistance moment on base ($M_{res\ ULS\ base\ 2}$)	106.3	kNm/m
Distance to reaction ($X_{ULS\ 2}$)	0.45	m
Eccentricity of vertical load in ULS ($e_{ULS\ 2}$)	0.57	m
l_{base} / 6 = 0.34 < 0.57 Load resultant lies outside middle third		
Maximum pressure under base ($p_{max\ ULS\ base\ 2}$)	105.8	kN/m^2
Minimum pressure under base ($p_{min\ ULS\ base\ 2}$)	0.0	kN/m^2
Bearing length of base ($L_{p\ base\ 2}$)	1.36	m
Bearing length of heel ($L_{p\ heel\ 2}$)	-0.69	m
Pressure under heel/stem interface ($p_{ULS\ heel\ 2}$)	0.0	kN/m^2
Pressure under toe/stem interface ($p_{ULS\ toe\ 2}$)	-18.9	kN/m^2
Total vertical load on heel ($N_{ULS\ heel\ 2}$)	0.0	kN/m^2
Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 2}$)	0.0	kNm/m
Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 2}$)	0.0	kNm/m
Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 2}$)	0.0	kNm/m
Moment for toe at wall centre ($M_{ULS\ toe\ 2}$)	73.1	kNm/m
Max net moment for base at face of wall ($M_{ULS\ base\ net\ 2}$)	73.1	kNm/m

CASE 3: AFTER CONSTRUCTION ANALYSIS

(Consider using all loads but no check for stability against sliding is required)

Left hand side wall		
Stability for overturning		
Surcharge ($M_{s\ 3}$)	3.6	kNm/m
Additional horizontal load ($M_{h\ 3}$)	0.0	kNm/m
Moist backfill above water table ($M_{mbaw\ 3}$)	14.7	kNm/m
Moist backfill below water table ($M_{mbbw\ 3}$)	21.4	kNm/m
Saturated backfill ($M_{sb\ 3}$)	-6.4	kNm/m
Water ($M_{w\ 3}$)	13.1	kNm/m
Total overturning moment (M_3)	46.4	kNm/m
Resistance by stem & vertical loads ($M_{r\ stem\ 3}$)	88.8	kNm/m
Resistance by base ($M_{r\ base\ 3}$)	22.7	kNm/m
Resistance by loads on toe ($M_{r\ toe\ 3}$)	0.0	kNm/m
Resistance by surcharge on heel ($M_{r\ s\ heel\ 3}$)	0.0	kNm/m
Resistance by moist backfill ($M_{r\ mb\ 3}$)	0.0	kNm/m
Resistance by saturated backfill ($M_{r\ sb\ 3}$)	0.0	kNm/m
Total resistance moment ($M_{res\ 3}$)	111.5	kNm/m

Right hand side wall		
Stability for overturning		
Surcharge ($M_{s\ 3}$)	3.6	kNm/m
Additional horizontal load ($M_{h\ 3}$)	0.0	kNm/m
Moist backfill above water table ($M_{mbaw\ 3}$)	14.7	kNm/m
Moist backfill below water table ($M_{mbbw\ 3}$)	21.4	kNm/m
Saturated backfill ($M_{sb\ 3}$)	-6.4	kNm/m
Water ($M_{w\ 3}$)	13.1	kNm/m
Total overturning moment (M_3)	46.4	kNm/m
Resistance by stem & vertical loads ($M_{r\ stem\ 3}$)	85.0	kNm/m
Resistance by base ($M_{r\ base\ 3}$)	22.7	kNm/m
Resistance by loads on toe ($M_{r\ toe\ 3}$)	0.0	kNm/m
Resistance by surcharge on heel ($M_{r\ s\ heel\ 3}$)	0.0	kNm/m
Resistance by moist backfill ($M_{r\ mb\ 3}$)	0.0	kNm/m
Resistance by saturated backfill ($M_{r\ sb\ 3}$)	0.0	kNm/m
Total resistance moment ($M_{res\ 3}$)	107.7	kNm/m

Ratio of resistance against overturning = $M_{res\ 3}$ / M_3			2.4		Ratio of resistance against overturning = $M_{res\ 3}$ / M_3		2.3	
2.4	>=	1.5	OK		2.3	>=	1.5	OK
Bearing pressure in SLS					**Bearing pressure in SLS**			
Total vertical load on base ($N_{SLS\ base\ 3}$)			70.8	kN/m	Total vertical load on base ($N_{SLS\ base\ 3}$)		68.7	kN/m
Distance to reaction ($X_{SLS\ 3}$)			0.92	m	Distance to reaction ($X_{SLS\ 3}$)		0.89	m
Eccentricity of vertical load in SLS ($e_{SLS\ 3}$)			0.11	m	Eccentricity of vertical load in SLS ($e_{SLS\ 3}$)		0.13	m
l_{base} / 6 =	0.34	>=	0.11	Load resultant lies inside middle third	l_{base} / 6 =	0.34	>=	0.13	Load resultant lies inside middle third
Pressure under base (p_{SLS}) :			45.2	kN/m^2	Pressure under base (p_{SLS}) :		46.6	kN/m^2
45.2	<=	200	OK		46.6	<=	200	OK
Moment for stem in ULS					**Moment for stem in ULS**			
Surcharge ($M_{s\ ULS\ stem\ 3}$)			5.0039058	kNm/m	Surcharge ($M_{s\ ULS\ stem\ 3}$)		5.0039058	kNm/m
Additional horizontal loads ($M_{h\ ULS\ stem\ 3}$)			0.0	kNm/m	Additional horizontal loads ($M_{h\ ULS\ stem\ 3}$)		0	kNm/m
Moist backfill above water table ($M_{mbaw\ ULS\ stem\ 3}$)			18.6	kNm/m	Moist backfill above water table ($M_{mbaw\ ULS\ stem\ 3}$)		18.6	kNm/m
Moist backfill below water table ($M_{mbbw\ ULS\ stem\ 3}$)			18.0	kNm/m	Moist backfill below water table ($M_{mbbw\ ULS\ stem\ 3}$)		18.0	kNm/m
Saturated backfill ($M_{sb\ ULS\ stem\ 3}$)			-4.2	kNm/m	Saturated backfill ($M_{sb\ ULS\ stem\ 3}$)		-4.2	kNm/m
Water ($M_{w\ ULS\ stem\ 3}$)			8.5	kNm/m	Water ($M_{w\ ULS\ stem\ 3}$)		8.5	kNm/m
Total moment for stem ($M_{ULS\ stem\ 3}$)			46.0	kNm/m	Total moment for stem ($M_{ULS\ stem\ 3}$)		46.0	kNm/m
Moment for base in ULS					**Moment for base in ULS**			
Total vertical load on base ($N_{ULS\ base\ 3}$)			100.1	kN/m	Total vertical load on base ($N_{ULS\ base\ 3}$)		96.9	kN/m
Total moment on base ($M_{ULS\ base\ 3}$)			65.7	kNm/m	Total moment on base ($M_{ULS\ base\ 3}$)		65.7	kNm/m
Total resistance moment on base ($M_{res\ ULS\ base\ 3}$)			157.9	kNm/m	Total resistance moment on base ($M_{res\ ULS\ base\ 3}$)		152.0	kNm/m
Distance to reaction ($X_{ULS\ 3}$)			0.92	m	Distance to reaction ($X_{ULS\ 3}$)		0.89	m
Eccentricity of vertical load in ULS ($e_{ULS\ 3}$)			0.10	m	Eccentricity of vertical load in ULS ($e_{ULS\ 3}$)		0.13	
l_{base} / 6 =	0.34	<	0.92	Load resultant lies outside middle third	l_{base} / 6 =	0.34	<	0.89	Load resultant lies outside middle third
Maximum pressure under base ($p_{max\ ULS\ base\ 3}$)			72.5	kN/m^2	Maximum pressure under base ($p_{max\ ULS\ base\ 3}$)		72.5	kN/m^2
Minimum pressure under base ($p_{min\ ULS\ base\ 3}$)			0.0	kN/m^2	Minimum pressure under base ($p_{min\ ULS\ base\ 3}$)		0.0	kN/m^2
Bearing length of base ($L_{p\ base\ 3}$)			2.05	m	Bearing length of base ($L_{p\ base\ 3}$)		2.05	m
Bearing length of heel ($L_{p\ heel\ 3}$)			0.00	m	Bearing length of heel ($L_{p\ heel\ 3}$)		0.00	m
Pressure under heel/stem interface ($p_{ULS\ heel\ 3}$)			0.0	kN/m^2	Pressure under heel/stem interface ($p_{ULS\ heel\ 3}$)		0.0	kN/m^2
Pressure under toe/stem interface ($p_{ULS\ toe\ 3}$)			15.9	kN/m^2	Pressure under toe/stem interface ($p_{ULS\ toe\ 3}$)		15.9	kN/m^2
Total vertical load on heel ($N_{ULS\ heel\ 3}$)			0.0	kN/m^2	Total vertical load on heel ($N_{ULS\ heel\ 3}$)		0.0	kN/m^2
Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 3}$)			0.0	kNm/m	Clockwise moment for heel at wall centre ($M_{ULS\ heel\ pos\ 3}$)		0.0	kNm/m
Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 3}$)			0.0	kNm/m	Anticlock moment for heel at wall centre ($M_{ULS\ heel\ neg\ 3}$)		0.0	kNm/m
Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 3}$)			0.0	kNm/m	Net moment for heel at wall centre ($M_{ULS\ heel\ net\ 3}$)		0.0	kNm/m
Moment for toe at wall centre ($M_{ULS\ toe\ 3}$)			59.7	kNm/m	Moment for toe at wall centre ($M_{ULS\ toe\ 3}$)		59.8	kNm/m
Max net moment for base at face of wall ($M_{ULS\ base\ net\ 3}$)			59.7	kNm/m	Max net moment for base at face of wall ($M_{ULS\ base\ net\ 3}$)		59.8	kNm/m

DESIGN OF STEMS

Left hand side stem				Right hand side stem			
Cover for reinforcement (c_w) :		75	mm	Cover for reinforcement (c_w) :		75	mm
Tension bars ($\phi_{t\ w}$) :	3 No. Layers Mesh A393	10	mm	Tension bars ($\phi_{t\ w}$) :	3 No. Layers Mesh A393	10	mm
C/C spacing for tension reinforcement ($S_{t\ wall}$) :		200	mm	C/C spacing for tension reinforcement ($S_{t\ wall}$) :		200	mm
Distribution bars ($\phi_{d\ w}$) :	3 No. Layers Mesh A393	10	mm	Distribution bars ($\phi_{d\ w}$) :	3 No. Layers Mesh A393	10	mm
C/C spacing for distribution reinforcement ($S_{d\ wall}$) :		200	mm	C/C spacing for distribution reinforcement ($S_{d\ wall}$) :		200	mm
Design moment (M_{wall}) = Max ($M_{ULS\ stem\ 2}$, $M_{ULS\ stem\ 3}$)		58.5	kNm/m	Design moment (M_{wall}) = Max ($M_{ULS\ stem\ 2}$, $M_{ULS\ stem\ 3}$)		58.5	kNm/m
Depth for tension reinforcement (d_{wall})		350.0	mm	Depth for tension reinforcement (d_{wall})		350.0	mm

$K_{wall} = M_{wall} / (f_{cu} * 1000 * d_{wall}^2)$				0.012	
0.012	<=	0.156	then only tension reinforcement is required.		
Lever arm (Z_{wall})				332.5	mm
Required tension reinforcement ($A_{st\ req\ wall}$)				404	mm^2/m
Minimum required tension reinforcement ($A_{st\ min\ wall}$)				585	mm^2/m
Tension reinforcement ($A_{st\ wall}$) = Max ($A_{st\ req\ wall}$, $A_{st\ min\ wall}$)				585	mm^2/m
Provided tension reinforcement ($A_{st\ pro\ wall}$)				1178	mm^2/m
1178	>	585	OK		
Minimum required distribution reinforcement ($A_{s\ min\ dis\ wall}$) = $A_{st\ min\ wall}$					
Provided distribution reinforcement ($A_{s\ pro\ dis\ wall}$)				1178	mm^2/m
1178	>=	585	OK		
Total horizontal force to wall in ULS ($F_{ULS\ wall}$)				49.4	kN/m
Applied shear stress to wall ($v_{ULS\ wall}$)				0.14	N/mm^2
0.14	<=	5.0	OK		
$A_{st\ pro\ in\ wall} / (d_{wall} * 10)$				0.34	
Design concrete shear stress $\mathbf{v_{c\ wall}}$ from Table 3.8 – BS 8110:				0.57	N/mm^2
0.57	>=	0.14	No shear reinforcement required.		
Design service stress ($f_{s\ wall}$)				165.5	N/mm^2
Modification factor for tension				2.0	
Permissible span to depth ration				14.0	
Actual span to depth ration = h_{stem} / d_{wall}				7.7	
14.0	>=	7.7	OK		

$K_{wall} = M_{wall} / (f_{cu} * 1000 * d_{wall}^2)$				0.012	
0.012	<=	0.156	then only tension reinforcement is required.		
Lever arm (Z_{wall})				332.5	mm
Required tension reinforcement ($A_{st\ req\ wall}$)				404	mm^2/m
Minimum required tension reinforcement ($A_{st\ min\ wall}$)				585	mm^2/m
Tension reinforcement ($A_{st\ wall}$) = Max ($A_{st\ req\ wall}$, $A_{st\ min\ wall}$)				585	mm^2/m
Provided tension reinforcement ($A_{st\ pro\ in\ wall}$)				1178	mm^2/m
1178	>	585	OK		
Minimum required distribution reinforcement ($A_{s\ min\ dis\ wall}$) = $A_{st\ min\ wall}$					
Provided distribution reinforcement ($A_{s\ pro\ dis\ wall}$)				1178	mm^2/m
1178	>=	585	OK		
Total horizontal force to wall in ULS ($F_{ULS\ wall}$)				49.4	kN/m
Applied shear stress to wall ($v_{ULS\ wall}$)				0.14	N/mm^2
0.14	<=	5.0	OK		
$A_{st\ pro\ in\ wall} / (d_{wall} * 10)$				0.34	
Design concrete shear stress $\mathbf{v_{c\ wall}}$ from Table 3.8 – BS 8110:				0.57	N/mm^2
0.57	>=	0.14	No shear reinforcement required.		
Design service stress ($f_{s\ wall}$)				165.5	N/mm^2
Modification factor for tension				2.0	
Permissible span to depth ration				14.0	
Actual span to depth ration = h_{stem} / d_{wall}				7.7	
14.0	>=	7.7	OK		

DESIGN OF BASES

Left hand side base				
Cover for reinforcement (c_b) :		75	mm	
Tension bars ($\phi_{t\ b}$) :	4 No. Layers Mesh A393	10	mm	
C/C spacing for tension reinforcement ($S_{t\ base}$) :		200	mm	
Distribution bars ($\phi_{d\ b}$) :	4 No. Layers Mesh A393	10	mm	
C/C spacing for distribution reinforcement ($S_{d\ base}$) :		200	mm	
Moment for base ($M_{ULS\ base\ net}$) = Max ($M_{ULS\ base\ net\ 2}$, $M_{ULS\ base\ net\ 3}$)		73.1	kNm/m	
Depth for tension reinforcement in base (d_{base})		340.0	mm	
$K_{base} = M_{ULS\ base\ net} / (f_{cu} * 1000 * d_{base}^2)$		0.016		
0.016	<= 0.156	then only tension reinforcement is required.		
Lever arm (Z_{base})		323.0	mm	
Required tension reinforcement ($A_{st\ req\ base}$)		520	mm^2/m	
Minimum required tension reinforcement ($A_{st\ min\ base}$)		585	mm^2/m	
Tension reinforcement ($A_{st\ base}$) = Max($A_{st\ req\ base}$, $A_{st\ min\ base}$)		585	mm^2/m	
Provided tension reinforcement ($A_{st\ pro\ base}$)		1571	mm^2/m	
1571	> 585	OK		
Minimum required distribution reinforcement ($A_{s\ min\ dis\ base}$) = $A_{st\ min\ base}$				
Provided distribution reinforcement ($A_{s\ pro\ dis\ base}$)		1571	mm^2/m	
1571	>= 585	OK		
Shear for heel at face of wall ($V_{ULS\ heel}$)		0.0	kN/m	
Shear for toe at face of wall ($V_{ULS\ toe}$)		75.9	kN/m	
Applied shear stress to base ($v_{ULS\ base}$)		0.22	N/mm^2	
0.22	<= 5.0	OK		
$A_{st\ pro\ base} / (d_{base} * 10)$		0.46		

Right hand side base				
Cover for reinforcement (c_b) :		75	mm	
Tension bars ($\phi_{t\ b}$) :	4 No. Layers Mesh A393	10	mm	
C/C spacing for tension reinforcement ($S_{t\ base}$) :		200	mm	
Distribution bars ($\phi_{d\ b}$) :	4 No. Layers Mesh A393	10	mm	
C/C spacing for distribution reinforcement ($S_{d\ base}$) :		200	mm	
Moment for base ($M_{ULS\ base\ net}$) = Max ($M_{ULS\ base\ net\ 2}$, $M_{ULS\ base\ net\ 3}$)		73.1	kNm/m	
Depth for tension reinforcement in base (d_{base})		340.0	mm	
$K_{base} = M_{ULS\ base\ net} / (f_{cu} * 1000 * d_{base}^2)$		0.016		
0.016	<= 0.156	then only tension reinforcement is required.		
Lever arm (Z_{base})		323.0	mm	
Required tension reinforcement ($A_{st\ req\ base}$)		520	mm^2/m	
Minimum required tension reinforcement ($A_{st\ min\ base}$)		585	mm^2/m	
Tension reinforcement ($A_{st\ base}$) = Max($A_{st\ req\ base}$, $A_{st\ min\ base}$)		585	mm^2/m	
Provided tension reinforcement ($A_{st\ pro\ base}$)		1571	mm^2/m	
1571	> 585	OK		
Minimum required distribution reinforcement ($A_{s\ min\ dis\ base}$) = $A_{st\ min\ base}$				
Provided distribution reinforcement ($A_{s\ pro\ dis\ base}$)		1571	mm^2/m	
1571	>= 585	OK		
Shear for heel at face of wall ($V_{ULS\ heel}$)		0.0	kN/m	
Shear for toe at face of wall ($V_{ULS\ toe}$)		72.7	kN/m	
Applied shear stress to base ($v_{ULS\ base}$)		0.21	N/mm^2	
0.21	<= 5.0	OK		
$A_{st\ pro\ base} / (d_{base} * 10)$		0.46		

Design concrete shear stress $v_{c\ base}$ from Table 3.8 – BS 8110: 0.50 N/mm^2

0.50 **>=** 0.22 No shear reinforcement required

Tension reinforcement for each face of stem: **3 No. Layers Mesh A393**

Tension reinforcement in top & bottom of base: **4 No. Layers Mesh A393**

Provide T10 @ 200 mm U-bars for top of stem

Design concrete shear stress $v_{c\ base}$ from Table 3.8 – BS 8110: 0.61 N/mm^2

0.61 **>=** 0.21 No shear reinforcement required

Reinforcement for each face of stem: **3 No. Layers Mesh A393**

Reinforcement in top & bottom of base: **4 No. Layers Mesh A393**

Provide T10 @ 200 mm U-bars for top of stem