General Loadings:

Walls:

215mm Solid Wall: 4.30 kN/m (per metre high)

			Dead Load	Live Load	
Floors:	Timber Floor	Boards, Plywood, Finishes:	0.30 kN/m^2	Domestic	**1.50 kN/m2**
		Timber Joists, Insulation:	0.25 kN/m^2		
		Ceiling, Joists:	0.25 kN/m^2	Attic Storage	**0.50 kN/m2**
		Total:	**0.80 kN/m^2**		
Roof:	Pitched Timber Roof	Tiles, Timber Battens, Felt:	0.55 kN/m^2	Snow Load	**0.60 kN/m2**
		Timber Rafters, Insulation:	0.25 kN/m^2		
		Ceiling, Services:	0.20 kN/m^2		
		Total:	**1.00 kN/m^2**		
	Flat Timber Roof:	Felt, Finishes:	0.20 kN/m^2	Snow Load, Access:	**0.75 kN/m2**
		Timber Joists, Insulation:	0.25 kN/m^2		
		Ceiling, Services:	0.25 kN/m^2		
		Total:	**0.70 kN/m^2**		

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Work Section	Structural Calculations				

LINTEL NUMBER = L1

LENGTH	1,20 m
CLEAR SPAN	1,00 m

LOADING

UDL

	Load Type	Load location		Load value				
Dead Load	Wall	0,00	1,20	1,75 kN/m2 x	4,00 m	7,00 kN/m	1,0	7,00 kN/m
	Gr.Floor	0,00	1,20	0,95 kN/m2 x	4,00 m	3,80 kN/m	1,0	3,80 kN/m
	1st Floor	0,00	1,20	0,95 kN/m2 x	4,00 m	3,80 kN/m	1,0	3,80 kN/m
	Type 4	0,00	1,20	0,00 kN/m2 x	0,00 m	0,00 kN/m	1,0	0,00 kN/m

Imposed Load	Wall	0,00	1,20	0,00 kN/m2 x	4,00 m	0,00 kN/m	1,0	0,00 kN/m
	Gr.Floor	0,00	1,20	1,50 kN/m2 x	4,00 m	6,00 kN/m	1,0	6,00 kN/m
	1st Floor	0,00	1,20	1,50 kN/m2 x	4,00 m	6,00 kN/m	1,0	6,00 kN/m
	Type 4	0,00	1,20	0,00 kN/m2 x	0,00 m	0,00 kN/m	1,0	0,00 kN/m

UDL = 26,60 kN/m

POINT LOADS

Point Load 1 x=	0,00 m	From :		Point Load 2 x=	0,00 m	From :	
Dead Load	0,00 kN	1,4	0,00 kN	Dead Load	0,00 kN	1,4	0,00 kN
Imposed Load	0,00 kN	1,6	0,00 kN	Imposed Load	0,00 kN	1,6	0,00 kN
		P1	0,00 kN			P2	0,00 kN

Total Supported Load = 1,20 m x 26,60 kN/m = 31,92 kN

LINTEL SUMMARY - PROVIDE Hi-Spec Range R6 1200 mm NAYLOR CONCRETE LINTEL SWL = 36,74 kN/m

Hi-Spec Range		P100	S4	R6	R9	R12
Load Table Units suitable for 100mm wide walls Unfactored Loads in kN/m		100 x 70	100 x 110	100 x 145	100 x 215	100 x 290
Fire Resistance Available (mins)		30	30	30	30	30
Suitable for Foundation Use		yes	yes	yes	yes	yes
Maximum Stock Length Available		2400mm	3000mm	3600mm	3600mm	3600mm
					Longer lengths available on request.	
Available Range Finish		Chem	Faced Colour Chem	Faced Colour Chem	Faced Colour Chem	Faced Colour Chem
Length	Clear Span	100x70	100x100	100x140	100x215	100x290
900mm	700mm	17.67	34.27	50.74	78.18	100.05
1100mm	900mm	10.89	23.18	40.47	62.44	79.90
1200mm	1000mm	8.86	19.04	36.74	56.72	72.57
1500mm	1200mm	6.18	13.48	26.19	48.57	60.85
1800mm	1500mm	3.95	8.75	17.14	36.27	49.66
2100mm	1800mm	2.72	6.10	12.04	25.78	41.91
2400mm	2100mm	1.96	4.47	8.89	19.21	31.70
2700mm	2400mm	n/a	3.39	6.80	14.83	24.53
3000mm	2700mm	n/a	2.64	5.34	11.76	19.49
3300mm	3000mm	n/a	n/a	4.29	9.53	15.83
3600mm	3300mm	n/a	n/a	3.75	8.36	13.49
Lintel Weight kg/m		17	26	35	53	69.6

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	Date	Jul' 2023	Eng	PCh
Project Title	28 John Street, London WC1N 2BL			
Work Section	Structural Calculations			

PORTAL FRAME = B1

SPAN	3.70 m	HEIGHT	2.70 m

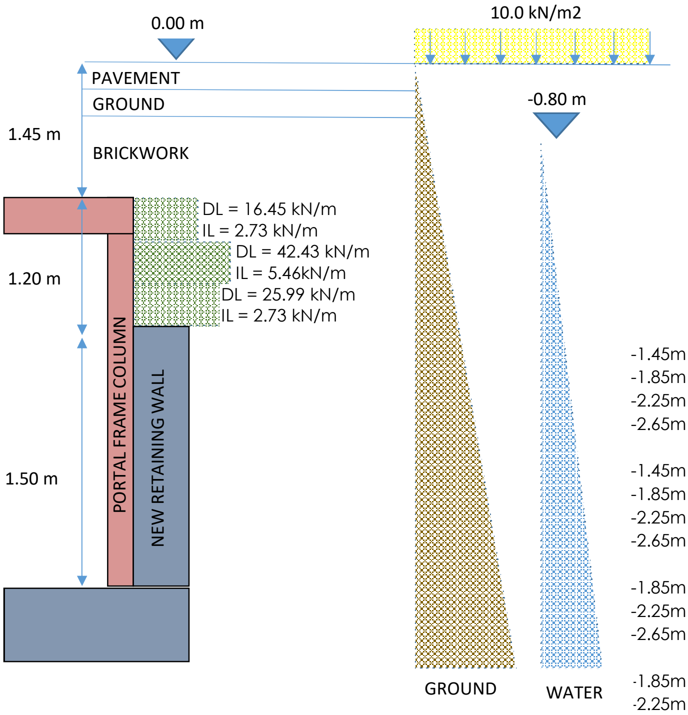
VERTICAL LOADING — LOADING FOR SINGLE FRAME

	Load Type	Load location		Load value			
Dead Load	Pavement	0.00	3.70	24.00 kN/m3	x	1.6m x 0.2 m	7.68 kN/m
	Pavement	0.00	3.70	0.00 kN/m2	x	1.60 m	0.00 kN/m
	Ground	0.00	3.70	18.00 kN/m3	x	1.6m x 0.2 m	5.76 kN/m
	Brickwork	0.00	3.70	24.00 kN/m3	x	0.90 m2	21.60 kN/m
						UDL =	35.04 kN/m

	Load Type	Load location		Load value			
Imposed Load	Pavement	0.00	3.70	0.00 kN/m2	x	0.32 m	0.00 kN/m
	Pavement	0.00	3.70	10.00 kN/m2	x	1.60 m	16.00 kN/m
	Ground	0.00	3.70	0.00 kN/m2	x	0.32 m	0.00 kN/m
	Brickwork	0.00	3.70	0.00 kN/m2	x	0.90 m	0.00 kN/m
						UDL =	16.00 kN/m

HORIZONTAL LOADING

SIDE VIEW



ARRANGEMENT AND MATERIAL DETAILS

Retained Soil Density, γ_m	18.00 kN/m3
Angle of int'l friction of retain mat'l, $\varnothing_b$	26.00 °
Angle of soil surface, β	0.00 °

GROUND CONDITIONS TBC BY SUITABLY QUALIFIED INDIVIDUAL

<u>Loading</u>

Surcharge 10.00 kN/m2

<u>Rankine Coefficient</u>

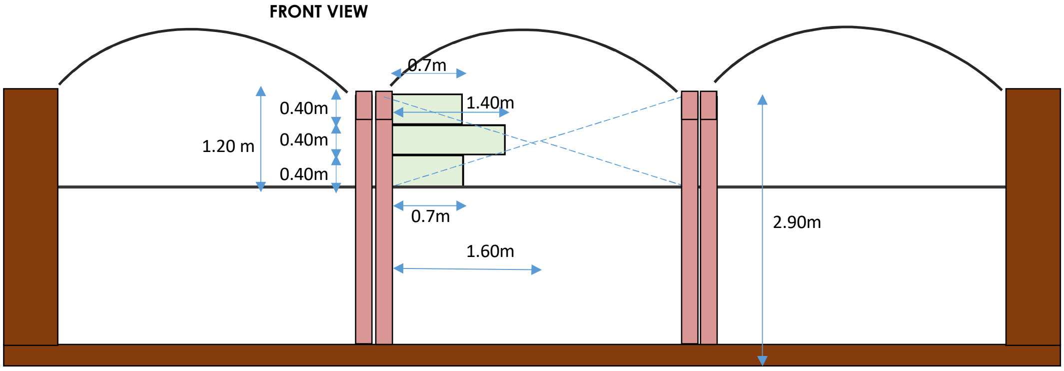
Using active earth pressure coefficient

$k_a = (1 - \sin\varphi) / (1 + \sin\varphi)$ 0.39

<u>Characteristic loading</u>

	Surcharge, A	k_a x q	3.90	kN/m2
-1.45m	Water pressure, W	depth x γ_w	6.50	kN/m2
-1.85m	Water pressure, W	depth x γ_w	10.50	kN/m2
-2.25m	Water pressure, W	depth x γ_w	14.50	kN/m2
-2.65m	Water pressure, W	depth x γ_w	18.50	kN/m2
-1.45m	Backfill, B	k_a x γ_m x depth	10.19	kN/m2
-1.85m	Backfill, B	k_a x γ_m x depth	13.00	kN/m2
-2.25m	Backfill, B	k_a x γ_m x depth	15.81	kN/m2
-2.65m	Backfill, B	k_a x γ_m x depth	18.63	kN/m2
-1.85m	DL	(W + B) x 0.70m	16.45	kN/m
-2.25m	DL	(W + B) x 1.40m	42.43	kN/m
-2.65m	DL	(W + B) x 0.70m	25.99	kN/m
-1.85m	IL	A x 0.70m	2.73	kN/m
-2.25m	IL	A x 1.40m	5.46	kN/m
-2.65m	IL	A x 0.70m	2.73	kN/m

FRONT VIEW



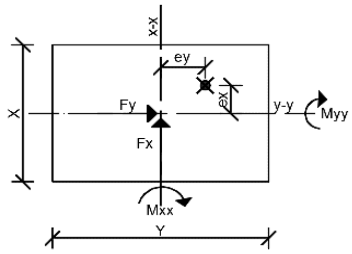
FRAME SUMMARY

COLUMN C1	203x203x52 UC
COLUMN C1	203x203x52 UC
BEAM B1	203x203x60 UC

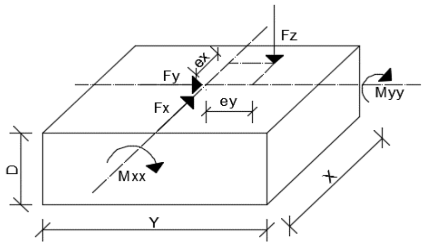
(SEE APPENDIX A FOR DETAIL ANALYSIS AND DESIGN)

DESIGN OF PAD FOUNDATION UNDER 2 COLUMNS C1

Unfactored Forces			
Axial Force	DL	139,38	kN
	IL	60,40	kN
	Fz	199,78	kN
Horizonal Force	Fx	0,00	kN
	Fy	0,00	kN
Moment	Mxx	0,00	kNm
	Myy	0,00	kNm
Eccentricity	ex	0,00	mm
	ey	0,00	mm



Foundation Dimensions			
Length	x	1,20	m
Width	y	1,20	m
Depth		0,45	m
Self Weight		15,55	kN
Column Length	x	0,40	m
Column Width	y	0,40	m



Foundation Dimensions			
Allowale Bearing Pressure	170,00	kN/m2	
Bearing Pressure	149,54	kN/m2	Pass

Check Against Overturning	X-Direction			
Moment		0,00	kNm	
Resultant Eccentricity	e	0,00	m	
Parametr	c	0,60		
Maximum Earth pressure		149,54	kN/m2	Pass
Minimum Earth pressuer		149,54	kN/m2	

Check Against Overturning	Y-Direction			
Moment		0,00	kNm	
Resultant Eccentricity	e	0,00		
Parametr	c	0,60		
Maximum Earth pressure		149,54	kN/m2	Pass
Minimum Earth pressuer		149,54	kN/m2	

RETAINING WALL DESIGN

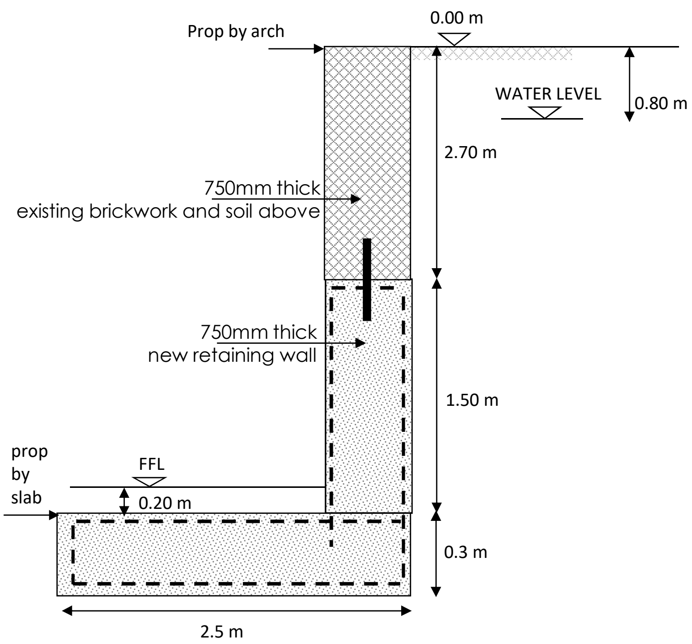
ARRANGEMENT AND MATERIAL DETAILS

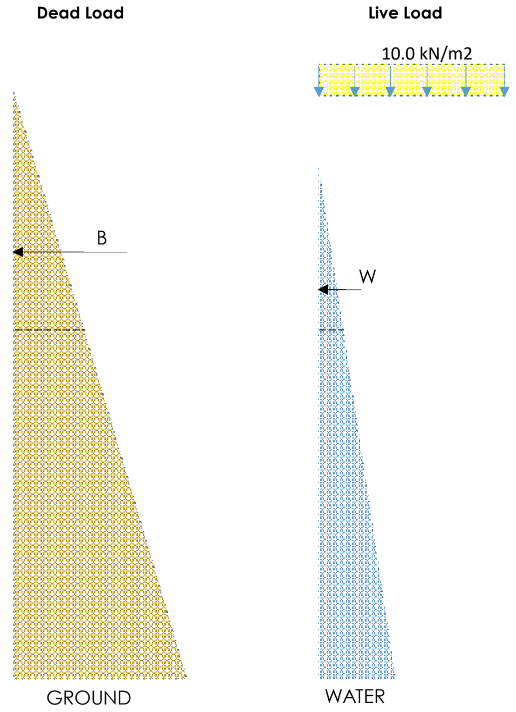
Wall Height (H)	1.50 m
Wall Width (W)	0,75 m
Concrete density	24 kN/m3
Retained Soil Density, γ_m	18 kN/m3
Angle of int'l friction of retain mat'l, $Ø_b$	26 °
Angle of soil surface, β	0 °
Ground conditions beneath base	Dense Gravel
Allowable Bearing Capacity	120 kN/m2

GROUND CONDITIONS TBC BY SUITABLY QUALIFIED INDIVIDUAL

LOADING

Surcharge Live Load, q_1 — 10,00 kN/m2





Rankine Coefficient (Using active earth pressure coefficient)

$k_a = (1 - \sin\varphi) / (1 + \sin\varphi)$ — 0,39

LOADING FOR RC CANTILEVER RETAINING WALL

Surcharge DL + Water, q_2 — $\gamma_m \cdot 2.70\ m + \gamma_w \cdot 1.90\ m$ — 67,60 kN/m2

Pressure

-2.70m	Backfill, B	$k_a \cdot \gamma_m \cdot$ depth	18,98 kN/m2
-2.70m	Water, W	$\gamma_w \cdot$ depth	19,00 kN/m2
-2.70m	Surcharge IL, A	$k_a \cdot q_1$	3,90 kN/m2

Horizontal Dead Load

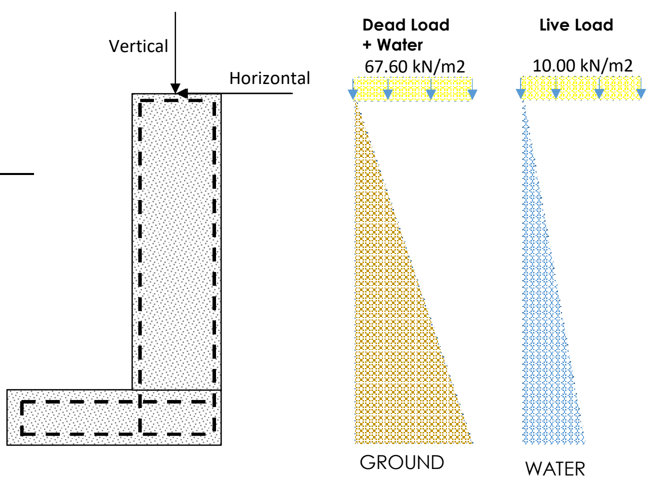
-2.70m	Backfill, B	25,62 kN/m
-2.70m	Water, W	18,05 kN/m
		43,67 kN/m

33% of load (wall is propped by frames & at the top by arch) — **14,41 kN/m**

Horizontal Live Load

-2.70m — Surcharge IL, A — 10,54 kN/m

33% of load (wall is propped by frames & at the top by arch) — **3,48 kN/m**



Vertical Load

Wall thickness above retaining wall	0,75 m
Wall height above retaining wall	2,70 m
Density	22,00 kN/m3
Vertical Load	**44,55 kN/m**

(SEE APPENDIX B FOR DETAIL ANALYSIS AND DESIGN)

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	Date	Jul' 2023	Eng	PCh
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Work Section	Structural Calculations			

RETAINING WALL DESIGN

ARRANGEMENT AND MATERIAL DETAILS

Check for potential uplift

Approximate total weight of structure (Dead Load Only)

Pavement + Ground + Arch	(0.20m x 24kN/m3 + 0.20m x 18kN/m3 + 0.30m x 24kN/m3) x 69.90m2	1090,44 kN
Walls	2.20m x 0.40m x 18.20m x 24kN/m3	384,38 kN
	2.20m x 0.75m x 18.20m x 24kN/m3	720,72 kN
Retaining Wall Stem	1.40m x (0.40m + 0.75m) x 18.20m x 24kN/m3	703,25 kN
Retaining Wall Base + Ground	0.45m x 46.57m2 x 24kN/m3	502,96 kN
0.2m thick Concrete under base	0.20m x (1.40m + 1.75m) x 14.30m x 24kN/m3	216,22 kN
TOTAL DEAD LOAD:		3617,97 **kN**

Pressure
Water table has been measured -0.80m below ground level.

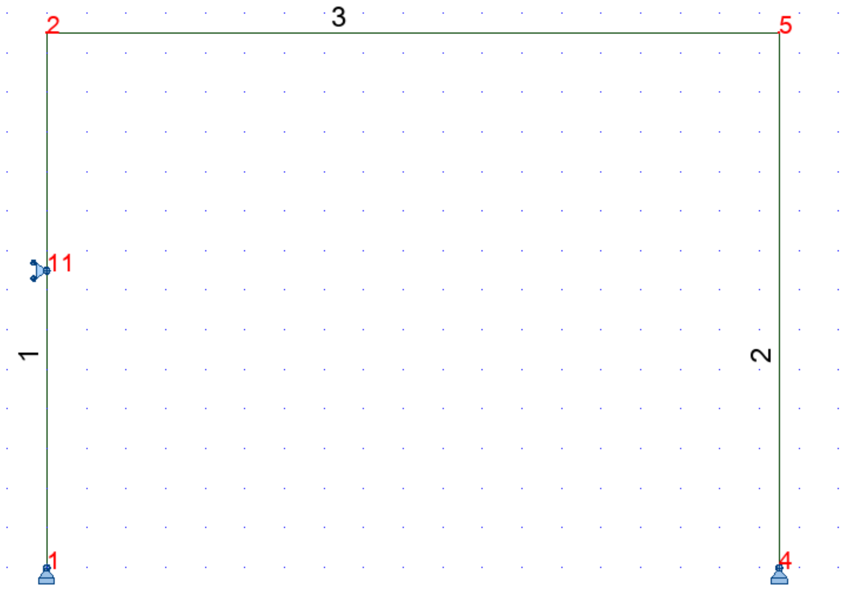
	10kN/m3 x 4.4m	44,00 kN/m2
TOTAL UPLIFT:	44kN/m2 x 69.90m2	3075,60 **kN**

3617,97 kN > **3075,6 kN** Satisfactory

APPENDIX A

Portal Frame

Structure View



Data - Nodes

Node	X (m)	Z (m)	Support code	Support
1	0,0	0,0	xxf	Pinned
2	0,0	2,70		
4	3,70	0,0	xxf	Pinned
5	3,70	2,70		
11	0,0	1,50	xff	Pinned 2

Data - Bars

Bar	Node 1	Node 2	Section	Material	Length (m)	Gamma (Deg)	Type
1	1	2	UC 203x203x52	S275	2,70	0,0	Column 1
2	4	5	UC 203x203x52	S275	2,70	0,0	Column 1
3	2	5	UC 203x203x60	S275	3,70	0,0	Beam 7

Data - Sections

Section name	Bar list	AX (mm2)	AY (mm2)	AZ (mm2)
UC 203x203x52	1 2	6630	5098	1650
UC 203x203x60	3	7640	5828	1949

Section name	IX (mm4)	IY (mm4)	IZ (mm4)
UC 203x203x52	318000	52590000	17780000
UC 203x203x60	472000	61250000	20650000

Data - Materials

	Material	E (MPa)	G (MPa)	NI	LX (1/°C)	RO (kN/m3)	Re (MPa)
1	S275	205000,00	80000,00	0,30	0,00	77,01	275,00

Data - Supports

Support name	List of nodes	List of edges	List of objects	Support conditions
Pinned	1 4			UX UZ

Support name	List of nodes	List of edges	List of objects	Support conditions
Pinned 2	11			UX

Loads - Cases

Case	Label	Case name
1	DL1	DL1
2	IL1	IL1
3	WL1	WL1 - LEFT
4	WL2	WL2 - RIGHT
5		COMB1 (1.4DL+1.6IL)
6		COMB2a (1.2DL+1.2IL+1.2WL1)
7		COMB2b (1.2DL+1.2IL+1.2WL2)
8		COMB9
9		COMB3a (0.9DL+1.4WL1)
10		COMB4a (1.0IL+1.0WL1)
11		COMB4b (1.0IL+1.0WL2)
12		COMB5a (1.0DL+1.0IL+1.0WL1)
13		COMB5b (1.0DL+1.0IL+1.0WL2)
14		COMB6 (1.0DL+1.0IL)

Case	Nature	Analysis type
1	dead	Static - Linear
2	live	Static - Linear
3	wind	Static - Linear
4	wind	Static - Linear
5		Linear Combination
6		Linear Combination
7		Linear Combination
8		Linear Combination
9		Linear Combination
10		Linear Combination
11		Linear Combination
12		Linear Combination
13		Linear Combination
14		Linear Combination

Loads - Values

Case	Load type	List	Load values
1	self-weight	1to3	PZ Negative Factor=1,00
1	uniform load	3	PZ=-35,04(kN/m)
1	trapezoidal load (2p)		PX2=-13,65(kN/m) PX1=-13,65(kN/m) X2=2,70(m) X1=2,30(m) global not project. absolute
1	trapezoidal load (2p)		PX2=-36,83(kN/m) PX1=-36,83(kN/m) X2=2,30(m) X1=1,90(m) global not project. absolute
1	trapezoidal load (2p)		PX2=-23,19(kN/m) PX1=-23,19(kN/m) X2=1,90(m) X1=1,50(m) global not project. absolute
1	trapezoidal load (2p)	2	PX2=-16,45(kN/m) PX1=-16,45(kN/m) X2=2,70(m) X1=2,30(m) global not project. absolute
1	trapezoidal load (2p)	2	PX2=-42,45(kN/m) PX1=-42,45(kN/m) X2=2,30(m) X1=1,90(m) global not project. absolute
1	trapezoidal load (2p)	2	PX2=-26,00(kN/m) PX1=-26,00(kN/m) X2=1,90(m) X1=1,50(m) global not project. absolute
2	uniform load	3	PZ=-16,00(kN/m)
2	trapezoidal load (2p)	2	PX2=-2,73(kN/m) PX1=-2,73(kN/m) X2=2,70(m) X1=2,30(m) global not project. absolute

Case	Load type	List	Load values
2	trapezoidal load (2p)	2	PX2=-5,46(kN/m) PX1=-5,46(kN/m) X2=2,30(m) X1=1,90(m) global not project. absolute
2	trapezoidal load (2p)	2	PX2=-2,73(kN/m) PX1=-2,73(kN/m) X2=1,90(m) X1=1,50(m) global not project. absolute

Combinations

Combinations	Name	Analysis type	Combination type
5 (C)	COMB1 (1.4DL+1.6IL)	Linear Combination	ULS
6 (C)	COMB2a (1.2DL+1.2IL+1.2W-L1)	Linear Combination	ULS
7 (C)	COMB2b (1.2DL+1.2IL+1.2W-L2)	Linear Combination	ULS
8 (C)	COMB9	Linear Combination	SLS
9 (C)	COMB3a (0.9DL+1.4WL1)	Linear Combination	ULS
10 (C)	COMB4a (1.0IL+1.0WL1)	Linear Combination	SLS
11 (C)	COMB4b (1.0IL+1.0WL2)	Linear Combination	SLS
12 (C)	COMB5a (1.0DL+1.0IL+1.0W-L1)	Linear Combination	ULS
13 (C)	COMB5b (1.0DL+1.0IL+1.0W-L2)	Linear Combination	ULS
14 (C)	COMB6 (1.0DL+1.0IL)	Linear Combination	ULS

Combinations	Case nature	Definition
5 (C)		1*1.40+2*1.60
6 (C)		(1+2+3)*1.20
7 (C)		(1+2+4)*1.20
8 (C)		(1+2+3)*1.00
9 (C)		1*0.90+3*1.40
10 (C)		(2+3)*1.00
11 (C)		(2+4)*1.00
12 (C)		(1+2+3)*1.00
13 (C)		(1+2+4)*1.00
14 (C)		(1+2)*1.00

Reactions ULS: global extremes

	FX (kN)	FZ (kN)	MY (kNm)
MAX	64,27	145,88	0,00
Node	11	1	11
Case	5 (C)	5 (C)	5 (C)
MIN	-17,04	0,0	-0,00
Node	1	1	11
Case	5 (C)	3	2

Displacements SLS: global extremes

	UX (mm)	UZ (mm)	RY (Rad)
MAX	0,11	0,0	0,006

	UX (mm)	UZ (mm)	RY (Rad)
Node	2	1	2
Case	2	1	8 (C)
MIN	-1,53	-0,20	-0,007
Node	5	2	5
Case	1	8 (C)	8 (C)

Forces - Envelope

Bar/Node/Case	FX (kN)	FZ (kN)	MY (kNm)
1/ 1/ 5 (C)	145,88>>	17,04	0,0
1/ 1/ 3	0,0<<	0,0	0,0
1/ 1/ 5 (C)	145,88	17,04>>	0,0
1/ 2/ 5 (C)	143,95	-47,24<<	-31,12
1/ 1/ 1	69,69	12,11	0,0>>
1/ 2/ 5 (C)	143,95	-47,24	-31,12<<
2/ 4/ 5 (C)	137,25>>	-7,30	0,00
2/ 4/ 3	0,0<<	0,0	0,0
2/ 5/ 5 (C)	135,32	47,24>>	15,16
2/ 4/ 5 (C)	137,25	-7,30<<	0,00
2/ 5/ 5 (C)	135,32	47,24	15,16>>
2/ 4/ 2	29,00	0,22	-0,00<<
3/ 2/ 5 (C)	47,24>>	143,95	-31,12
3/ 2/ 3	0,0<<	0,0	0,0
3/ 2/ 5 (C)	47,24	143,95>>	-31,12
3/ 5/ 5 (C)	47,24	-135,32<<	-15,16
3/ 2/ 3	0,0	0,0	0,0>>
3/ 2/ 5 (C)	47,24	143,95	-31,12<<

Member Forces ULS: envelope

Bar	FX (kN)	FZ (kN)	MY (kNm)
1 / MAX	145,88	17,04	0,0
Node	1	1	1
Case	5 (C)	5 (C)	1
1 / MIN	0,0	-47,24	-31,12
Node	1	2	2
Case	3	5 (C)	5 (C)
2 / MAX	137,25	47,24	15,16
Node	4	5	5
Case	5 (C)	5 (C)	5 (C)
2 / MIN	0,0	-7,30	-0,00
Node	4	4	4
Case	3	5 (C)	2
3 / MAX	47,24	143,95	0,0
Node	2	2	2
Case	5 (C)	5 (C)	3
3 / MIN	0,0	-135,32	-31,12
Node	2	5	2
Case	3	5 (C)	5 (C)

Members - Definition

Member	Name	Components	Code group	Section	Type	Ly (m)	Lz (m)
1	COL 1	1	(N/A)	UC 203x203x52	Column 1	4,05	4,05
2	COL 1	2	(N/A)	UC 203x203x52	Column 1	4,05	4,05
3	B1	3	(N/A)	UC 203x203x60	Beam 7	3,70	3,70

Member Verification

STEEL DESIGN

CODE: *British Standard BS 5950:2000*
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 1 COL 1 **POINT:** 3 **COORDINATE:** x = 1.00 L = 2.70 m

---

LOADS:
Governing Load Case: 5 COMB1 (1.4DL+1.6IL) 1*1.40+2*1.60

MATERIAL
S275 py = 275.00 MPa E = 205000.00 MPa

SECTION PARAMETERS: **UC 203x203x52**
D=206 mm
B=204 mm Ay=5108 mm2 Az=1629 mm2 A=6630 mm2
t=8 mm Iy=52590000 mm4 Iz=17780000 mm4 Ix=318000 mm4
T=13 mm Wely=510087 mm3 Welz=174058 mm3

INTERNAL FORCES
Fc = 143.95 kN My = -31.12 kN*m
Mlt = -31.12 kN*m Mymax = -31.12 kN*m Fvz = -47.24 kN
mlt = 0.60 my = 0.60

CAPACITIES
Pc = 1823.25 kN Mcy = 155.93 kN*m
Section class = 1 Mey = 140.27 kN*m Pvz = 268.78 kN

LATERAL BUCKLING PARAMETERS:
Le = 2.70 m u = 0.85 LamLT = 39.65 pb = 262.65 MPa
x = 15.83 v = 0.90 NLT = 0.04 Mb = 148.92 kN*m

BUCKLING PARAMETERS:

About Y axis:
Ly = 4.05 m pey = 978.44 MPa
Ley = 4.05 m Fiy = 675.21 MPa
Lamy = 45.47 py = 242.96 MPa
ny = 0.10 Pcy = 1610.85 kN

About Z axis:
Lz = 4.05 m pez = 330.80 MPa
Lez = 4.05 m Fiz = 358.44 MPa
Lamz = 78.21 pz = 164.77 MPa
nz = 0.34 Pcz = 1092.41 kN

VERIFICATION FORMULAS:
Section check
Fc/Pc + My/Mcy = 0.28 < 1.00 (4.8.3.2)
Fvz/Pvz = 0.18 < 1.00 (4.2.3)
Member stability check
Fc/Pcy + (1+0.5*Fc/Pcy)*my*Mymax/Mcy = 0.21 < 1.00 (4.8.3.3.2a)

Fc/Pcz + mlt*Mlt/Mb = 0.26 < 1.00   (4.8.3.3.2a)

LIMIT DISPLACEMENTS

Deflections (LOCAL SYSTEM): *Not analyzed*

Displacements (GLOBAL SYSTEM):

vx = 0.11 mm < vx max = L/300.00 = 9.00 mm   Verified

Governing Load Case: 10 COMB4a (1.0IL+1.0WL1) (2+3)*1.00

Section OK !!!

STEEL DESIGN

CODE: *British Standard BS 5950:2000*

ANALYSIS TYPE: Member Verification

CODE GROUP:

MEMBER: 2 COL 1   **POINT:** 2   **COORDINATE:** x = 0.50 L = 1.35 m

---

LOADS:

Governing Load Case: 5 COMB1 (1.4DL+1.6IL) 1*1.40+2*1.60

MATERIAL

S275	py = 275.00 MPa	E = 205000.00 MPa

SECTION PARAMETERS: UC 203x203x52

D=206 mm			
B=204 mm	Ay=5108 mm2	Az=1629 mm2	A=6630 mm2
t=8 mm	Iy=52590000 mm4	Iz=17780000 mm4	Ix=318000 mm4
T=13 mm	Wely=510087 mm3	Welz=174058 mm3	

INTERNAL FORCES

Fc = 136.29 kN	My = -9.85 kN*m	
Mlt = 15.16 kN*m	Mymax = 15.16 kN*m	Fvz = -7.30 kN
mlt = 0.60	my = 0.60	

CAPACITIES

Pc = 1823.25 kN	Mcy = 155.93 kN*m	
Section class = 1	Mey = 140.27 kN*m	Pvz = 268.78 kN

LATERAL BUCKLING PARAMETERS:

Le = 2.70 m	u = 0.85	LamLT = 39.65	pb = 262.65 MPa
x = 15.83	v = 0.90	NLT = 0.04	Mb = 148.92 kN*m

BUCKLING PARAMETERS:

About Y axis:		About Z axis:	
Ly = 4.05 m	pey = 978.44 MPa	Lz = 4.05 m	pez = 330.80 MPa
Ley = 4.05 m	Fiy = 675.21 MPa	Lez = 4.05 m	Fiz = 358.44 MPa
Lamy = 45.47	py = 242.96 MPa	Lamz = 78.21	pz = 164.77 MPa
ny = 0.10	Pcy = 1610.85 kN	nz = 0.34	Pcz = 1092.41 kN

VERIFICATION FORMULAS:

Section check

Fc/Pc + My/Mcy = 0.14 < 1.00   (4.8.3.2)

Fvz/Pvz = 0.03 < 1.00   (4.2.3)

Member stability check

Fc/Pcy + (1+0.5*Fc/Pcy)*my*Mymax/Mcy = 0.15 < 1.00   (4.8.3.3.2a)

Fc/Pcz + mlt*Mlt/Mb = 0.19 < 1.00   (4.8.3.3.2a)

LIMIT DISPLACEMENTS

Deflections (LOCAL SYSTEM): *Not analyzed*

Displacements (GLOBAL SYSTEM):

vx = 0.10 mm < vx max = L/300.00 = 9.00 mm Verified

Governing Load Case: 10 COMB4a (1.0IL+1.0WL1) (2+3)*1.00

Section OK !!!

STEEL DESIGN

CODE: *British Standard BS 5950:2000*

ANALYSIS TYPE: Member Verification

CODE GROUP:

MEMBER: 3 B1 **POINT:** 1 **COORDINATE:** x = 0.00 L = 0.00 m

---

LOADS:

Governing Load Case: 5 COMB1 (1.4DL+1.6IL) 1*1.40+2*1.60

MATERIAL

S275	py = 275.00 MPa	E = 205000.00 MPa

SECTION PARAMETERS: UC 203x203x60

D=210 mm			
B=206 mm	Ay=5845 mm2	Az=1970 mm2	A=7640 mm2
t=9 mm	Iy=61250000 mm4	Iz=20650000 mm4	Ix=472000 mm4
T=14 mm	Wely=584447 mm3	Welz=200680 mm3	

INTERNAL FORCES

Fc = 47.24 kN	My = -31.12 kN*m		
Mlt = 106.02 kN*m	Mymax = 106.02 kN*m		Fvz = 143.95 kN
mlt = 0.91	my = 0.94		

CAPACITIES

Pc = 2101.00 kN	Mcy = 180.40 kN*m		
Section class = 1	Mey = 160.72 kN*m		Pvz = 325.09 kN

LATERAL BUCKLING PARAMETERS:

Le = 3.70 m	u = 0.85	LamLT = 49.00	pb = 240.42 MPa
x = 14.07	v = 0.81	NLT = 0.10	Mb = 157.72 kN*m

BUCKLING PARAMETERS:

About Y axis:		About Z axis:	
Ly = 3.70 m	pey = 1184.85 MPa	Lz = 3.70 m	pez = 399.46 MPa
Ley = 3.70 m	Fiy = 780.04 MPa	Lez = 3.70 m	Fiz = 396.57 MPa
Lamy = 41.32	py = 248.41 MPa	Lamz = 71.17	pz = 178.82 MPa
ny = 0.08	Pcy = 1897.87 kN	nz = 0.30	Pcz = 1366.20 kN

VERIFICATION FORMULAS:

Section check

Fc/Pc + My/Mcy = 0.20 < 1.00 (4.8.3.2)

Fvz/Pvz = 0.44 < 1.00 (4.2.3)

Member stability check

Fc/Pcy + (1+0.5*Fc/Pcy)*my*Mymax/Mcy = 0.58 < 1.00 (4.8.3.3.2a)

Fc/Pcz + mlt*Mlt/Mb = 0.65 < 1.00 (4.8.3.3.2a)

LIMIT DISPLACEMENTS

Deflections (LOCAL SYSTEM):

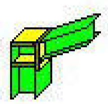
uz = 2.52 mm < uz max = L/500.00 = 7.40 mm Verified

Governing Load Case: 10 COMB4a (1.0IL+1.0WL1) (2+3)*1.00

Displacements (GLOBAL SYSTEM): *Not analyzed*

Section OK !!!

Connection Verification



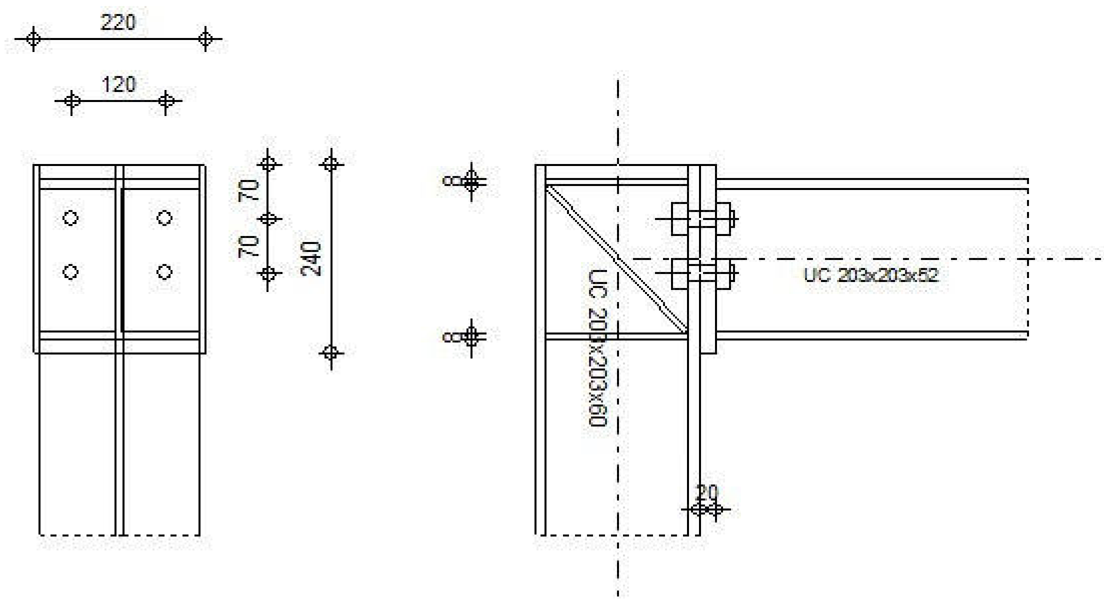
Autodesk Robot Structural Analysis Professional 2019

Design of fixed beam-to-column connection

EN 1993-1-8:2005/AC:2009

OK

Ratio
0,78



General

Connection no.: `1`

Connection name: `Frame knee`

Structure node: `2`

Structure bars: `3, 1`

Geometry

Column

Section: `UC 203x203x60`

Bar no.: `3`

α =	-90,0	[Deg]	Inclination angle
h_c =	210	[mm]	Height of column section
b_{fc} =	206	[mm]	Width of column section
t_{wc} =	9	[mm]	Thickness of the web of column section
t_{fc} =	14	[mm]	Thickness of the flange of column section
r_c =	10	[mm]	Radius of column section fillet
A_c =	7640	[mm^2]	Cross-sectional area of a column
I_{xc} =	61250000	[mm^4]	Moment of inertia of the column section

Material: S275

f_{yc} =	275,00	[MPa]	Resistance

BEAM

Section: UC 203x203x52

Bar no.: 1

α =	0,0	[Deg]	Inclination angle
h_b =	206	[mm]	Height of beam section
b_f =	204	[mm]	Width of beam section
t_{wb} =	8	[mm]	Thickness of the web of beam section
t_{fb} =	13	[mm]	Thickness of the flange of beam section
r_b =	10	[mm]	Radius of beam section fillet
r_b =	10	[mm]	Radius of beam section fillet
A_b =	6630	[mm^2]	Cross-sectional area of a beam
I_{xb} =	52590000	[mm^4]	Moment of inertia of the beam section

Material: S275

f_{yb} =	275,00	[MPa]	Resistance

BOLTS

The shear plane passes through the THREADED portion of the bolt.

d =	20	[mm]	Bolt diameter
Class =	8.8		Bolt class
F_{tRd} =	141,12	[kN]	Tensile resistance of a bolt
n_h =	2		Number of bolt columns
n_v =	2		Number of bolt rows
h_1 =	70	[mm]	Distance between first bolt and upper edge of front plate

Horizontal spacing e_i = 120 [mm]

Vertical spacing p_i = 70 [mm]

PLATE

h_p =	240	[mm]	Plate height
b_p =	220	[mm]	Plate width
t_p =	20	[mm]	Plate thickness

Material: S275

f_{yp} =	275,00	[MPa]	Resistance

COLUMN STIFFENER

Upper

h_{su} =	181	[mm]	Stiffener height
b_{su} =	98	[mm]	Stiffener width
t_{hu} =	8	[mm]	Stiffener thickness

Material: S275

f_{ysu} =	275,00	[MPa]	Resistance

Lower

h_{sd} =	181	[mm]	Stiffener height
b_{sd} =	98	[mm]	Stiffener width
t_{hd} =	8	[mm]	Stiffener thickness

Material: S275

f_{ysu} =	275,00	[MPa]	Resistance

DIAGONAL STIFFENER

Typ: Left

w_a =	98	[mm]	Width of diagonal stiffener
t_a =	8	[mm]	Thickness of diagonal stiffener

Material: S275

f_{ya} =	275,00	[MPa]	Resistance

FILLET WELDS

a_w =	4	[mm]	Web weld
a_f =	4	[mm]	Flange weld
a_s =	4	[mm]	Stiffener weld

MATERIAL FACTORS

γ_{M0} =	1,00		Partial safety factor	[2.2]
γ_{M1} =	1,00		Partial safety factor	[2.2]
γ_{M2} =	1,25		Partial safety factor	[2.2]
γ_{M3} =	1,25		Partial safety factor	[2.2]

LOADS

Ultimate limit state

Case: 5: COMB1 (1.4DL+1.6IL) 1*1.40+2*1.60

$M_{b1,Ed}$ =	31,12	[kN*m]	Bending moment in the right beam
$V_{b1,Ed}$ =	47,24	[kN]	Shear force in the right beam
$N_{b1,Ed}$ =	-143,95	[kN]	Axial force in the right beam
$M_{c1,Ed}$ =	31,12	[kN*m]	Bending moment in the lower column
$V_{c1,Ed}$ =	143,95	[kN]	Shear force in the lower column
$N_{c1,Ed}$ =	-47,24	[kN]	Axial force in the lower column

RESULTS

BEAM RESISTANCES

COMPRESSION

A_b = 6630 [mm^2] Area EN1993-1-1:[6.2.4]

$N_{cb,Rd} = A_b f_{yb} / \gamma_{M0}$

$N_{cb,Rd}$ = 1823,25 [kN] Design compressive resistance of the section EN1993-1-1:[6.2.4]

SHEAR

A_{vb} = 1876 [mm^2] Shear area EN1993-1-1:[6.2.6.(3)]

$V_{cb,Rd} = A_{vb} (f_{yb} / \sqrt{3}) / \gamma_{M0}$

$V_{cb,Rd}$ = 297,89 [kN] Design sectional resistance for shear EN1993-1-1:[6.2.6.(2)]

$V_{b1,Ed} / V_{cb,Rd} \leq 1,0$ 0,16 < 1,00 verified (0,16)

BENDING - PLASTIC MOMENT (WITHOUT BRACKETS)

W_{plb} = 567000 [mm^3] Plastic section modulus EN1993-1-1:[6.2.5.(2)]

$M_{b,pl,Rd} = W_{plb} f_{yb} / \gamma_{M0}$

$M_{b,pl,Rd}$ = 155,93 [kN*m] Plastic resistance of the section for bending (without stiffeners) EN1993-1-1:[6.2.5.(2)]

BENDING ON THE CONTACT SURFACE WITH PLATE OR CONNECTED ELEMENT

W_{pl} = 567000 [mm^3] Plastic section modulus EN1993-1-1:[6.2.5]

$M_{cb,Rd} = W_{pl}\, f_{yb} / \gamma_{M0}$

$M_{cb,Rd}$ = 155,93 [kN*m] Design resistance of the section for bending EN1993-1-1:[6.2.5]

FLANGE AND WEB - COMPRESSION

$M_{cb,Rd}$ = 155,93 [kN*m] Design resistance of the section for bending EN1993-1-1:[6.2.5]

h_f = 194 [mm] Distance between the centroids of flanges [6.2.6.7.(1)]

$F_{c,fb,Rd} = M_{cb,Rd} / h_f$

$F_{c,fb,Rd}$ = 804,98 [kN] Resistance of the compressed flange and web [6.2.6.7.(1)]

COLUMN RESISTANCES

WEB PANEL - SHEAR

$M_{b1,Ed}$ = 31,12 [kN*m] Bending moment (right beam) [5.3.(3)]

$M_{b2,Ed}$ = 0,00 [kN*m] Bending moment (left beam) [5.3.(3)]

$V_{c1,Ed}$ = 143,95 [kN] Shear force (lower column) [5.3.(3)]

$V_{c2,Ed}$ = 0,00 [kN] Shear force (upper column) [5.3.(3)]

z = 148 [mm] Lever arm [6.2.5]

$V_{wp,Ed} = (M_{b1,Ed} - M_{b2,Ed}) / z - (V_{c1,Ed} - V_{c2,Ed}) / 2$

$V_{wp,Ed}$ = 138,40 [kN] Shear force acting on the web panel [5.3.(3)]

A_{vs} = 2218 [mm^2] Shear area of the column web EN1993-1-1:[6.2.6.(3)]

A_{vd} = 1120 [mm^2] Area of the diagonal stiffener subjected to shear EN1993-1-1:[6.2.6.(3)]

A_{vc} = 3338 [mm^2] Shear area EN1993-1-1:[6.2.6.(3)]

d_s = 198 [mm] Distance between the centroids of stiffeners [6.2.6.1.(4)]

$M_{pl,fc,Rd}$ = 2,85 [kN*m] Plastic resistance of the column flange for bending [6.2.6.1.(4)]

$M_{pl,stu,Rd}$ = 0,91 [kN*m] Plastic resistance of the upper transverse stiffener for bending [6.2.6.1.(4)]

$M_{pl,stl,Rd}$ = 0,91 [kN*m] Plastic resistance of the lower transverse stiffener for bending [6.2.6.1.(4)]

$V_{wp,Rd} = 0.9\,(A_{vs}*f_{y,wc}+A_{vd}*f_{ya}) / (\sqrt{3}\,\gamma_{M0}) + Min(4\, M_{pl,fc,Rd} / d_s , (2\, M_{pl,fc,Rd} + M_{pl,stu,Rd} + M_{pl,stl,Rd}) / d_s)$

$V_{wp,Rd}$ = 514,98 [kN] Resistance of the column web panel for shear [6.2.6.1]

$V_{wp,Ed} / V_{wp,Rd} \leq 1,0$ 0,27 < 1,00 verified (0,27)

WEB - TRANSVERSE COMPRESSION - LEVEL OF THE BEAM BOTTOM FLANGE

Bearing:

t_{wc} =	9	[mm]	Effective thickness of the column web	[6.2.6.2.(6)]
$b_{eff,c,wc}$ =	186	[mm]	Effective width of the web for compression	[6.2.6.2.(1)]
A_{vc} =	2218	[mm^2]	Shear area	EN1993-1-1:[6.2.6.(3)]
ω =	0,74		Reduction factor for interaction with shear	[6.2.6.2.(1)]
$\sigma_{com,Ed}$ =	47,04	[MPa]	Maximum compressive stress in web	[6.2.6.2.(2)]
k_{wc} =	1,00		Reduction factor conditioned by compressive stresses	[6.2.6.2.(2)]
A_s =	1571	[mm^2]	Area of the web stiffener	EN1993-1-1:[6.2.4]
α =	44,5	[Deg]	Inclination angle of a diagonal stiffener	
A_{sd} =	1571	[mm^2]	Diagonal stiffener area	EN1993-1-1:[6.2.4]

$F_{c,wc,Rd1} = \omega\ k_{wc}\ b_{eff,c,wc}\ t_{wc}\ f_{yc} / \gamma_{M0} + A_s\ f_{ys} / \gamma_{M0} + A_{sd} \cos(\alpha)\ f_{ya} / \gamma_{M0}$

$F_{c,wc,Rd1}$ =	1097,53	[kN]	Column web resistance	[6.2.6.2.(1)]

Buckling:

d_{wc} =	161	[mm]	Height of compressed web	[6.2.6.2.(1)]
λ_p =	0,63		Plate slenderness of an element	[6.2.6.2.(1)]
ρ =	1,00		Reduction factor for element buckling	[6.2.6.2.(1)]
λ_s =	2,64		Stiffener slenderness	EN1993-1-1:[6.3.1.2]
χ_s =	1,00		Buckling coefficient of the stiffener	EN1993-1-1:[6.3.1.2]
λ_{sd} =	3,71		Diagonal stiffener slenderness	EN1993-1-1:[6.3.1.2]
χ_{sd} =	1,00		Buckling coefficient of a diagonal stiffener	EN1993-1-1:[6.3.1.2]

$F_{c,wc,Rd2} = \omega\ k_{wc}\ \rho\ b_{eff,c,wc}\ t_{wc}\ f_{yc} / \gamma_{M1} + A_s\ \chi_s\ f_{ys} / \gamma_{M1} + A_{sd}\ \chi_{sd} \cos(\alpha)\ f_{ya} / \gamma_{M1}$

$F_{c,wc,Rd2}$ =	1097,53	[kN]	Column web resistance	[6.2.6.2.(1)]

Final resistance:

$F_{c,wc,Rd,low} = \text{Min}\ (F_{c,wc,Rd1}\ ,\ F_{c,wc,Rd2})$

$F_{c,wc,Rd}$ =	1097,53	[kN]	Column web resistance	[6.2.6.2.(1)]

WEB - TRANSVERSE COMPRESSION - LEVEL OF THE BEAM TOP FLANGE

Bearing:

t_{wc} =	9	[mm]	Effective thickness of the column web	[6.2.6.2.(6)]
$b_{eff,c,wc}$ =	186	[mm]	Effective width of the web for compression	[6.2.6.2.(1)]

t_{wc} =	9	[mm]	Effective thickness of the column web	[6.2.6.2.(6)]
A_{vc} =	2218	[mm^2]	Shear area	EN1993-1-1:[6.2.6.(3)]
ω =	0,74		Reduction factor for interaction with shear	[6.2.6.2.(1)]
$\sigma_{com,Ed}$ =	47,04	[MPa]	Maximum compressive stress in web	[6.2.6.2.(2)]
k_{wc} =	1,00		Reduction factor conditioned by compressive stresses	[6.2.6.2.(2)]
A_s =	1571	[mm^2]	Area of the web stiffener	EN1993-1-1:[6.2.4]

$F_{c,wc,Rd1} = \omega\ k_{wc}\ b_{eff,c,wc}\ t_{wc}\ f_{yc} / \gamma_{M0} + A_s\ f_{ys} / \gamma_{M0}$

$F_{c,wc,Rd1}$ =	789,51	[kN]	Column web resistance	[6.2.6.2.(1)]

Buckling:

d_{wc} =	161	[mm]	Height of compressed web	[6.2.6.2.(1)]
λ_p =	0,63		Plate slenderness of an element	[6.2.6.2.(1)]
ρ =	1,00		Reduction factor for element buckling	[6.2.6.2.(1)]
λ_s =	2,64		Stiffener slenderness	EN1993-1-1:[6.3.1.2]
χ_s =	1,00		Buckling coefficient of the stiffener	EN1993-1-1:[6.3.1.2]

$F_{c,wc,Rd2} = \omega\ k_{wc}\ \rho\ b_{eff,c,wc}\ t_{wc}\ f_{yc} / \gamma_{M1} + A_s\ \chi_s\ f_{ys} / \gamma_{M1}$

$F_{c,wc,Rd2}$ =	789,51	[kN]	Column web resistance	[6.2.6.2.(1)]

Final resistance:

$F_{c,wc,Rd,upp} = \text{Min}\ (F_{c,wc,Rd1}\ ,\ F_{c,wc,Rd2})$

$F_{c,wc,Rd,upp}$ =	789,51	[kN]	Column web resistance	[6.2.6.2.(1)]

GEOMETRICAL PARAMETERS OF A CONNECTION

EFFECTIVE LENGTHS AND PARAMETERS - COLUMN FLANGE

Nr	m	m_x	e	e_x	p	$l_{eff,cp}$	$l_{eff,nc}$	$l_{eff,1}$	$l_{eff,2}$	$l_{eff,cp,g}$	$l_{eff,nc,g}$	$l_{eff,1,g}$	$l_{eff,2,g}$
1	47	-	43	-	70	296	284	284	284	218	198	198	198
2	47	-	43	-	70	296	250	250	250	218	164	164	164

EFFECTIVE LENGTHS AND PARAMETERS - FRONT PLATE

Nr	m	m_x	e	e_x	p	$l_{eff,cp}$	$l_{eff,nc}$	$l_{eff,1}$	$l_{eff,2}$	$l_{eff,cp,g}$	$l_{eff,nc,g}$	$l_{eff,1,g}$	$l_{eff,2,g}$
1	52	-	50	-	70	324	319	319	319	232	220	220	220

Nr	m	m_x	e	e_x	p	$l_{eff,cp}$	$l_{eff,nc}$	$l_{eff,1}$	$l_{eff,2}$	$l_{eff,cp,g}$	$l_{eff,nc,g}$	$l_{eff,1,g}$	$l_{eff,2,g}$
2	52	-	50	-	70	324	269	269	269	232	169	169	169

m – Bolt distance from the web

m_x – Bolt distance from the beam flange

e – Bolt distance from the outer edge

e_x – Bolt distance from the horizontal outer edge

p – Distance between bolts

$l_{eff,cp}$ – Effective length for a single bolt in the circular failure mode

$l_{eff,nc}$ – Effective length for a single bolt in the non-circular failure mode

$l_{eff,1}$ – Effective length for a single bolt for mode 1

$l_{eff,2}$ – Effective length for a single bolt for mode 2

$l_{eff,cp,g}$ – Effective length for a group of bolts in the circular failure mode

$l_{eff,nc,g}$ – Effective length for a group of bolts in the non-circular failure mode

$l_{eff,1,g}$ – Effective length for a group of bolts for mode 1

$l_{eff,2,g}$ – Effective length for a group of bolts for mode 2

CONNECTION RESISTANCE FOR COMPRESSION

$N_{j,Rd} = \text{Min} (N_{cb,Rd} , 2 F_{c,wc,Rd,low} , 2 F_{c,wc,Rd,upp})$

$N_{j,Rd}$ = 1579,03 [kN] Connection resistance for compression [6.2]

$N_{b1,Ed} / N_{j,Rd} \leq 1,0$ 0,09 < 1,00 verified (0,09)

CONNECTION RESISTANCE FOR BENDING

$F_{t,Rd}$ = 141,12 [kN] Bolt resistance for tension [Table 3.4]

$B_{p,Rd}$ = 276,23 [kN] Punching shear resistance of a bolt [Table 3.4]

$F_{t,fc,Rd}$ – column flange resistance due to bending

$F_{t,wc,Rd}$ – column web resistance due to tension

$F_{t,ep,Rd}$ – resistance of the front plate due to bending

$F_{t,wb,Rd}$ – resistance of the web in tension

$F_{t,fc,Rd} = \mathrm{Min}\ (F_{T,1,fc,Rd}\ ,\ F_{T,2,fc,Rd}\ ,\ F_{T,3,fc,Rd})$ [6.2.6.4] , [Tab.6.2]

$F_{t,wc,Rd} = \omega\ b_{eff,t,wc}\ t_{wc}\ f_{yc} / \gamma_{M0}$ [6.2.6.3.(1)]

$F_{t,ep,Rd} = \mathrm{Min}\ (F_{T,1,ep,Rd}\ ,\ F_{T,2,ep,Rd}\ ,\ F_{T,3,ep,Rd})$ [6.2.6.5] , [Tab.6.2]

$F_{t,wb,Rd} = b_{eff,t,wb}\ t_{wb}\ f_{yb} / \gamma_{M0}$ [6.2.6.8.(1)]

RESISTANCE OF THE BOLT ROW NO. 1

$F_{t1,Rd,comp}$ - Formula	$F_{t1,Rd,comp}$	Component
$F_{t1,Rd} = \mathrm{Min}\ (F_{t1,Rd,comp})$	221,82	Bolt row resistance
$F_{t,fc,Rd(1)} = 221{,}82$	221,82	Column flange - tension
$F_{t,wc,Rd(1)} = 432{,}22$	432,22	Column web - tension
$F_{t,ep,Rd(1)} = 282{,}24$	282,24	Front plate - tension
$F_{t,wb,Rd(1)} = 692{,}61$	692,61	Beam web - tension
$B_{p,Rd} = 552{,}46$	552,46	Bolts due to shear punching
$V_{wp,Rd}/\beta = 514{,}98$	514,98	Web panel - shear
$F_{c,wc,Rd} = 1097{,}53$	1097,53	Column web - compression
$F_{c,fb,Rd} = 804{,}98$	804,98	Beam flange - compression

RESISTANCE OF THE BOLT ROW NO. 2

$F_{t2,Rd,comp}$ - Formula	$F_{t2,Rd,comp}$	Component
$F_{t2,Rd} = \mathrm{Min}\ (F_{t2,Rd,comp})$	158,40	Bolt row resistance
$F_{t,fc,Rd(2)} = 211{,}42$	211,42	Column flange - tension
$F_{t,wc,Rd(2)} = 412{,}07$	412,07	Column web - tension
$F_{t,ep,Rd(2)} = 282{,}24$	282,24	Front plate - tension
$F_{t,wb,Rd(2)} = 583{,}53$	583,53	Beam web - tension
$B_{p,Rd} = 552{,}46$	552,46	Bolts due to shear punching
$V_{wp,Rd}/\beta - \sum_1^1 F_{ti,Rd} = 514{,}98 - 221{,}82$	293,16	Web panel - shear
$F_{c,wc,Rd} - \sum_1^1 F_{tj,Rd} = 1097{,}53 - 221{,}82$	875,71	Column web - compression
$F_{c,fb,Rd} - \sum_1^1 F_{tj,Rd} = 804{,}98 - 221{,}82$	583,16	Beam flange - compression
$F_{t,fc,Rd(2+1)} - \sum_1^1 F_{tj,Rd} = 380{,}22 - 221{,}82$	158,40	Column flange - tension - group
$F_{t,wc,Rd(2+1)} - \sum_1^1 F_{tj,Rd} = 464{,}29 - 221{,}82$	242,48	Column web - tension - group
$F_{t,ep,Rd(2+1)} - \sum_1^1 F_{tj,Rd} = 482{,}93 - 221{,}82$	261,11	Front plate - tension - group
$F_{t,wb,Rd(2+1)} - \sum_1^1 F_{tj,Rd} = 844{,}68 - 221{,}82$	622,87	Beam web - tension - group

SUMMARY TABLE OF FORCES

Nr	h_j	$F_{tj,Rd}$	$F_{t,fc,Rd}$	$F_{t,wc,Rd}$	$F_{t,ep,Rd}$	$F_{t,wb,Rd}$	$F_{t,Rd}$	$B_{p,Rd}$
1	148	221,82	221,82	432,22	282,24	692,61	282,24	552,46
2	78	158,40	211,42	412,07	282,24	583,53	282,24	552,46

CONNECTION RESISTANCE FOR BENDING $M_{j,Rd}$

$M_{j,Rd} = \sum h_j F_{tj,Rd}$

$M_{j,Rd} =$ 45,17 [kN*m] Connection resistance for bending [6.2]

$M_{b1,Ed} / M_{j,Rd} \leq 1,0$ 0,69 < 1,00 verified (0,69)

VERIFICATION OF M+N INTERACTION

$M_{b1,Ed} / M_{j,Rd} + N_{b1,Ed} / N_{j,Rd} \leq 1$ [6.2.5.1.(3)]

$M_{b1,Ed} / M_{j,Rd} + N_{b1,Ed} / N_{j,Rd}$ 0,78 < 1,00 verified (0,78)

CONNECTION RESISTANCE FOR SHEAR

$\alpha_v =$ 0,60 Coefficient for calculation of $F_{v,Rd}$ [Table 3.4]

$F_{v,Rd} =$ 94,08 [kN] Shear resistance of a single bolt [Table 3.4]

$F_{t,Rd,max} =$ 141,12 [kN] Tensile resistance of a single bolt [Table 3.4]

$F_{b,Rd,int} =$ 197,98 [kN] Bearing resistance of an intermediate bolt [Table 3.4]

$F_{b,Rd,ext} =$ 244,24 [kN] Bearing resistance of an outermost bolt [Table 3.4]

Nr	$F_{tj,Rd,N}$	$F_{tj,Ed,N}$	$F_{tj,Rd,M}$	$F_{tj,Ed,M}$	$F_{tj,Ed}$	$F_{vj,Rd}$
1	282,24	-71,98	221,82	152,86	80,88	149,64
2	282,24	-71,98	158,40	109,16	37,18	170,45

$F_{tj,Rd,N}$ – Bolt row resistance for simple tension

$F_{tj,Ed,N}$ – Force due to axial force in a bolt row

$F_{tj,Rd,M}$ – Bolt row resistance for simple bending

$F_{tj,Ed,M}$ – Force due to moment in a bolt row

$F_{tj,Rd,N}$ – Bolt row resistance for simple tension

$F_{tj,Ed}$ – Maximum tensile force in a bolt row

$F_{vj,Rd}$ – Reduced bolt row resistance

$F_{tj,Ed,N} = N_{j,Ed} F_{tj,Rd,N} / N_{j,Rd}$

$F_{tj,Ed,M} = M_{j,Ed} F_{tj,Rd,M} / M_{j,Rd}$

$F_{tj,Ed} = F_{tj,Ed,N} + F_{tj,Ed,M}$

$F_{vj,Rd} = \text{Min} (n_h F_{v,Ed} (1 - F_{tj,Ed}/ (1.4\ n_h F_{t,Rd,max}), n_h F_{v,Rd} , n_h F_{b,Rd}))$

$V_{j,Rd} = n_h \sum_1^n F_{vj,Rd}$				[Table 3.4]
$V_{j,Rd}$ =	320,10	[kN]	Connection resistance for shear	[Table 3.4]

$V_{b1,Ed} / V_{j,Rd} \leq 1,0$	0,15 < 1,00	verified	(0,15)

WELD RESISTANCE

A_w =	4329	[mm²]	Area of all welds	[4.5.3.2(2)]
A_{wy} =	3042	[mm²]	Area of horizontal welds	[4.5.3.2(2)]
A_{wz} =	1286	[mm²]	Area of vertical welds	[4.5.3.2(2)]
I_{wy} =	31882231	[mm⁴]	Moment of inertia of the weld arrangement with respect to the hor. axis	[4.5.3.2(5)]
$\sigma_{\perp max}=\tau_{\perp max}$ =	-96,07	[MPa]	Normal stress in a weld	[4.5.3.2(6)]
$\sigma_{\perp}=\tau_{\perp}$ =	-79,02	[MPa]	Stress in a vertical weld	[4.5.3.2(5)]
τ_{II} =	36,72	[MPa]	Tangent stress	[4.5.3.2(5)]
β_w =	0,85		Correlation coefficient	[4.5.3.2(7)]

$\sqrt{[\sigma_{\perp max}^2 + 3*(\tau_{\perp max}^2)]} \leq f_u/(\beta_w*\gamma_{M2})$	192,13 < 404,71	verified	(0,47)
$\sqrt{[\sigma_{\perp}^2 + 3*(\tau_{\perp}^2+\tau_{II}^2)]} \leq f_u/(\beta_w*\gamma_{M2})$	170,35 < 404,71	verified	(0,42)
$\sigma_{\perp} \leq 0.9*f_u/\gamma_{M2}$	96,07 < 309,60	verified	(0,31)

CONNECTION STIFFNESS

t_{wash} =	4	[mm]	Washer thickness	[6.2.6.3.(2)]
h_{head} =	14	[mm]	Bolt head height	[6.2.6.3.(2)]
h_{nut} =	20	[mm]	Bolt nut height	[6.2.6.3.(2)]
L_b =	59	[mm]	Bolt length	[6.2.6.3.(2)]
k_{10} =	7	[mm]	Stiffness coefficient of bolts	[6.3.2.(1)]

STIFFNESSES OF BOLT ROWS

Nr	hj	k_3	k_4	k_5	$k_{eff,j}$	$k_{eff,j}\ h_j$	$k_{eff,j}\ h_j^2$
					Sum	369	46505
1	148	7	5	12	2	254	37563
2	78	6	4	9	1	115	8942

$k_{eff,j} = 1 / (\sum_3^5 (1 / k_{i,j}))$ [6.3.3.1.(2)]

$z_{eq} = \sum_j k_{eff,j}\ h_j^2 / \sum_j k_{eff,j}\ h_j$

$z_{eq} =$ 126 [mm] Equivalent force arm [6.3.3.1.(3)]

$k_{eq} = \sum_j k_{eff,j}\ h_j / z_{eq}$

$k_{eq} =$ 3 [mm] Equivalent stiffness coefficient of a bolt arrangement [6.3.3.1.(1)]

$k_1 = \infty$ Stiffness coefficient of the column web panel subjected to shear [6.3.2.(1)]

$k_2 = \infty$ Stiffness coefficient of the compressed column web [6.3.2.(1)]

$S_{j,ini} = E\ z_{eq}^2 / \sum_i (1 / k_1 + 1 / k_2 + 1 / k_{eq})$ [6.3.1.(4)]

$S_{j,ini} =$ 9533,61 [kN*m] Initial rotational stiffness [6.3.1.(4)]

$\mu =$ 1,09 Stiffness coefficient of a connection [6.3.1.(6)]

$S_j = S_{j,ini} / \mu$ [6.3.1.(4)]

$S_j =$ 8717,76 [kN*m] Final rotational stiffness [6.3.1.(4)]

Connection classification due to stiffness.

$S_{j,rig} =$ 15401,36 [kN*m] Stiffness of a rigid connection [5.2.2.5]

$S_{j,pin} =$ 962,58 [kN*m] Stiffness of a pinned connection [5.2.2.5]

$S_{j,pin} \le S_{j,ini} < S_{j,rig}$ SEMI-RIGID

WEAKEST COMPONENT:

COLUMN FLANGE - TENSION

Connection conforms to the code	Ratio	0,78

APPENDIX B

Retaining wall

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 2.6.06

Retaining wall details

Stem type;	Cantilever
Stem height;	h_{stem} = **1500** mm
Stem thickness;	t_{stem} = **750** mm
Angle to rear face of stem;	α = **90** deg
Stem density;	γ_{stem} = **25** kN/m^3
Toe length;	l_{toe} = **1750** mm
Heel length;	l_{heel} = **0** mm
Base thickness;	t_{base} = **300** mm
Base density;	γ_{base} = **25** kN/m^3
Height of retained soil;	h_{ret} = **1300** mm
Angle of soil surface;	β = **0** deg
Depth of cover;	d_{cover} = **200** mm
Height of water;	h_{water} = **1300** mm
Water density;	γ_w = **9.8** kN/m^3

Retained soil properties

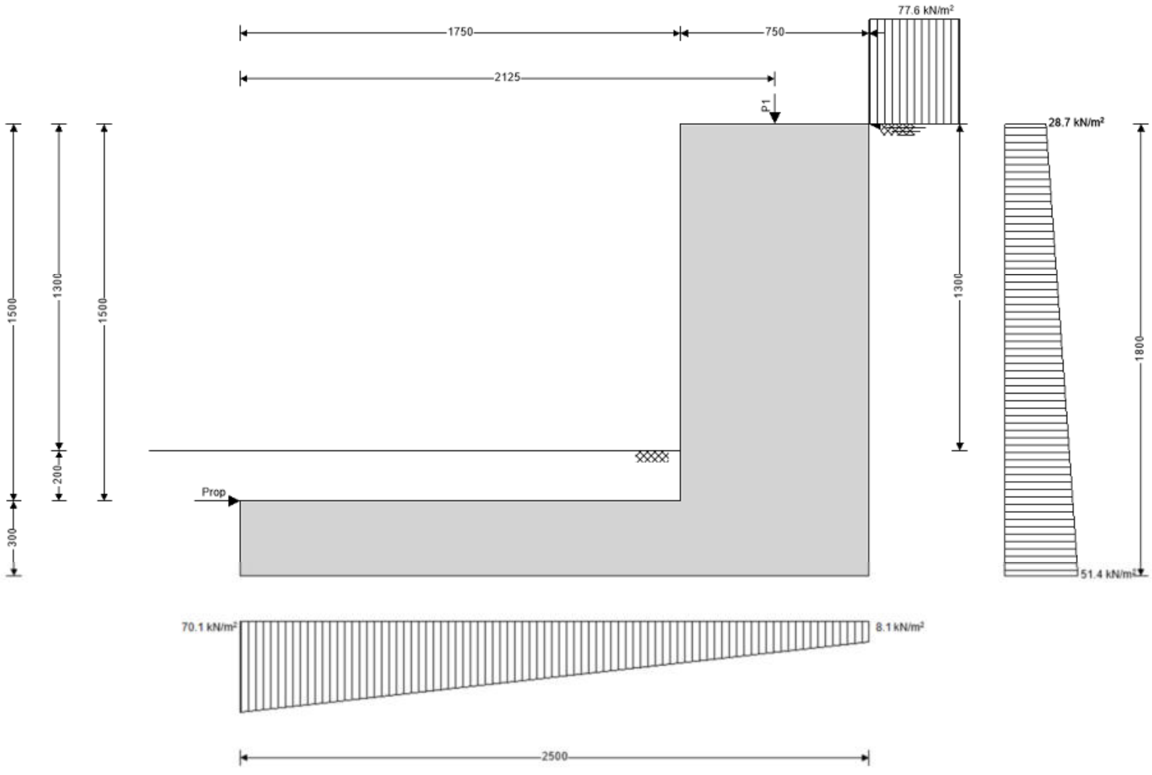
Soil type;	Soft sandy clay
Moist density;	γ_{mr} = **17** kN/m^3
Saturated density;	γ_{sr} = **17** kN/m^3
Characteristic effective shear resistance angle;	$\phi'_{r.k}$ = **26** deg
Characteristic wall friction angle;	$\delta_{r.k}$ = **13** deg

Base soil properties

Soil type;	Dense gravel
Soil density;	γ_b = **18** kN/m^3
Characteristic effective shear resistance angle;	$\phi'_{b.k}$ = **36** deg
Characteristic wall friction angle;	$\delta_{b.k}$ = **18** deg
Characteristic base friction angle;	$\delta_{bb.k}$ = **24** deg
Presumed bearing capacity;	$P_{bearing}$ = 120 kN/m^2

Loading details

Permanent surcharge load;	$Surcharge_G$ = **67.6** kN/m^2
Variable surcharge load;	$Surcharge_Q$ = **10** kN/m^2
Vertical line load at 2125 mm;	P_{G1} = **44.6** kN/m
Horizontal line load at 1500 mm;	P_{G2} = **14.5** kN/m
;	P_{Q2} = **3.5** kN/m



General arrangement

Calculate retaining wall geometry

Base length; $l_{base} = l_{toe} + t_{stem} + l_{heel} = \mathbf{2500}$ mm

Saturated soil height; $h_{sat} = h_{water} + d_{cover} = \mathbf{1500}$ mm

Moist soil height; $h_{moist} = h_{ret} - h_{water} = \mathbf{0}$ mm

Length of surcharge load; $l_{sur} = l_{heel} = \mathbf{0}$ mm

- Distance to vertical component; $x_{sur\_v} = l_{base} - l_{heel} / 2 = \mathbf{2500}$ mm

Effective height of wall; $h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{1800}$ mm

- Distance to horizontal component; $x_{sur\_h} = h_{eff} / 2 = \mathbf{900}$ mm

Area of wall stem; $A_{stem} = h_{stem} \times t_{stem} = \mathbf{1.125}$ m^2

- Distance to vertical component; $x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{2125}$ mm

Area of wall base; $A_{base} = l_{base} \times t_{base} = \mathbf{0.75}$ m^2

- Distance to vertical component; $x_{base} = l_{base} / 2 = \mathbf{1250}$ mm

Area of saturated soil; $A_{sat} = h_{sat} \times l_{heel} = \mathbf{0}$ m^2

- Distance to vertical component; $x_{sat\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat} = \mathbf{2500}$ mm
- Distance to horizontal component; $x_{sat\_h} = (h_{sat} + h_{base}) / 3 = \mathbf{600}$ mm

Area of water; $A_{water} = h_{sat} \times l_{heel} = \mathbf{0}$ m^2

- Distance to vertical component; $x_{water\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat} = \mathbf{2500}$ mm
- Distance to horizontal component; $x_{water\_h} = (h_{sat} + h_{base}) / 3 = \mathbf{600}$ mm

Area of base soil; $A_{pass} = d_{cover} \times l_{toe} = \mathbf{0.35}$ m^2

- Distance to vertical component; $x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = \mathbf{875}$ mm
- Distance to horizontal component; $x_{pass\_h} = (d_{cover} + h_{base}) / 3 = \mathbf{167}$ mm

Area of excavated base soil;	$A_{exc} = h_{pass} \times l_{toe}$ = **0.35** m^2
- Distance to vertical component;	$x_{exc\_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc}$ = **875** mm
- Distance to horizontal component;	$x_{exc\_h} = (h_{pass} + h_{base}) / 3$ = **167** mm

Using Rankine theory

Active pressure coefficient;	$K_A = (1 - \sin(\phi'_{r.k})) / (1 + \sin(\phi'_{r.k}))$ = **0.390**
Passive pressure coefficient;	$K_P = (1 + \sin(\phi'_{b.k})) / (1 - \sin(\phi'_{b.k}))$ = **3.852**

Bearing pressure check

Vertical forces on wall

Wall stem;	$F_{stem} = A_{stem} \times \gamma_{stem}$ = **28.1** kN/m
Wall base;	$F_{base} = A_{base} \times \gamma_{base}$ = **18.8** kN/m
Surcharge load;	$F_{sur\_v} = (Surcharge_G + Surcharge_Q) \times l_{heel}$ = **0** kN/m
Line loads;	$F_{P\_v} = P_{G1}$ = **44.6** kN/m
Saturated retained soil;	$F_{sat\_v} = A_{sat} \times (\gamma_{sr}' - \gamma_w')$ = **0** kN/m
Water;	$F_{water\_v} = A_{water} \times \gamma_w'$ = **0** kN/m
Base soil;	$F_{pass\_v} = A_{pass} \times \gamma_b'$ = **6.3** kN/m
Total;	$F_{total\_v} = F_{stem} + F_{base} + F_{sat\_v} + F_{pass\_v} + F_{water\_v} + F_{sur\_v} + F_{P\_v}$ = **97.7** kN/m

Horizontal forces on wall

Surcharge load;	$F_{sur\_h} = K_A \times (Surcharge_G + Surcharge_Q) \times h_{eff}$ = **54.5** kN/m
Line loads;	$F_{P\_h} = P_{G2} + P_{Q2}$ = **18** kN/m
Saturated retained soil;	$F_{sat\_h} = K_A \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2$ = **4.5** kN/m
Water;	$F_{water\_h} = \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2$ = **15.9** kN/m
Base soil;	$F_{pass\_h} = -K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2$ = **-8.7** kN/m
Total;	$F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{pass\_h} + F_{water\_h} + F_{sur\_h} + F_{P\_h}$ = **84.2** kN/m

Moments on wall

Wall stem;	$M_{stem} = F_{stem} \times x_{stem}$ = **59.8** kNm/m
Wall base;	$M_{base} = F_{base} \times x_{base}$ = **23.4** kNm/m
Surcharge load;	$M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h}$ = **-49.1** kNm/m
Line loads;	$M_P = P_{G1} \times p_1 - ((P_{G2} + P_{Q2}) \times (p_2 + t_{base}))$ = **62.4** kNm/m
Saturated retained soil;	$M_{sat} = F_{sat\_v} \times x_{sat\_v} - F_{sat\_h} \times x_{sat\_h}$ = **-2.7** kNm/m
Water;	$M_{water} = F_{water\_v} \times x_{water\_v} - F_{water\_h} \times x_{water\_h}$ = **-9.5** kNm/m
Base soil;	$M_{pass} = F_{pass\_v} \times x_{pass\_v}$ = **5.5** kNm/m
Total;	$M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{pass} + M_{water} + M_{sur} + M_P$ =**89.8** kNm/m

Check bearing pressure

Propping force;	$F_{prop\_base} = F_{total\_h}$ = **84.2** kN/m
Distance to reaction;	$\bar{x} = M_{total} / F_{total\_v}$ = **919** mm
Eccentricity of reaction;	$e = \bar{x} - l_{base} / 2$ = **-331** mm
Loaded length of base;	$l_{load} = l_{base}$ = **2500** mm
Bearing pressure at toe;	$q_{toe} = F_{total\_v} / l_{base} \times (1 - 6 \times e / l_{base})$ = **70.1** kN/m^2
Bearing pressure at heel;	$q_{heel} = F_{total\_v} / l_{base} \times (1 + 6 \times e / l_{base})$ = **8.1** kN/m^2
Factor of safety;	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel})$ = **1.71**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure