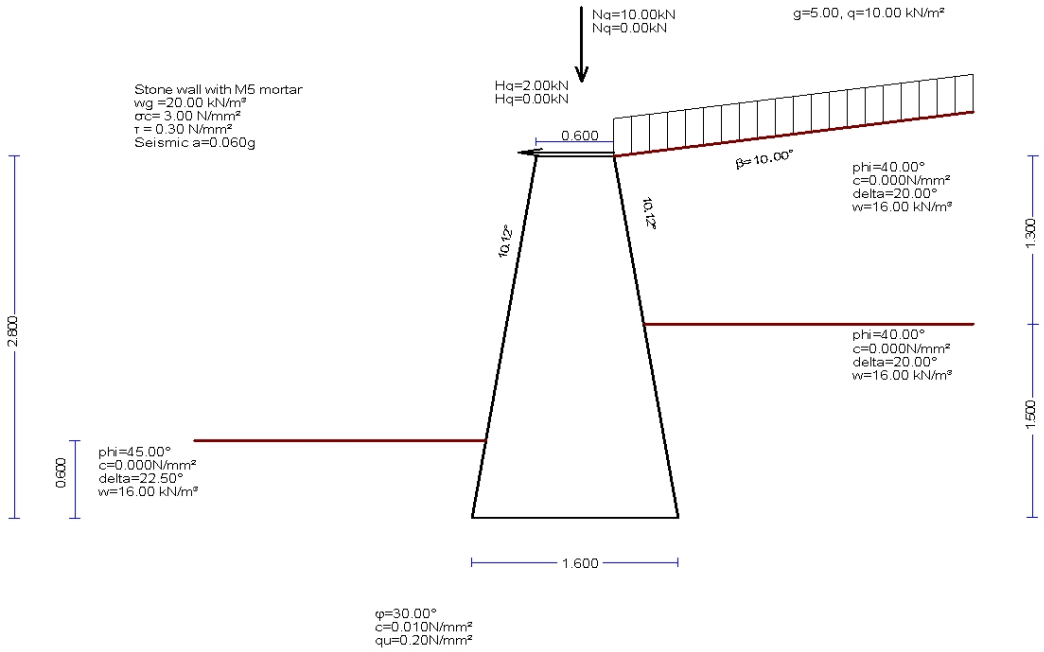
CONTENTS

Example of retaining walls

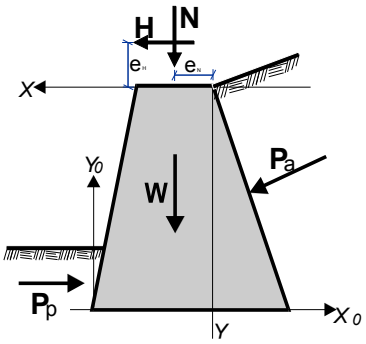
1. G. WALL-001

Gravity retaining wall

(EC2 EN1992-1-1:2004, EC0 EN1990-1-1:2002, EC7 EN1997-1-1:2004, EC8 EN1998-5:2004)



1.1. Wall properties-Parameters-Code requirements



Dimensions

Height of wall	h= 2.800 m
Transverse length of wall	L=10.000 m
Width of wall at top	B1= 0.600 m
Width of wall at base	B= 1.600 m
Slope (batter) at frontface	10.125° (1:5.60)
Slope (batter) at backface	10.125° (1:5.60)

Loads on wall top

Vertical permanent load	Ng= 10.00 kN/m
Vertical variable load	Nq= 0.00 kN/m
Eccentricity of vertical load	eN= 0.25 kN/m
Horizontal permanent load	Hg= 2.00 kN/m
Horizontal variable load	Hq= 0.00 kN/m
Eccentricity of horizontal load	eH= 0.00 kN/m

Weight of wall

Unit weight of wall material γg=20.000 kN/m³
Cross section area of wall A= 3.080 m²
Self weight per meter of wall W= 3.080x20.000= 61.60 kN/m
Center of gravity of wall at x=0.300 m, y=1.612 m (xo=0.800 m, yo=1.188 m)

Wall materials

Allowable compressive stress	3.00 N/mm²
Allowable tensile stress	0.00 N/mm²
Allowable shear stress	0.30 N/mm²

1.2. Partial factors for actions and soil properties

(EC7 Tables A.1-A.4, EC8-5 §3.1)

Equilibrium limit state (EQU), Structural limit state (STR), Geotechnical limit state (GEO)

				(EQU)	(STR)	(GEO)	(SEISMIC)
Actions	Permanent Unfavourable	γGdst:	1.10	1.35	1.00	1.00	
	Permanent Favourable	γGstb:	0.90	1.00	1.00	1.00	
	Variable Unfavourable	γQdst:	1.50	1.50	1.30	1.00	
	Variable Favourable	γQstb:	0.00	0.00	0.00	0.00	
Soil parameters	Angle of shearing resistance	γφ:	1.25	1.00	1.25	1.25	
	Effective cohesion	γc:	1.25	1.00	1.25	1.25	
	Undrained shear strength	γcu:	1.40	1.00	1.40	1.40	
	Unconfined strength	γqu:	1.40	1.00	1.40	1.40	
	Weight density	γw:	1.00	1.00	1.00	1.00	

1.3. Properties of foundation soil

Bearing capacity of foundation soil qu=0.20 N/mm²
Friction angle between wall footing and soil φ=30.00°, friction coefficient tan(φ)=0.577
Cohesion between wall footing and soil c=0.010 N/mm²

1.4. Seismic coefficients

(EC8 EN1998-5:2004, §7.3.2)

Design ground acceleration ratio	gh=axg, a=0.06	(EC8-5 §7.3.2)
Reduction factor for seismic coefficient	r=1.50	(EC8-5 Table 7.1)
Coefficient for horizontal seismic force	kh=0.06/1.500=0.040	(EC8-5 Eq.7.1)
Coefficient for vertical seismic force	kv=0.50x0.040=0.020	(EC8-5 Eq.7.2)

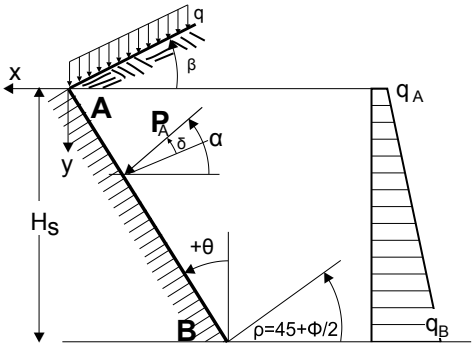
Forces due to seismic load (except from earth pressure)

Horizontal seismic force due to self weight	Fwx= 61.60x0.040=	2.46 kN/m
Vertical seismic force due to self weight	Fwy= 61.60x0.020=	1.23 kN/m
Horizontal seismic force of top loading Ng	Fgx= 10.00x0.040=	0.40 kN/m
Vertical seismic force of top loading Ng	Fgy= 10.00x0.020=	0.20 kN/m

1.5. Computation of active earth pressure (Coulomb theory)

1.5.1. Wall part from y=0.000 m to y=1.300 m, Hs=1.300 m

Top point A x= 0.000 m y= 0.000 m
Bottom point B x=-0.232 m y= 1.300 m



Soil properties

Soil type : Mean gravel

Unit weight of soil	γ =16.00 kN/m³
Unit weight of soil (saturated)	γs=20.00 kN/m³
Unit weight of water	γw=10.00 kN/m³
Angle of shearing resistance of ground	φ=40.00°
Cohesion of ground	c=0.000 N/mm²
Slope angle of ground surface	β=10.00°
Inclination angle of the wall backface	θ=10.12°
Angle of shear resist. between ground-wall	δ=20.00°

Loads on soil surface

Permanent uniform load	g= 5.00 kN/m²
Variable uniform load	q= 10.00 kN/m²

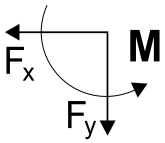
Earth pressure according to Coulomb theory

$$K_A = \frac{\cos^2(\varphi-\theta)}{\cos^2\theta\,\cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\theta+\delta)\sin(\theta-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$

		EQU	STR	GEO
Angle of rupture plane ρ=45°+φ/2	=	61.00	65.00	61.00°
Coefficient of active earth pressure Ka=		0.408	0.308	0.408

Earth pressure q(y)=qA+γ·y·Ka

Permanent actions



		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	1.98	1.49	1.98	kN/m²
Earth pressure at the bottom (y=yA+ 1.30m)	qB=	10.47	7.90	10.47	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	8.09	6.10	8.09	kN/m
Angle of earth force	α =	24.10	30.12	24.10	°
Earth force in x direction	Pax=	7.00	5.28	7.00	kN/m
Earth force in y direction	Pay=	4.06	3.06	4.06	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-6.16	-4.65	-6.16	kNm/m

Point of application of earth force x= -0.142 m, y= 0.798 m

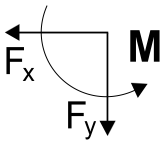
Variable actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	3.96	2.99	3.96	kN/m²
Earth pressure at the bottom (y=yA+ 1.30m)	qB=	3.96	2.99	3.96	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	5.15	3.89	5.15	kN/m
Angle of earth force	α =	24.10	30.12	24.10	°
Earth force in x direction	Pax=	4.45	3.36	4.45	kN/m
Earth force in y direction	Pay=	2.58	1.95	2.58	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-3.19	-2.41	-3.19	kNm/m

Point of application of earth force x= -0.116 m, y= 0.650 m

Total forces and moments

Forces and moments at bottom point B (x=-0.232 m, y=1.300 m)



Permanent actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	7.00	5.28	7.00	kN/m
Total vertical earth force	Fsy=	4.06	3.06	4.06	kN/m
Total moment of earth force	Ms =	3.88	2.93	3.88	kNm/m

Variable actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	4.45	3.36	4.45	kN/m
Total vertical earth force	Fsy=	2.58	1.95	2.58	kN/m
Total moment of earth force	Ms =	3.19	2.41	3.19	kNm/m

Seismic loading (EC8 EN1998-5:2004, §7.3.2, Annex E)

Horizontal seismic coefficient kh=0.06/1.500=0.040 (EC8-5 Eq.7.1, T.7.1)
Vertical seismic coefficient kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)
Soil above the water table (EC8-5 Annex E.5)
tan(ω)=kh/(1-kv)=0.040/(1-0.020)=0.041, ω=2.34°

Method Mononobe-Okabe (EC8-5 Annex E.4)
for active earth force during seismic loading

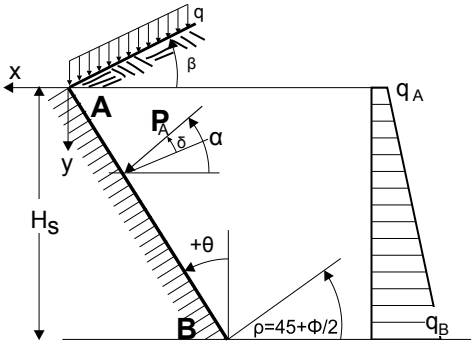
$$K_E = \frac{\cos^2(\varphi-\omega-\theta)}{\cos\omega\,\cos^2\theta\,\cos(\delta+\theta+\omega)\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\omega-\beta)}{\cos(\theta+\omega+\delta)\cos(\theta-\beta)}}\right]^2}$$

Coefficient of active earth pressure, Ke*= 0.437
Additional earth pressure due to seismic load
over STR load case ξ=(Ke*/Ke-1)=(0.437/0.308-1)=0.419

Earth force due to seismic load (Permanent actions) Fx=1.419x 5.28= 7.49 kN/m
Earth force due to seismic load (Variable actions) Fx=1.419x 3.36= 4.77 kN/m

1.5.2. Wall part from y=1.300 m to y=2.800 m, Hs=1.500 m

Top point A x=-0.232 m y= 1.300 m
Bottom point B x=-0.500 m y= 2.800 m



Soil properties

Soil type : Mean gravel

Unit weight of soil	γ	=16.00 kN/m³
Unit weight of soil (saturated)	γs	=20.00 kN/m³
Unit weight of water	γw	=10.00 kN/m³
Angle of shearing resistance of ground	φ	=40.00°
Cohesion of ground	c	=0.000 N/mm²
Slope angle of ground surface	β	= 0.00°
Inclination angle of the wall backface	θ	=10.12°
Angle of shear resist. between ground-wall	δ	=20.00°

Loads on soil surface

Permanent uniform load	g	= 25.80 kN/m²
Variable uniform load	q	= 10.00 kN/m²

Earth pressure according to Coulomb theory

$$K_A = \frac{\cos^2(\varphi-\theta)}{\cos^2\theta\,\cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\theta+\delta)\sin(\theta-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$

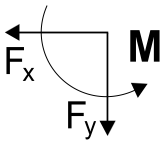
	EQU	STR	GEO
Angle of rupture plane ρ=45°+φ/2	= 61.00	65.00	61.00°
Coefficient of active earth pressure Ka=	0.356	0.274	0.356

Earth pressure q(y)=qA+γ·y·Ka

Permanent actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	9.18	7.07	9.18	kN/m²
Earth pressure at the bottom (y=yA+ 1.50m)	qB=	17.72	13.65	17.72	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	20.17	15.54	20.17	kN/m
Angle of earth force	α =	24.10	30.12	24.10	°
Earth force in x direction	Pax=	17.45	13.44	17.45	kN/m
Earth force in y direction	Pay=	10.12	7.80	10.12	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-41.00	-31.58	-41.00	kNm/m

Point of application of earth force x= -0.380 m, y= 2.129 m



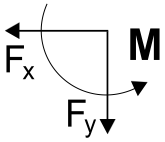
Variable actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	3.56	2.74	3.56	kN/m²
Earth pressure at the bottom (y=yA+ 1.50m)	qB=	3.56	2.74	3.56	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	5.34	4.11	5.34	kN/m
Angle of earth force	α =	24.10	30.12	24.10	°
Earth force in x direction	Pax=	4.62	3.55	4.62	kN/m
Earth force in y direction	Pay=	2.68	2.06	2.68	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-10.45	-8.03	-10.45	kNm/m

Point of application of earth force x= -0.366 m, y= 2.050 m

Total forces and moments

Forces and moments at bottom point B (x=-0.500 m, y=2.800 m)



Permanent actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	24.45	18.72	24.45	kN/m
Total vertical earth force	Fsy=	14.18	10.86	14.18	kN/m
Total moment of earth force	Ms =	28.39	21.62	28.39	kNm/m

Variable actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	9.07	6.91	9.07	kN/m
Total vertical earth force	Fsy=	5.26	4.01	5.26	kN/m
Total moment of earth force	Ms =	14.38	10.91	14.38	kNm/m

Seismic loading (EC8 EN1998-5:2004, §7.3.2, Annex E)

Horizontal seismic coefficient kh=0.06/1.500=0.040 (EC8-5 Eq.7.1, T.7.1)
Vertical seismic coefficient kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)
Soil above the water table (EC8-5 Annex E.5)
tan(ω)=kh/(1-kv)=0.040/(1-0.020)=0.041, ω=2.34°

Method Mononobe-Okabe (EC8-5 Annex E.4)
for active earth force during seismic loading
Coefficient of active earth pressure, Ke*= 0.377
Additional earth pressure due to seismic load
over STR load case ξ=(Ke*/Ke-1)=(0.377/0.274-1)=0.376

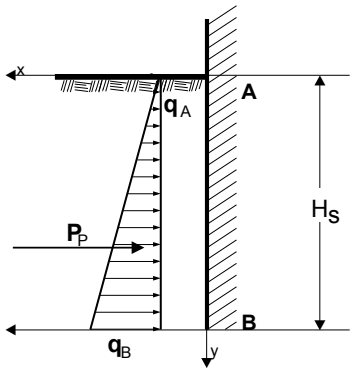
$$K_E=\frac{\cos^2(\varphi-\omega-\theta)}{\cos\omega\cos^2\theta\cos(\delta+\theta+\omega)\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\omega-\beta)}{\cos(\theta+\omega+\delta)\cos(\theta-\beta)}}\right]^2}$$

Earth force due to seismic load (Permanent actions) Fx=1.376x13.44=18.49 kN/m
Earth force due to seismic load (Variable actions) Fx=1.376x 3.55= 4.88 kN/m

1.6. Computation of passive earth pressure (Rankine theory)

1.6.1. Wall part from y=2.200 m to y=2.800 m, Hs=0.600 m

Top point A x= 0.993 m y= 2.200 m
Bottom point B x= 0.993 m y= 2.800 m



Soil properties

Soil type : Large gravel
Unit weight of soil γ =16.00 kN/m³
Unit weight of soil (saturated) γs=20.00 kN/m³
Unit weight of water γw=10.00 kN/m³
Angle of shearing resistance of ground φ=45.00°
Cohesion of ground c=0.000 N/mm²
Slope angle of ground surface β= 0.00°
Earth pressure on vertical surface θ= 0.00°
Angle of shear resist. between ground-wall δ= 0.00°

Earth pressure according to Coulomb theory

$$K_p=\frac{\cos^2(\varphi+\theta)}{\cos^2\theta\cos(\theta-\delta)\left[1-\sqrt{\frac{\sin(\theta+\delta)\sin(\theta+\beta)}{\cos(\theta-\delta)\cos(\theta-\beta)}}\right]^2}$$

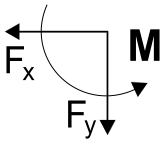
	EQU	STR	GEO
Angle of rupture plane ρ=45°-φ/2	= 27.00	22.50	27.00°
Coefficient of passive earth pressure Kp=	3.852	5.828	3.852

Earth pressure q(y)=qA+γ·y·Kp

Permanent actions

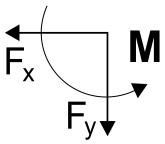
		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.00	0.00	0.00	kN/m²
Earth pressure at the bottom (y=yA+ 0.60m)	qB=	-36.98	-55.95	-36.98	kN/m²
Earth force Pa=½(qA+qB)H	Pp=	11.09	16.78	11.09	kN/m
Angle of earth force	α =	0.00	0.00	0.00	°
Earth force in x direction	Ppx=	-11.09	-16.78	-11.09	kN/m
Earth force in y direction	Ppy=	0.00	0.00	0.00	kN/m
Moment of earth force at top point (x=0,y=0)	M =	28.83	43.63	28.83	kNm/m

Point of application of earth force x= 0.993 m, y= 2.600 m



Total forces and moments

Forces and moments at bottom point B (x=0.993 m, y=2.800 m)



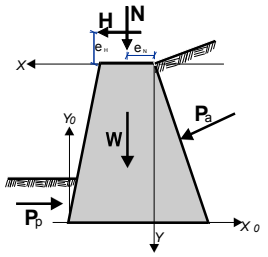
Permanent actions

	EQU	STR	GEO	
Total horizontal earth force Fsx=	-11.09	-16.78	-11.09	kN/m
Total vertical earth force Fsy=	0.00	0.00	0.00	kN/m
Total moment of earth force Ms =	-2.22	-3.36	-2.22	kNm/m

1.7. Checks of wall stability (EQU)

1.7.1. Forces (driving and resisting) on the wall (EQU)

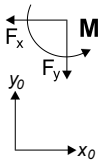
Action		y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa	0.00- 1.30	7.00	4.06	-0.142	0.798
Backfill surcharge (live)	Pq	0.00- 1.30	4.45	2.58	-0.116	0.650
Active earth pressure	Pa	1.30- 2.80	17.45	10.12	-0.380	2.129
Backfill surcharge (live)	Pq	1.30- 2.80	4.62	2.68	-0.366	2.050
Passive earth pressure	Pp	2.20- 2.80	-11.09	0.00	0.993	2.600
Wall weight	W		0.00	61.60	0.300	1.612
Vert. load on top (dead)	Ng		0.00	10.00	0.250	0.000
Horiz. load on top (dead)	Hg		2.00	0.00	0.300	0.000



1.7.2. Check of soil bearing capacity (EQU)

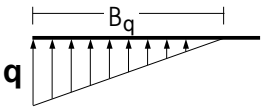
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 0.90x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	M [m]	[kNm/m]
Active earth pressure	Pax1.10	0.00- 1.30	7.70	4.47	1.242	2.002	9.87	
Backfill surcharge (live)	Pqx1.50	0.00- 1.30	6.68	3.87	1.216	2.150	9.64	
Active earth pressure	Pax1.10	1.30- 2.80	19.20	11.13	1.480	0.671	-3.60	
Backfill surcharge (live)	Pqx1.50	1.30- 2.80	6.93	4.02	1.466	0.750	-0.70	
Wall weight	W x0.90		0.00	55.44	0.800	1.188	-44.35	
Vert. load on top (dead)	Ngx0.90		0.00	9.00	0.850	2.800	-7.65	
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	0.800	2.800	6.16	
			Sum=	87.93			-30.63	

Sum of vertical forces = 87.93 kN/m
Sum of moments at front toe = -30.63 kNm/m
Sum of moments at middle of base = 39.71 kNm/m
Eccentricity ec=39.71/87.93=0.452m, ec>1.600/6=0.267m
Soil pressure q=0.168 N/mm² Bq=1.045 m

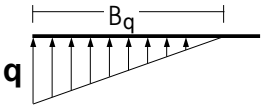


Effective footing L=1.600-2x0.452= 0.697 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.697x(1000x0.20)/1.40= 99.57 kN/m
Bearing resistance check Vd=87.93 < Rd=99.57 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

Check for 1.10x(self weight+top vertical dead load)+1.50x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	M [m]	[kNm/m]
Active earth pressure	Pax1.10	0.00- 1.30	7.70	4.47	1.242	2.002	9.87	
Backfill surcharge (live)	Pqx1.50	0.00- 1.30	6.68	3.87	1.216	2.150	9.64	
Active earth pressure	Pax1.10	1.30- 2.80	19.20	11.13	1.480	0.671	-3.60	
Backfill surcharge (live)	Pqx1.50	1.30- 2.80	6.93	4.02	1.466	0.750	-0.70	
Wall weight	W x1.10		0.00	67.76	0.800	1.188	-54.21	
Vert. load on top (dead)	Ngx1.10		0.00	11.00	0.850	2.800	-9.35	
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	0.800	2.800	6.16	
			Sum=	102.25			-42.19	

Sum of vertical forces = 102.25 kN/m
Sum of moments at front toe = -42.19 kNm/m
Sum of moments at middle of base = 39.61 kNm/m
Eccentricity ec=39.61/102.25=0.387m, ec>1.600/6=0.267m
Soil pressure q=0.165 N/mm² Bq=1.238 m



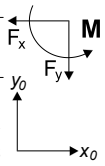
Effective footing L=1.600-2x0.387= 0.825 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.825x(1000x0.20)/1.40= 117.86 kN/m
Bearing resistance check Vd=102.25 < Rd=117.86 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

1.7.3. Failure check due to overturning (EQU)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.100,y=2.800 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.10	0.00- 1.30	7.70	4.47	1.242	2.002	15.41	5.54
Backfill surcharge (live)	Pqx1.50	0.00- 1.30	6.68	3.87	1.216	2.150	14.36	4.71
Active earth pressure	Pax1.10	1.30- 2.80	19.20	11.13	1.480	0.671	12.88	16.48
Backfill surcharge (live)	Pqx1.50	1.30- 2.80	6.93	4.02	1.466	0.750	5.19	5.90
Wall weight	W x0.90		0.00	55.44	0.800	1.188	0.00	44.35
Vert. load on top (dead)	Ngx0.90		0.00	9.00	0.850	2.800	0.00	7.65
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	0.800	2.800	6.16	0.00
					Sum=		54.00	84.63

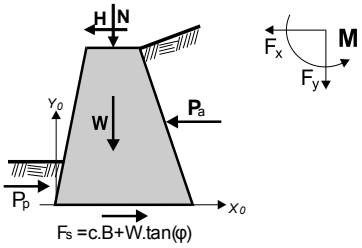


Sum of overturning moments = 54.00 kNm/m
Sum of moments resisting overturning = 84.63 kNm/m
Overturning check Msd=54.00 < Mrd=84.63 kNm/m, Check is verified

1.7.4. Failure check against sliding (EQU)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.10	0.00- 1.30	7.70	0.00	4.47
Backfill surcharge (live)	Pqx1.50	0.00- 1.30	6.68	0.00	3.87
Active earth pressure	Pax1.10	1.30- 2.80	19.20	0.00	11.13
Backfill surcharge (live)	Pqx1.50	1.30- 2.80	6.93	0.00	4.02
Passive earth pressure	Ppx0.90	2.20- 2.80	0.00	9.98	0.00
Wall weight	W x0.90		0.00	0.00	55.44
Vert. load on top (dead)	Ngx0.90		0.00	0.00	9.00
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	0.00
		Sum=	42.71	9.98	87.93

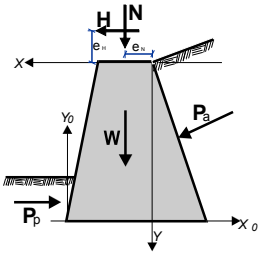


Soil friction Rd=Vd·tanφ/γM= 87.93xtan(30.00°)/1.25= 40.61 kN/m
Soil cohesion Rd=A·cu/γM = 1000x1.045x0.010/1.25= 8.36 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 42.71 kN/m
Sum of resisting forces (9.98+40.61) = 50.59 kN/m
Sliding resistance check Hd=42.71 < Rd=50.59 kN/m, Check is verified

1.8. Checks of wall stability (STR)

1.8.1. Forces (driving and resisting) on the wall (STR)

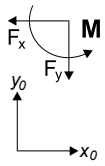
Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa 0.00- 1.30	5.28	3.06	-0.142	0.798
Backfill surcharge (live)	Pq 0.00- 1.30	3.36	1.95	-0.116	0.650
Active earth pressure	Pa 1.30- 2.80	13.44	7.80	-0.380	2.129
Backfill surcharge (live)	Pq 1.30- 2.80	3.55	2.06	-0.366	2.050
Passive earth pressure	Pp 2.20- 2.80	-16.78	0.00	0.993	2.600
Wall weight	W	0.00	61.60	0.300	1.612
Vert. load on top (dead)	Ng	0.00	10.00	0.250	0.000
Horiz. load on top (dead)	Hg	2.00	0.00	0.300	0.000



1.8.2. Check of soil bearing capacity (STR)

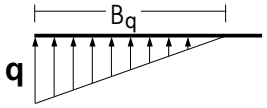
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 1.00x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.35	0.00- 1.30	7.13	4.13	1.242	2.002	9.14
Backfill surcharge (live)	Pqx1.50	0.00- 1.30	5.04	2.93	1.216	2.150	7.27
Active earth pressure	Pax1.35	1.30- 2.80	18.14	10.53	1.480	0.671	-3.40
Backfill surcharge (live)	Pqx1.50	1.30- 2.80	5.32	3.09	1.466	0.750	-0.54
Wall weight	W x1.00		0.00	61.60	0.800	1.188	-49.28
Vert. load on top (dead)	Ngx1.00		0.00	10.00	0.850	2.800	-8.50
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	0.800	2.800	7.56
			Sum=	92.28			-37.75

Sum of vertical forces = 92.28 kN/m
Sum of moments at front toe = -37.75 kNm/m
Sum of moments at middle of base = 36.07 kNm/m
Eccentricity ec=36.07/92.28=0.391m, ec>1.600/6=0.267m
Soil pressure q=0.150 N/mm² Bq=1.227 m

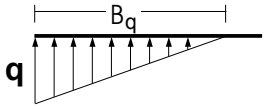


Effective footing L=1.600-2x0.391= 0.818 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.818x(1000x0.20)/1.00= 163.60 kN/m
Bearing resistance check Vd=92.28 < Rd=163.60 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

Check for 1.35x(self weight+top vertical dead load)+1.50x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.35	0.00- 1.30	7.13	4.13	1.242	2.002	9.14
Backfill surcharge (live)	Pqx1.50	0.00- 1.30	5.04	2.93	1.216	2.150	7.27
Active earth pressure	Pax1.35	1.30- 2.80	18.14	10.53	1.480	0.671	-3.40
Backfill surcharge (live)	Pqx1.50	1.30- 2.80	5.32	3.09	1.466	0.750	-0.54
Wall weight	W x1.35		0.00	83.16	0.800	1.188	-66.53
Vert. load on top (dead)	Ngx1.35		0.00	13.50	0.850	2.800	-11.48
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	0.800	2.800	7.56
			Sum=	117.34			-57.98

Sum of vertical forces = 117.34 kN/m
Sum of moments at front toe = -57.98 kNm/m
Sum of moments at middle of base = 35.89 kNm/m
Eccentricity ec=35.89/117.34=0.306m, ec>1.600/6=0.267m
Soil pressure q=0.158 N/mm² Bq=1.482 m

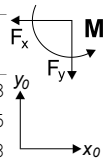


Effective footing L=1.600-2x0.306= 0.988 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.988x(1000x0.20)/1.00= 197.60 kN/m
Bearing resistance check Vd=117.34 < Rd=197.60 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

1.8.3. Failure check due to overturning (STR)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.100,y=2.800 m)



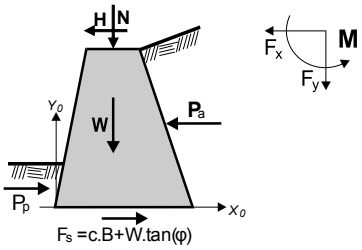
Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.35	0.00- 1.30	7.13	4.13	1.242	2.002	14.27	5.13
Backfill surcharge (live)	Pqx1.50	0.00- 1.30	5.04	2.93	1.216	2.150	10.83	3.55
Active earth pressure	Pax1.35	1.30- 2.80	18.14	10.53	1.480	0.671	12.18	15.58
Backfill surcharge (live)	Pqx1.50	1.30- 2.80	5.32	3.09	1.466	0.750	3.99	4.53
Wall weight	W x1.00		0.00	61.60	0.800	1.188	0.00	49.28
Vert. load on top (dead)	Ngx1.00		0.00	10.00	0.850	2.800	0.00	8.50
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	0.800	2.800	7.56	0.00
						Sum=	48.83	86.57

Sum of overturning moments = 48.83 kNm/m
Sum of moments resisting overturning = 86.57 kNm/m
Overturning check Msd=48.83 < Mrd=86.57 kNm/m, Check is verified

1.8.4. Failure check against sliding (STR)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.35	0.00- 1.30	7.13	0.00	4.13
Backfill surcharge (live)	Pqx1.50	0.00- 1.30	5.04	0.00	2.93
Active earth pressure	Pax1.35	1.30- 2.80	18.14	0.00	10.53
Backfill surcharge (live)	Pqx1.50	1.30- 2.80	5.32	0.00	3.09
Passive earth pressure	Ppx1.00	2.20- 2.80	0.00	16.78	0.00
Wall weight	W x1.00		0.00	0.00	61.60
Vert. load on top (dead)	Ngx1.00		0.00	0.00	10.00
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	0.00
		Sum=	38.33	16.78	92.28

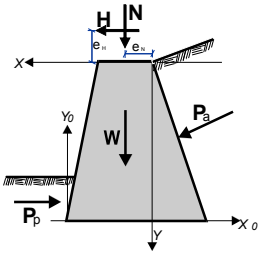


Soil friction Rd=Vd·tanφ/γM= 92.28xtan(30.00°)/1.00= 53.28 kN/m
Soil cohesion Rd=A·cu/γM = 1000x1.227x0.010/1.00= 12.27 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 38.33 kN/m
Sum of resisting forces (16.78+53.28) = 70.06 kN/m
Sliding resistance check Hd=38.33 < Rd=70.06 kN/m, Check is verified

1.9. Checks of wall stability (GEO)

1.9.1. Forces (driving and resisting) on the wall (GEO)

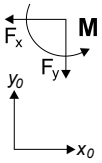
Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa 0.00- 1.30	7.00	4.06	-0.142	0.798
Backfill surcharge (live)	Pq 0.00- 1.30	4.45	2.58	-0.116	0.650
Active earth pressure	Pa 1.30- 2.80	17.45	10.12	-0.380	2.129
Backfill surcharge (live)	Pq 1.30- 2.80	4.62	2.68	-0.366	2.050
Passive earth pressure	Pp 2.20- 2.80	-11.09	0.00	0.993	2.600
Wall weight	W	0.00	61.60	0.300	1.612
Vert. load on top (dead)	Ng	0.00	10.00	0.250	0.000
Horiz. load on top (dead)	Hg	2.00	0.00	0.300	0.000



1.9.2. Check of soil bearing capacity (GEO)

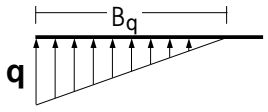
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 1.00x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.00	0.00- 1.30	7.00	4.06	1.242	2.002	8.97
Backfill surcharge (live)	Pqx1.30	0.00- 1.30	5.78	3.35	1.216	2.150	8.36
Active earth pressure	Pax1.00	1.30- 2.80	17.45	10.12	1.480	0.671	-3.27
Backfill surcharge (live)	Pqx1.30	1.30- 2.80	6.01	3.48	1.466	0.750	-0.61
Wall weight	W x1.00		0.00	61.60	0.800	1.188	-49.28
Vert. load on top (dead)	Ngx1.00		0.00	10.00	0.850	2.800	-8.50
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.800	2.800	5.60
			Sum=	92.61			-38.73

Sum of vertical forces = 92.61 kN/m
Sum of moments at front toe = -38.73 kNm/m
Sum of moments at middle of base = 35.36 kNm/m
Eccentricity ec=35.36/92.61=0.382m, ec>1.600/6=0.267m
Soil pressure q=0.148 N/mm² Bq=1.255 m

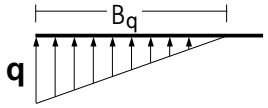


Effective footing L=1.600-2x0.382= 0.836 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.836x(1000x0.20)/1.40= 119.43 kN/m
Bearing resistance check Vd=92.61 < Rd=119.43 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

Check for 1.00x(self weight+top vertical dead load)+1.30x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.00	0.00- 1.30	7.00	4.06	1.242	2.002	8.97
Backfill surcharge (live)	Pqx1.30	0.00- 1.30	5.78	3.35	1.216	2.150	8.36
Active earth pressure	Pax1.00	1.30- 2.80	17.45	10.12	1.480	0.671	-3.27
Backfill surcharge (live)	Pqx1.30	1.30- 2.80	6.01	3.48	1.466	0.750	-0.61
Wall weight	W x1.00		0.00	61.60	0.800	1.188	-49.28
Vert. load on top (dead)	Ngx1.00		0.00	10.00	0.850	2.800	-8.50
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.800	2.800	5.60
			Sum=	92.61			-38.73

Sum of vertical forces = 92.61 kN/m
Sum of moments at front toe = -38.73 kNm/m
Sum of moments at middle of base = 35.36 kNm/m
Eccentricity ec=35.36/92.61=0.382m, ec>1.600/6=0.267m
Soil pressure q=0.148 N/mm² Bq=1.255 m
Effective footing L=1.600-2x0.382= 0.836 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.836x(1000x0.20)/1.40= 119.43 kN/m
Bearing resistance check Vd=92.61 < Rd=119.43 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

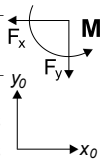


1.9.3. Failure check due to overturning (GEO)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.100,y=2.800 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.00	0.00- 1.30	7.00	4.06	1.242	2.002	14.01	5.04
Backfill surcharge (live)	Pqx1.30	0.00- 1.30	5.78	3.35	1.216	2.150	12.44	4.08
Active earth pressure	Pax1.00	1.30- 2.80	17.45	10.12	1.480	0.671	11.71	14.98
Backfill surcharge (live)	Pqx1.30	1.30- 2.80	6.01	3.48	1.466	0.750	4.50	5.11
Wall weight	W x1.00		0.00	61.60	0.800	1.188	0.00	49.28
Vert. load on top (dead)	Ngx1.00		0.00	10.00	0.850	2.800	0.00	8.50
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.800	2.800	5.60	0.00
					Sum=		48.26	86.99

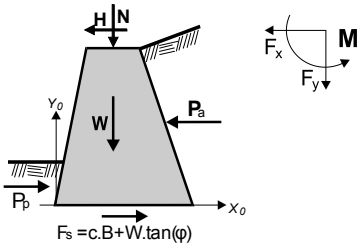


Sum of overturning moments = 48.26 kNm/m
Sum of moments resisting overturning = 86.99 kNm/m
Overturning check Msd=48.26 < Mrd=86.99 kNm/m, Check is verified

1.9.4. Failure check against sliding (GEO)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.00	0.00- 1.30	7.00	0.00	4.06
Backfill surcharge (live)	Pqx1.30	0.00- 1.30	5.78	0.00	3.35
Active earth pressure	Pax1.00	1.30- 2.80	17.45	0.00	10.12
Backfill surcharge (live)	Pqx1.30	1.30- 2.80	6.01	0.00	3.48
Passive earth pressure	Ppx1.00	2.20- 2.80	0.00	11.09	0.00
Wall weight	W x1.00		0.00	0.00	61.60
Vert. load on top (dead)	Ngx1.00		0.00	0.00	10.00
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.00
		Sum=	38.24	11.09	92.61



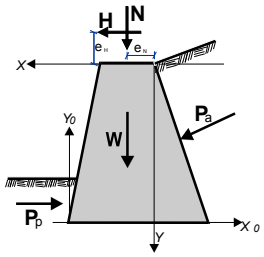
Soil friction Rd=Vd·tanφ/γM= 92.61xtan(30.00°)/1.25= 42.77 kN/m
Soil cohesion Rd=A·cu/γM = 1000x1.255x0.010/1.25= 10.04 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 38.24 kN/m
Sum of resisting forces (11.09+42.77) = 53.86 kN/m
Sliding resistance check Hd=38.24 < Rd=53.86 kN/m, Check is verified

1.10. Seismic design

(EC8 EN1998-5:2004)

Checks of wall stability (with seismic loading)

1.10.1. Forces (driving and resisting) on the wall



Action		y1 - y2	Fx	Fy	x	y	
				[kN/m]	[kN/m]	[m]	[m]
Active earth pressure	Pa	0.00- 1.30		5.28	3.06	-0.142	0.798
Backfill surcharge (live)	Pq	0.00- 1.30		3.36	1.95	-0.116	0.650
Active earth pressure	Pa	1.30- 2.80		13.44	7.80	-0.380	2.129
Backfill surcharge (live)	Pq	1.30- 2.80		3.55	2.06	-0.366	2.050
Passive earth pressure	Pp	2.20- 2.80		-16.78	0.00	0.993	2.600
Wall weight	W			0.00	61.60	0.300	1.612
Vert. load on top (dead)	Ng			0.00	10.00	0.250	0.000
Horiz. load on top (dead)	Hg			2.00	0.00	0.300	0.000

1.10.2. Additional forces due to seismic load

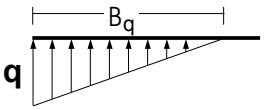
Action		y1 - y2	Fx	Fy	x	y	
				[kN/m]	[kN/m]	[m]	[m]
Active earth pressure	Pa	0.00- 1.30		2.21		-0.142	0.798
Backfill surcharge (live)	Pq	0.00- 1.30		1.41		-0.116	0.650
Active earth pressure	Pa	1.30- 2.80		5.05		-0.380	2.129
Backfill surcharge (live)	Pq	1.30- 2.80		1.33		-0.366	2.050
Wall weight	W			2.46	-1.23	0.300	1.612
Vert. load on top (dead)	Ng			0.40	-0.20	0.250	0.000

1.10.3. Check of soil bearing capacity (with seismic loading)

(EC7 §6.5.2)

Action	(γ)	y1 - y2	Fx	Fy	xo	yo	M	
				[kN/m]	[kN/m]	[m]	[m]	[kNm/m]
Active earth pressure	Pax1.00	0.00- 1.30		7.49	3.06	1.242	2.002	11.20
Backfill surcharge (live)	Pqx1.00	0.00- 1.30		4.77	1.95	1.216	2.150	7.88
Active earth pressure	Pax1.00	1.30- 2.80		18.49	7.80	1.480	0.671	0.87
Backfill surcharge (live)	Pqx1.00	1.30- 2.80		4.88	2.06	1.466	0.750	0.64
Wall weight	W x1.00			2.46	60.37	0.800	1.188	-45.37
Vert. load on top (dead)	Ngx1.00			0.40	9.80	0.850	2.800	-7.21
Horiz. load on top (dead)	Hgx1.00			2.00	0.00	0.800	2.800	5.60
				Sum=	85.04			-26.39

Sum of vertical forces = 85.04 kN/m
Sum of moments at front toe = -26.39 kNm/m
Sum of moments at middle of base = 41.64 kNm/m
Eccentricity ec=41.64/85.04=0.490m, ec>1.600/6=0.267m
Soil pressure q=0.183 N/mm² Bq=0.931 m



Effective footing L=1.600-2x0.490= 0.621 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.621x(1000x0.20)/1.00= 124.20 kN/m
Bearing resistance check Vd=85.04 < Rd=124.20 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

1.10.4. Failure check due to overturning (with seismic loading) (EC7 §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.100,y=2.800 m)

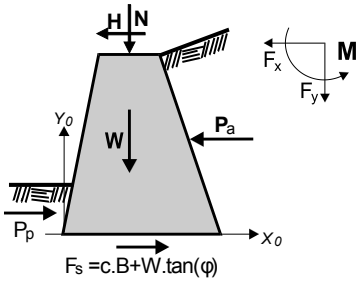
Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.00	0.00- 1.30	7.49	3.06	1.242	2.002	15.00	3.80
Backfill surcharge (live)	Pqx1.00	0.00- 1.30	4.77	1.95	1.216	2.150	10.25	2.37
Active earth pressure	Pax1.00	1.30- 2.80	18.49	7.80	1.480	0.671	12.41	11.54
Backfill surcharge (live)	Pqx1.00	1.30- 2.80	4.88	2.06	1.466	0.750	3.66	3.02
Wall weight	W x1.00		2.46	60.37	0.800	1.188	3.91	49.28*
Vert. load on top (dead)	Ngx1.00		0.40	9.80	0.850	2.800	1.29	8.50*
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.800	2.800	5.60	0.00
					Sum=		52.12	78.51

(*moments of negative seismic vertical loads, are added to the overturning moments)

Sum of overturning moments = 52.12 kNm/m
Sum of moments resisting overturning = 78.51 kNm/m
Overturning check Msd=52.12 < Mrd=78.51 kNm/m, Check is verified

1.10.5. Failure check against sliding (with seismic loading) (EC7 §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.00	0.00- 1.30	7.49	0.00	3.06
Backfill surcharge (live)	Pqx1.00	0.00- 1.30	4.77	0.00	1.95
Active earth pressure	Pax1.00	1.30- 2.80	18.49	0.00	7.80
Backfill surcharge (live)	Pqx1.00	1.30- 2.80	4.88	0.00	2.06
Passive earth pressure	Ppx1.00	2.20- 2.80	0.00	16.78	0.00
Wall weight	W x1.00		2.46	0.00	60.37
Vert. load on top (dead)	Ngx1.00		0.40	0.00	9.80
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.00
		Sum=	40.49	16.78	85.04



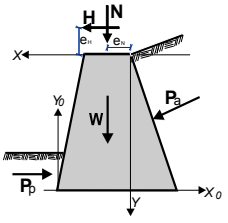
Soil friction Rd=Vd·tanφ/γM= 85.04xtan(30.00°)/1.00= 49.10 kN/m
Soil cohesion Rd=A·cu/γM = 1000x0.931x0.010/1.00= 9.31 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 40.49 kN/m
Sum of resisting forces (16.78+49.10) = 65.88 kN/m
Sliding resistance check Hd=40.49 < Rd=65.88 kN/m, Check is verified

1.11. Design of wall steam

1.11.1. Loading 1.35x(permanent unfavourable)+1.00x(permanent favourable)+1.50x(variable unfav.)

Forces (at centroid of cross section) and stresses at wall steam
x, y:cross section centroid, b:cross section width, e:eccentricity
Fx:horizontal force, Fy:vertical force, M:moment, e/b:relative eccentricity
σ1, σ2: cross section normal stresses, τ:shear stress, Bq:effective cross section width

y [m]	x [m]	b [m]	Fx [kN/m]	Fy [kN/m]	M [kNm/m]	e/b	σ1 [N/mm²]	σ2 [N/mm²]	Bq/B [N/mm²]	τ [N/mm²]
0.50	0.300	0.779	6.23	18.94	0.97	-0.066	-0.034	-0.015	1.000	0.008
1.00	0.300	0.957	11.22	30.51	4.01	-0.137	-0.058	-0.006	1.000	0.012
1.50	0.300	1.136	17.34	44.52	9.26	-0.183	-0.082	0.000	0.951	0.015
2.00	0.300	1.314	24.39	60.86	17.12	-0.214	-0.108	0.000	0.858	0.019
2.80	0.300	1.600	38.34	92.28	36.09	-0.244	-0.150	0.000	0.767	0.024



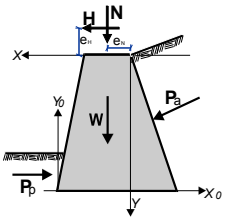
1.11.2. Strength check with allowable stresses

Compression σ max= 0.150 <= σ(allowable)= 3.000 N/mm²
Tension σ max= 0.000 <= σ(allowable)= 0.000 N/mm²
Shear τ max= 0.024 <= τ(allowable)= 0.300 N/mm²

1.11.3. Loading 1.00x(permanent unfav.)+1.00x(permanent favour.)+1.00x(variable)+1.00x(seismic)

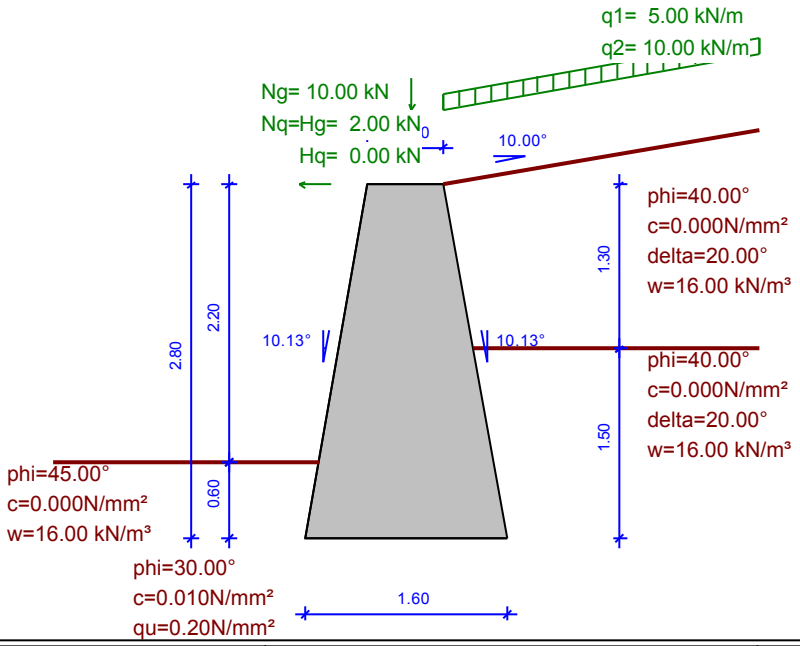
Forces (at centroid of cross section) and stresses at wall steam (with seismic loading)
x, y:cross section centroid, b:cross section width, e:eccentricity
Fx:horizontal force, Fy:vertical force, M:moment, e/b:relative eccentricity
σ1, σ2: cross section normal stresses, τ:shear stress, Bq:effective cross section width

y [m]	x [m]	b [m]	Fx [kN/m]	Fy [kN/m]	M [kNm/m]	e/b	σ1 [N/mm²]	σ2 [N/mm²]	Bq/B	τ [N/mm²]
0.50	0.300	0.779	6.18	17.99	1.10	-0.074	-0.035	-0.013	1.000	0.008
1.00	0.300	0.957	11.57	28.55	4.57	-0.157	-0.062	-0.002	1.000	0.012
1.50	0.300	1.136	16.74	41.36	9.44	-0.187	-0.083	0.000	0.940	0.015
2.00	0.300	1.314	24.23	56.31	17.81	-0.223	-0.111	0.000	0.832	0.018
2.80	0.300	1.600	39.09	85.04	38.62	-0.262	-0.161	0.000	0.715	0.024



1.11.4. Strength check with allowable stresses (with seismic loading)

Compression	σ max=	0.161 <=	σ(allowable)=	3.000 N/mm²
Tension	σ max=	0.000 <=	σ(allowable)=	0.000 N/mm²
Shear	τ max=	0.024 <=	τ(allowable)=	0.300 N/mm²



General information

Wall type : Gravity wall

Wall materials

Allowable compressive stress 3.00 N/mm²

Allowable tensile stress 0.00 N/mm²

Allowable shear stress 0.30 N/mm²

Design codes

Eurocode 0 EN1991-1-1, Basis of structural design

Eurocode 1 EN1991-1-1, Actions on structures

Eurocode 2 EN1992-1-1, Design of concrete structures

Eurocode 7 EN1997-1-1, Geotechnical design

Eurocode 8 EN1998-5, Earthquaqe design

Loads

Vertical : dead Ng=10.00kN, live Nq=0.00kN

Horizontal: dead Hg=2.00kN, live Hq=0.00kN

Surcharge : dead g=5.00kN/m², live q=10.00kN/m²

Seismic coefficients

Design ground acceleration ratio a =0.060

Coefficient for horizontal seismic force kh=0.040

Coefficient for vertical seismic force kv=0.020

Soil properties back-1

phi=40.00°

c=0.000N/mm²

delta=20.00°

w=16.00 kN/m³

Soil properties back-2

phi=40.00°

c=0.000N/mm²

delta=20.00°

w=16.00 kN/m³

Soil properties front

phi=45.00°

c=0.000N/mm²

w=16.00 kN/m³

Foundation soil properties

phi=30.00°

c=0.010N/mm²

qu=0.20N/mm²

Concrete volume V= 30.80 [m³]

Project: Example of retaining walls 12/0

G. WALL-001

Scale : 1:60 **Date:** 12/03/2007

Designer: **Draw.No.:**

Filename: Example of retaining w... **Sign:**

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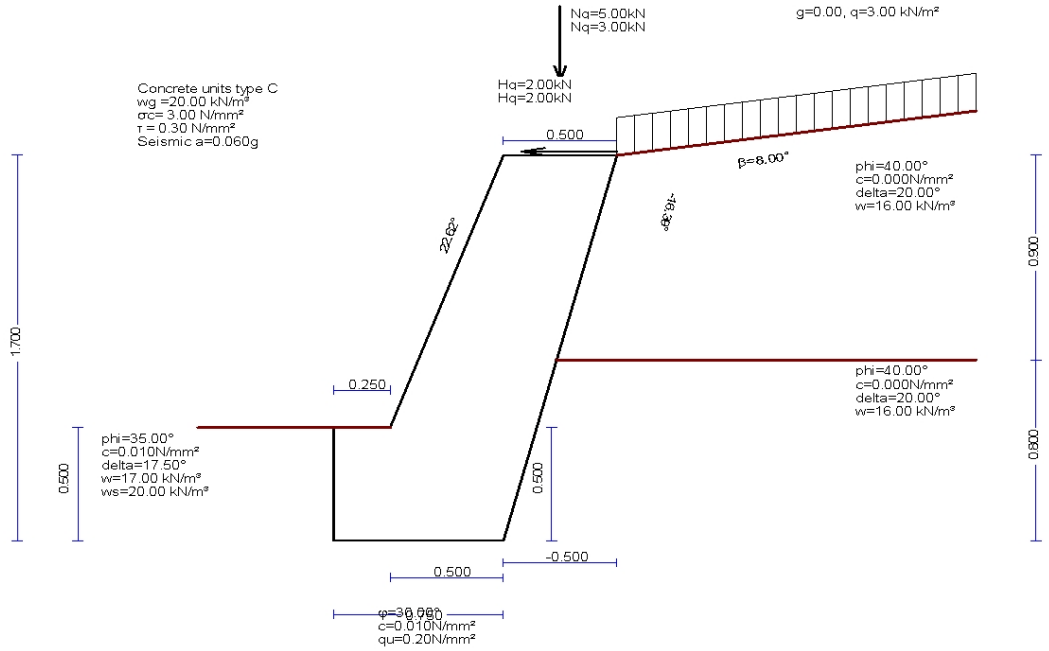
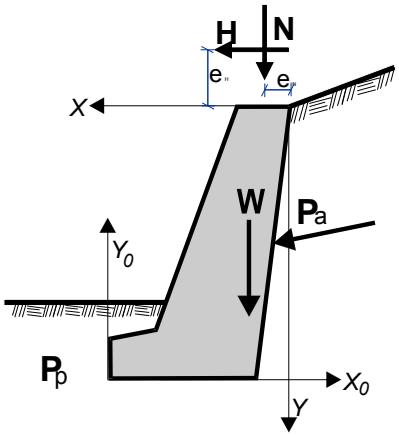
2. G. WALL-002

Gravity retaining wall

(EC2 EN1992-1-1:2004, EC0 EN1990-1-1:2002, EC7 EN1997-1-1:2004, EC8 EN1998-5:2004)



2.1. Wall properties-Parameters-Code requirements



Dimensions

Height of wall	h= 1.700 m
Transverse length of wall	L=10.000 m
Steam thickness at top	B1= 0.500 m
Steam thickness at bottom	B2= 0.647 m
Width of wall base	B= 0.750 m
Width of wall toe	0.250 m
Height of wall steam	1.200 m
Thickness of wall footing	0.500 m
Front thickness of wall toe	0.500 m
Slope (batter) at frontface	22.620° (1:2.40)
Slope (batter) at backface	-16.390° (1:3.40)

Loads on wall top

Vertical permanent load	Ng= 5.00 kN/m
Vertical variable load	Nq= 3.00 kN/m
Eccentricity of vertical load	eN= 0.25 kN/m
Horizontal permanent load	Hg= 2.00 kN/m
Horizontal variable load	Hq= 2.00 kN/m
Eccentricity of horizontal load	eH= 0.00 kN/m

Weight of wall

Unit weight of wall material γg=20.000 kN/m³
Cross section area of wall A= 1.100 m²
Self weight per meter of wall W= 1.100x20.000= 22.00 kN/m
Center of gravity of wall at x=0.609 m, y=0.931 m (xo=0.641 m, yo=0.769 m)

Wall materials

Allowable compressive stress	3.00 N/mm²
Allowable tensile stress	0.00 N/mm²
Allowable shear stress	0.30 N/mm²

2.2. Partial factors for actions and soil properties

(EC7 Tables A.1-A.4, EC8-5 §3.1)

Equilibrium limit state (EQU), Structural limit state (STR), Geotechnical limit state (GEO)

				(EQU)	(STR)	(GEO)	(SEISMIC)
Actions	Permanent Unfavourable	γGdst:	1.10	1.35	1.00	1.00	
	Permanent Favourable	γGstb:	0.90	1.00	1.00	1.00	
	Variable Unfavourable	γQdst:	1.50	1.50	1.30	1.00	
	Variable Favourable	γQstb:	0.00	0.00	0.00	0.00	
Soil parameters	Angle of shearing resistance	γφ:	1.25	1.00	1.25	1.25	
	Effective cohesion	γc:	1.25	1.00	1.25	1.25	
	Undrained shear strength	γcu:	1.40	1.00	1.40	1.40	
	Unconfined strength	γqu:	1.40	1.00	1.40	1.40	
	Weight density	γw:	1.00	1.00	1.00	1.00	

2.3. Properties of foundation soil

Bearing capacity of foundation soil qu=0.20 N/mm²
Friction angle between wall footing and soil φ=30.00°, friction coefficient tan(φ)=0.577
Cohesion between wall footing and soil c=0.010 N/mm²

2.4. Seismic coefficients

(EC8 EN1998-5:2004, §7.3.2)

Design ground acceleration ratio	gh=axg, a=0.06	(EC8-5 §7.3.2)
Reduction factor for seismic coefficient	r=1.50	(EC8-5 Table 7.1)
Coefficient for horizontal seismic force	kh=0.06/1.500=0.040	(EC8-5 Eq.7.1)
Coefficient for vertical seismic force	kv=0.50x0.040=0.020	(EC8-5 Eq.7.2)

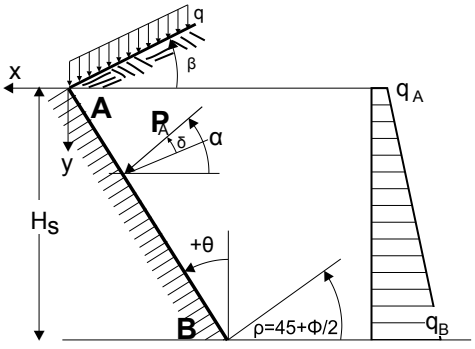
Forces due to seismic load (except from earth pressure)

Horizontal seismic force due to self weight	Fwx= 22.00x0.040=	0.88 kN/m
Vertical seismic force due to self weight	Fwy= 22.00x0.020=	0.44 kN/m
Horizontal seismic force of top loading Ng	Fgx= 5.00x0.040=	0.20 kN/m
Vertical seismic force of top loading Ng	Fgy= 5.00x0.020=	0.10 kN/m
Horizontal seismic force of top loading Nq	Fqx= 3.00x0.040=	0.12 kN/m
Vertical seismic force of top loading Nq	Fqy= 3.00x0.020=	0.06 kN/m

2.5. Computation of active earth pressure (Coulomb theory)

2.5.1. Wall part from y=0.000 m to y=0.900 m, Hs=0.900 m

Top point A x= 0.000 m y= 0.000 m
Bottom point B x= 0.265 m y= 0.900 m



Soil properties

Soil type : Mean gravel	
Unit weight of soil	γ =16.00 kN/m³
Unit weight of soil (saturated)	γs=20.00 kN/m³
Unit weight of water	γw=10.00 kN/m³
Angle of shearing resistance of ground	φ=40.00°
Cohesion of ground	c=0.000 N/mm²
Slope angle of ground surface	β= 8.00°
Inclination angle of the wall backface	θ=-16.39°
Angle of shear resist. between ground-wall	δ=20.00°

Loads on soil surface

Permanent uniform load	g=	0.00 kN/m²
Variable uniform load	q=	3.00 kN/m²

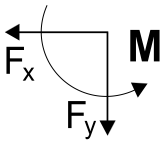
Earth pressure according to Coulomb theory

$$K_A = \frac{\cos^2(\varphi-\theta)}{\cos^2\theta\,\cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\theta+\delta)\sin(\theta-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$

		EQU	STR	GEO
Angle of rupture plane ρ=45°+φ/2	=	61.00	65.00	61.00°
Coefficient of active earth pressure Ka=		0.193	0.114	0.193

Earth pressure q(y)=qA+γ·y·Ka

Permanent actions



		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.00	0.00	0.00	kN/m²
Earth pressure at the bottom (y=yA+ 0.90m)	qB=	2.78	1.64	2.78	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	1.25	0.74	1.25	kN/m
Angle of earth force	α =	2.89	3.61	2.89	°
Earth force in x direction	Pax=	1.25	0.74	1.25	kN/m
Earth force in y direction	Pay=	0.08	0.05	0.08	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-0.74	-0.44	-0.74	kNm/m

Point of application of earth force x= 0.176 m, y= 0.600 m

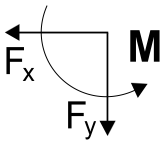
Variable actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.60	0.36	0.60	kN/m²
Earth pressure at the bottom (y=yA+ 0.90m)	qB=	0.60	0.36	0.60	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	0.54	0.32	0.54	kN/m
Angle of earth force	α =	2.89	3.61	2.89	°
Earth force in x direction	Pax=	0.54	0.32	0.54	kN/m
Earth force in y direction	Pay=	0.03	0.02	0.03	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-0.24	-0.14	-0.24	kNm/m

Point of application of earth force x= 0.132 m, y= 0.450 m

Total forces and moments

Forces and moments at bottom point B (x=0.265 m, y=0.900 m)



Permanent actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	1.25	0.74	1.25	kN/m
Total vertical earth force	Fsy=	0.08	0.05	0.08	kN/m
Total moment of earth force	Ms =	0.37	0.22	0.37	kNm/m

Variable actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	0.54	0.32	0.54	kN/m
Total vertical earth force	Fsy=	0.03	0.02	0.03	kN/m
Total moment of earth force	Ms =	0.24	0.14	0.24	kNm/m

Seismic loading (EC8 EN1998-5:2004, §7.3.2, Annex E)

Horizontal seismic coefficient kh=0.06/1.500=0.040 (EC8-5 Eq.7.1, T.7.1)
Vertical seismic coefficient kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)
Soil above the water table (EC8-5 Annex E.5)
tan(ω)=kh/(1-kv)=0.040/(1-0.020)=0.041, ω=2.34°

Method Mononobe-Okabe (EC8-5 Annex E.4)
for active earth force during seismic loading

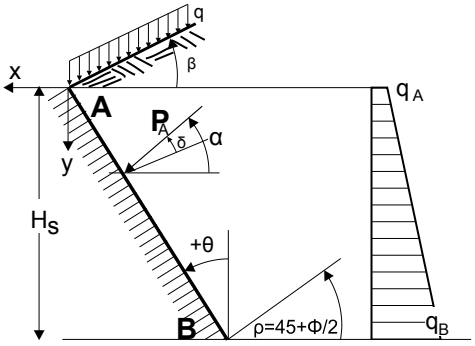
$$K_E = \frac{\cos^2(\varphi-\omega-\theta)}{\cos\omega\,\cos^2\theta\,\cos(\delta+\theta+\omega)\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\omega-\beta)}{\cos(\theta+\omega+\delta)\cos(\theta-\beta)}}\right]^2}$$

Coefficient of active earth pressure, Ke*= 0.213
Additional earth pressure due to seismic load
over STR load case ξ=(Ke*/Ke-1)=(0.213/0.114-1)=0.868

Earth force due to seismic load (Permanent actions) Fx=1.868x 0.74= 1.38 kN/m
Earth force due to seismic load (Variable actions) Fx=1.868x 0.32= 0.60 kN/m

2.5.2. Wall part from y=0.900 m to y=1.700 m, Hs=0.800 m

Top point A x= 0.265 m y= 0.900 m
Bottom point B x= 0.500 m y= 1.700 m



Soil properties

Soil type : Mean gravel
Unit weight of soil γ =16.00 kN/m³
Unit weight of soil (saturated) γs=20.00 kN/m³
Unit weight of water γw=10.00 kN/m³
Angle of shearing resistance of ground φ=40.00°
Cohesion of ground c=0.000 N/mm²
Slope angle of ground surface β= 0.00°
Inclination angle of the wall backface θ=-16.39°
Angle of shear resist. between ground-wall δ=20.00°

Loads on soil surface

Permanent uniform load g= 14.40 kN/m²
Variable uniform load q= 3.00 kN/m²

Earth pressure according to Coulomb theory

$$K_A = \frac{\cos^2(\varphi-\theta)}{\cos^2\theta\,\cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\theta+\delta)\sin(\theta-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$

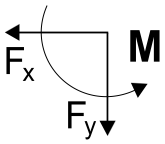
		EQU	STR	GEO	
Angle of rupture plane ρ=45°+φ/2	=	61.00	65.00	61.00°	
Coefficient of active earth pressure Ka=		0.178	0.107	0.178	

Earth pressure q(y)=qA+γ·y·Ka

Permanent actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	2.56	1.54	2.56	kN/m²
Earth pressure at the bottom (y=yA+ 0.80m)	qB=	4.84	2.91	4.84	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	2.96	1.78	2.96	kN/m
Angle of earth force	α =	2.89	3.61	2.89	°
Earth force in x direction	Pax=	2.95	1.78	2.95	kN/m
Earth force in y direction	Pay=	0.19	0.11	0.19	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-3.88	-2.34	-3.88	kNm/m

Point of application of earth force x= 0.395 m, y= 1.341 m



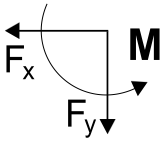
Variable actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.53	0.32	0.53	kN/m²
Earth pressure at the bottom (y=yA+ 0.80m)	qB=	0.53	0.32	0.53	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	0.42	0.26	0.42	kN/m
Angle of earth force	α =	2.89	3.61	2.89	°
Earth force in x direction	Pax=	0.42	0.26	0.42	kN/m
Earth force in y direction	Pay=	0.03	0.02	0.03	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-0.53	-0.33	-0.53	kNm/m

Point of application of earth force x= 0.383 m, y= 1.300 m

Total forces and moments

Forces and moments at bottom point B (x=0.500 m, y=1.700 m)



Permanent actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	4.20	2.52	4.20	kN/m
Total vertical earth force	Fsy=	0.27	0.16	0.27	kN/m
Total moment of earth force	Ms =	2.39	1.43	2.39	kNm/m

Variable actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	0.96	0.58	0.96	kN/m
Total vertical earth force	Fsy=	0.06	0.04	0.06	kN/m
Total moment of earth force	Ms =	0.83	0.49	0.83	kNm/m

Seismic loading (EC8 EN1998-5:2004, §7.3.2, Annex E)

Horizontal seismic coefficient kh=0.06/1.500=0.040 (EC8-5 Eq.7.1, T.7.1)
Vertical seismic coefficient kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)
Soil above the water table (EC8-5 Annex E.5)
tan(ω)=kh/(1-kv)=0.040/(1-0.020)=0.041, ω=2.34°

Method Mononobe-Okabe (EC8-5 Annex E.4)
for active earth force during seismic loading
Coefficient of active earth pressure, Ke*= 0.195
Additional earth pressure due to seismic load
over STR load case ξ=(Ke*/Ke-1)=(0.195/0.107-1)=0.822

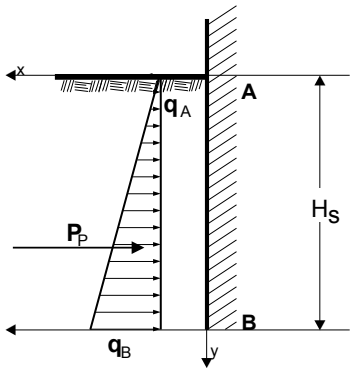
$$K_E=\frac{\cos^2(\varphi-\omega-\theta)}{\cos\omega\cos^2\theta\cos(\delta+\theta+\omega)\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\omega-\beta)}{\cos(\theta+\omega+\delta)\cos(\theta-\beta)}}\right]^2}$$

Earth force due to seismic load (Permanent actions) Fx=1.822x 1.78= 3.24 kN/m
Earth force due to seismic load (Variable actions) Fx=1.822x 0.26= 0.47 kN/m

2.6. Computation of passive earth pressure (Rankine theory)

2.6.1. Wall part from y=1.200 m to y=1.700 m, Hs=0.500 m

Top point A x= 1.250 m y= 1.200 m
Bottom point B x= 1.250 m y= 1.700 m



Soil properties

Soil type : Dense sand
Unit weight of soil γ =17.00 kN/m³
Unit weight of soil (saturated) γs=20.00 kN/m³
Unit weight of water γw=10.00 kN/m³
Soil under the water table lever
Soil weight suspended in water γo=10.00 kN/m³
Angle of shearing resistance of ground φ=35.00°
Cohesion of ground c=0.010 N/mm²
Slope angle of ground surface β= 0.00°
Earth pressure on vertical surface θ= 0.00°
Angle of shear resist. between ground-wall δ= 0.00°

Loads on soil surface

Permanent uniform load g= 0.00 kN/m²
Variable uniform load q= 0.00 kN/m²
Water pressure at the top qw= 0.00 kN/m²

Earth pressure according to Coulomb theory

	EQU	STR	GEO
Angle of rupture plane ρ=45°-φ/2	= 31.00	27.50	31.00°
Coefficient of passive earth pressure Kp=	2.770	3.690	2.770

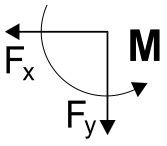
Earth pressure q(y)=qA+γ·y·Kp

$$K_p=\frac{\cos^2(\varphi+\theta)}{\cos^2\theta\cos(\theta-\delta)\left[1-\sqrt{\frac{\sin(\theta+\delta)\sin(\theta+\beta)}{\cos(\theta-\delta)\cos(\theta-\beta)}}\right]^2}$$

Permanent actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.00	0.00	0.00	kN/m²
Earth pressure at the bottom (y=yA+ 0.50m)	qB=	-13.85	-18.45	-13.85	kN/m²
Earth force Pa=½(qA+qB)H	Pp=	3.46	4.61	3.46	kN/m
Angle of earth force	α =	0.00	0.00	0.00	°
Earth force in x direction	Ppx=	-3.46	-4.61	-3.46	kN/m
Earth force in y direction	Ppy=	0.00	0.00	0.00	kN/m
Moment of earth force at top point (x=0,y=0)	M =	5.30	7.07	5.30	kNm/m

Point of application of earth force x= 1.250 m, y= 1.533 m

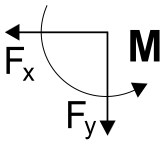


Hydrostatic pressure

Hydrostatic pressure qw=qwA+γw·Hw/cosθ
Hydrostatic pressure at the top (y=yA) qwA= 0.00 kN/m²
Hydrostatic pressure at the bottom (y=yA+ 0.50m) qwB= 5.00 kN/m²
Hydrostatic force Pw=½(qwA+qwB)H Pw = 1.25 kN/m
Angle of hydrostatic force α = 0.00 °
Hydrostatic force in x direction Pwx = 1.25 kN/m
Hydrostatic force in y direction Pwy = 0.00 kN/m
Moment of hydrostatic force at top point (x=0,y=0) M = -1.92 kNm/m
Point of application of hydrostatic force x= 1.250 m, y= 1.533 m

Total forces and moments

Forces and moments at bottom point B (x=1.250 m, y=1.700 m)



Permanent actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	-3.46	-4.61	-3.46	kN/m
Total vertical earth force	Fsy=	0.00	0.00	0.00	kN/m
Total moment of earth force	Ms =	-0.58	-0.77	-0.58	kNm/m

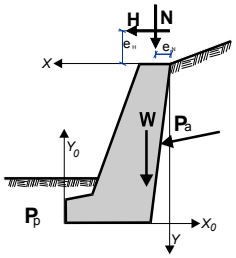
Hydrostatic pressure

Total horizontal hydrostatic force Fwx= 1.25 kN/m
Total vertical hydrostatic force Fwy= 0.00 kN/m
Total moment of hydrostatic force Mw = 0.21 kNm/m

2.7. Checks of wall stability (EQU)

2.7.1. Forces (driving and resisting) on the wall (EQU)

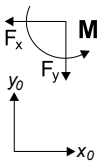
Action		y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa	0.00- 0.90	1.25	0.08	0.176	0.600
Backfill surcharge (live)	Pq	0.00- 0.90	0.54	0.03	0.132	0.450
Active earth pressure	Pa	0.90- 1.70	2.95	0.19	0.395	1.341
Backfill surcharge (live)	Pq	0.90- 1.70	0.42	0.03	0.383	1.300
Passive earth pressure	Pp	1.20- 1.70	-3.46	0.00	1.250	1.533
Wall weight	W		0.00	22.00	0.609	0.931
Vert. load on top (dead)	Ng		0.00	5.00	0.250	0.000
Vert. load on top (live)	Nq		0.00	3.00	0.250	0.000
Horiz. load on top (dead)	Hg		2.00	0.00	0.250	0.000
Horiz. load on top (live)	Hq		2.00	0.00	0.250	0.000



2.7.2. Check of soil bearing capacity (EQU)

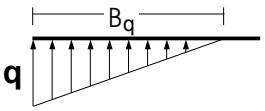
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 0.90x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	M [m]	[kNm/m]
Active earth pressure	Pax1.10	0.00- 0.90		1.38	0.09	1.074	1.100	1.42
Backfill surcharge (live)	Pqx1.50	0.00- 0.90		0.81	0.04	1.118	1.250	0.98
Active earth pressure	Pax1.10	0.90- 1.70		3.25	0.21	0.855	0.359	0.99
Backfill surcharge (live)	Pqx1.50	0.90- 1.70		0.63	0.04	0.867	0.400	0.21
Wall weight	W x0.90			0.00	19.80	0.641	0.769	-12.69
Vert. load on top (dead)	Ngx0.90			0.00	4.50	1.000	1.700	-4.50
Horiz. load on top (dead)	Hgx1.10			2.20	0.00	1.000	1.700	3.74
Horiz. load on top (live)	Hqx1.50			3.00	0.00	1.000	1.700	5.10
				Sum=	24.68			-4.75

Sum of vertical forces = 24.68 kN/m
Sum of moments at front toe = -4.75 kNm/m
Sum of moments at middle of base = 4.50 kNm/m
Eccentricity ec=4.50/24.68=0.182m, ec>0.750/6=0.125m
Soil pressure q=0.085 N/mm² Bq=0.578 m

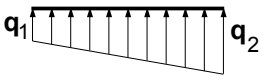


Effective footing L=0.750-2x0.182= 0.385 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.385x(1000x0.20)/1.40= 55.00 kN/m
Bearing resistance check Vd=24.68 < Rd=55.00 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

Check for 1.10x(self weight+top vertical dead load)+1.50x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.10	0.00- 0.90	1.38	0.09	1.074	1.100	1.42
Backfill surcharge (live)	Pqx1.50	0.00- 0.90	0.81	0.04	1.118	1.250	0.98
Active earth pressure	Pax1.10	0.90- 1.70	3.25	0.21	0.855	0.359	0.99
Backfill surcharge (live)	Pqx1.50	0.90- 1.70	0.63	0.04	0.867	0.400	0.21
Wall weight	W x1.10		0.00	24.20	0.641	0.769	-15.51
Vert. load on top (dead)	Ngx1.10		0.00	5.50	1.000	1.700	-5.50
Vert. load on top (live)	Nqx1.50		0.00	4.50	1.000	1.700	-4.50
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	1.000	1.700	3.74
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.000	1.700	5.10
			Sum=	34.58			-13.07

Sum of vertical forces = 34.58 kN/m
Sum of moments at front toe = -13.07 kNm/m
Sum of moments at middle of base = -0.10 kNm/m
Eccentricity ec=-0.10/34.58=-0.003m, ec<=0.750/6=0.125m
Soil pressure q1=0.045 N/mm² q2=0.047 N/mm²



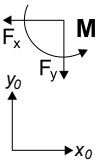
Effective footing L=0.750-2x0.003= 0.744 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.744x(1000x0.20)/1.40= 106.29 kN/m
Bearing resistance check Vd=34.58 < Rd=106.29 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

2.7.3. Failure check due to overturning (EQU)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.250,y=1.700 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	Mo+ [m]	Mo- [kNm/m]	[kNm/m]
Active earth pressure	Pax1.10	0.00- 0.90	1.38	0.09	1.074	1.100	1.52	0.10	
Backfill surcharge (live)	Pqx1.50	0.00- 0.90	0.81	0.04	1.118	1.250	1.02	0.04	
Active earth pressure	Pax1.10	0.90- 1.70	3.25	0.21	0.855	0.359	1.17	0.18	
Backfill surcharge (live)	Pqx1.50	0.90- 1.70	0.63	0.04	0.867	0.400	0.26	0.04	
Wall weight	W x0.90		0.00	19.80	0.641	0.769	0.00	12.69	
Vert. load on top (dead)	Ngx0.90		0.00	4.50	1.000	1.700	0.00	4.50	
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	1.000	1.700	3.74	0.00	
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.000	1.700	5.10	0.00	
					Sum=		12.81	17.55	

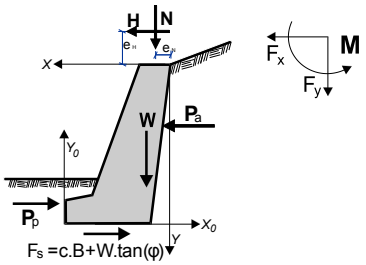


Sum of overturning moments = 12.81 kNm/m
Sum of moments resisting overturning = 17.55 kNm/m
Overturning check Msd=12.81 < Mrd=17.55 kNm/m, Check is verified

2.7.4. Failure check against sliding (EQU)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.10	0.00- 0.90	1.38	0.00	0.09
Backfill surcharge (live)	Pqx1.50	0.00- 0.90	0.81	0.00	0.04
Active earth pressure	Pax1.10	0.90- 1.70	3.25	0.00	0.21
Backfill surcharge (live)	Pqx1.50	0.90- 1.70	0.63	0.00	0.04
Passive earth pressure	Ppx0.90	1.20- 1.70	0.00	3.11	0.00
Wall weight	W x0.90		0.00	0.00	19.80
Vert. load on top (dead)	Ngx0.90		0.00	0.00	4.50
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	0.00
Horiz. load on top (live)	Hqx1.50		3.00	0.00	0.00
		Sum=	11.27	3.11	24.68

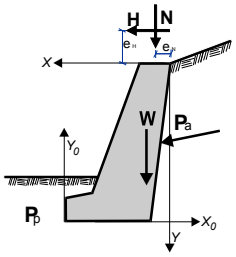


Soil friction Rd=Vd·tanφ/γM= 24.68xtan(30.00°)/1.25= 11.40 kN/m
Soil cohesion Rd=A·cu/γM = 1000x0.578x0.010/1.25= 4.62 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 11.27 kN/m
Sum of resisting forces (3.11+11.40) = 14.51 kN/m
Sliding resistance check Hd=11.27 < Rd=14.51 kN/m, Check is verified

2.8. Checks of wall stability (STR)

2.8.1. Forces (driving and resisting) on the wall (STR)

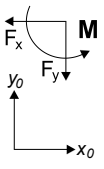
Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa 0.00- 0.90	0.74	0.05	0.176	0.600
Backfill surcharge (live)	Pq 0.00- 0.90	0.32	0.02	0.132	0.450
Active earth pressure	Pa 0.90- 1.70	1.78	0.11	0.395	1.341
Backfill surcharge (live)	Pq 0.90- 1.70	0.26	0.02	0.383	1.300
Passive earth pressure	Pp 1.20- 1.70	-4.61	0.00	1.250	1.533
Wall weight	W	0.00	22.00	0.609	0.931
Vert. load on top (dead)	Ng	0.00	5.00	0.250	0.000
Vert. load on top (live)	Nq	0.00	3.00	0.250	0.000
Horiz. load on top (dead)	Hg	2.00	0.00	0.250	0.000
Horiz. load on top (live)	Hq	2.00	0.00	0.250	0.000



2.8.2. Check of soil bearing capacity (STR)

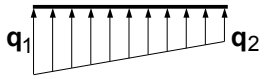
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 1.00x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.35	0.00- 0.90	1.00	0.07	1.074	1.100	1.03
Backfill surcharge (live)	Pqx1.50	0.00- 0.90	0.48	0.03	1.118	1.250	0.57
Active earth pressure	Pax1.35	0.90- 1.70	2.40	0.15	0.855	0.359	0.74
Backfill surcharge (live)	Pqx1.50	0.90- 1.70	0.39	0.03	0.867	0.400	0.12
Wall weight	W x1.00		0.00	22.00	0.641	0.769	-14.10
Vert. load on top (dead)	Ngx1.00		0.00	5.00	1.000	1.700	-5.00
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	1.000	1.700	4.59
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.000	1.700	5.10
			Sum=	27.28			-6.95

Sum of vertical forces = 27.28 kN/m
Sum of moments at front toe = -6.95 kNm/m
Sum of moments at middle of base = 3.28 kNm/m
Eccentricity ec=3.28/27.28=0.120m, ec<=0.750/6=0.125m
Soil pressure q1=0.071 N/mm² q2=0.001 N/mm²

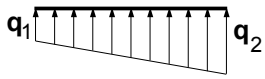


Effective footing L=0.750-2x0.120= 0.510 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.510x(1000x0.20)/1.00= 102.00 kN/m
Bearing resistance check Vd=27.28 < Rd=102.00 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

Check for 1.35x(self weight+top vertical dead load)+1.50x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.35	0.00- 0.90	1.00	0.07	1.074	1.100	1.03
Backfill surcharge (live)	Pqx1.50	0.00- 0.90	0.48	0.03	1.118	1.250	0.57
Active earth pressure	Pax1.35	0.90- 1.70	2.40	0.15	0.855	0.359	0.74
Backfill surcharge (live)	Pqx1.50	0.90- 1.70	0.39	0.03	0.867	0.400	0.12
Wall weight	W x1.35		0.00	29.70	0.641	0.769	-19.04
Vert. load on top (dead)	Ngx1.35		0.00	6.75	1.000	1.700	-6.75
Vert. load on top (live)	Nqx1.50		0.00	4.50	1.000	1.700	-4.50
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	1.000	1.700	4.59
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.000	1.700	5.10
			Sum=	41.23			-18.14

Sum of vertical forces = 41.23 kN/m
Sum of moments at front toe = -18.14 kNm/m
Sum of moments at middle of base = -2.68 kNm/m
Eccentricity ec=-2.68/41.23=-0.065m, ec<=0.750/6=0.125m
Soil pressure q1=0.026 N/mm² q2=0.084 N/mm²



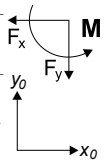
Effective footing L=0.750-2x0.065= 0.620 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.620x(1000x0.20)/1.00= 124.00 kN/m
Bearing resistance check Vd=41.23 < Rd=124.00 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

2.8.3. Failure check due to overturning (STR)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.250,y=1.700 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	Mo+ [m]	Mo- [kNm/m]	[kNm/m]
Active earth pressure	Pax1.35	0.00- 0.90	1.00	0.07	1.074	1.100	1.09	0.07	
Backfill surcharge (live)	Pqx1.50	0.00- 0.90	0.48	0.03	1.118	1.250	0.60	0.03	
Active earth pressure	Pax1.35	0.90- 1.70	2.40	0.15	0.855	0.359	0.86	0.12	
Backfill surcharge (live)	Pqx1.50	0.90- 1.70	0.39	0.03	0.867	0.400	0.15	0.03	
Wall weight	W x1.00		0.00	22.00	0.641	0.769	0.00	14.10	
Vert. load on top (dead)	Ngx1.00		0.00	5.00	1.000	1.700	0.00	5.00	
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	1.000	1.700	4.59	0.00	
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.000	1.700	5.10	0.00	
					Sum=		12.39	19.35	

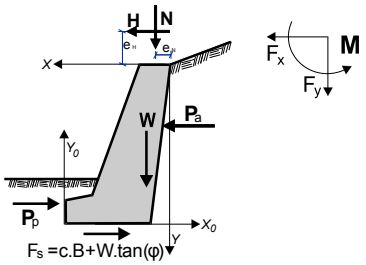


Sum of overturning moments = 12.39 kNm/m
Sum of moments resisting overturning = 19.35 kNm/m
Overturning check Msd=12.39 < Mrd=19.35 kNm/m, Check is verified

2.8.4. Failure check against sliding (STR)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.35	0.00- 0.90	1.00	0.00	0.07
Backfill surcharge (live)	Pqx1.50	0.00- 0.90	0.48	0.00	0.03
Active earth pressure	Pax1.35	0.90- 1.70	2.40	0.00	0.15
Backfill surcharge (live)	Pqx1.50	0.90- 1.70	0.39	0.00	0.03
Passive earth pressure	Ppx1.00	1.20- 1.70	0.00	4.61	0.00
Wall weight	W x1.00		0.00	0.00	22.00
Vert. load on top (dead)	Ngx1.00		0.00	0.00	5.00
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	0.00
Horiz. load on top (live)	Hqx1.50		3.00	0.00	0.00
		Sum=	9.97	4.61	27.28

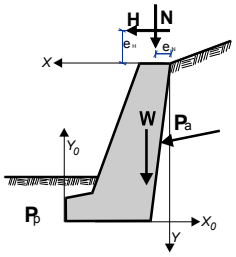


Soil friction Rd=Vd·tanφ/γM= 27.28xtan(30.00°)/1.00= 15.75 kN/m
Soil cohesion Rd=A·cu/γM = 1000x0.750x0.010/1.00= 7.50 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 9.97 kN/m
Sum of resisting forces (4.61+15.75) = 20.36 kN/m
Sliding resistance check Hd=9.97 < Rd=20.36 kN/m, Check is verified

2.9. Checks of wall stability (GEO)

2.9.1. Forces (driving and resisting) on the wall (GEO)

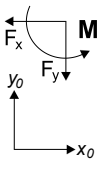
Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa 0.00- 0.90	1.25	0.08	0.176	0.600
Backfill surcharge (live)	Pq 0.00- 0.90	0.54	0.03	0.132	0.450
Active earth pressure	Pa 0.90- 1.70	2.95	0.19	0.395	1.341
Backfill surcharge (live)	Pq 0.90- 1.70	0.42	0.03	0.383	1.300
Passive earth pressure	Pp 1.20- 1.70	-3.46	0.00	1.250	1.533
Wall weight	W	0.00	22.00	0.609	0.931
Vert. load on top (dead)	Ng	0.00	5.00	0.250	0.000
Vert. load on top (live)	Nq	0.00	3.00	0.250	0.000
Horiz. load on top (dead)	Hg	2.00	0.00	0.250	0.000
Horiz. load on top (live)	Hq	2.00	0.00	0.250	0.000



2.9.2. Check of soil bearing capacity (GEO)

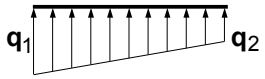
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 1.00x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	M [m]	[kNm/m]
Active earth pressure	Pax1.00	0.00- 0.90	1.25	0.08	1.074	1.100	1.29	
Backfill surcharge (live)	Pqx1.30	0.00- 0.90	0.70	0.04	1.118	1.250	0.84	
Active earth pressure	Pax1.00	0.90- 1.70	2.95	0.19	0.855	0.359	0.90	
Backfill surcharge (live)	Pqx1.30	0.90- 1.70	0.55	0.04	0.867	0.400	0.18	
Wall weight	W x1.00		0.00	22.00	0.641	0.769	-14.10	
Vert. load on top (dead)	Ngx1.00		0.00	5.00	1.000	1.700	-5.00	
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	1.000	1.700	3.40	
Horiz. load on top (live)	Hqx1.30		2.60	0.00	1.000	1.700	4.42	
			Sum=	27.35			-8.07	

Sum of vertical forces = 27.35 kN/m
Sum of moments at front toe = -8.07 kNm/m
Sum of moments at middle of base = 2.19 kNm/m
Eccentricity ec=2.19/27.35=0.080m, ec<=0.750/6=0.125m
Soil pressure q1=0.060 N/mm² q2=0.013 N/mm²

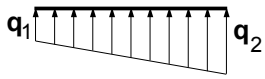


Effective footing L=0.750-2x0.080= 0.590 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.590x(1000x0.20)/1.40= 84.29 kN/m
Bearing resistance check Vd=27.35 < Rd=84.29 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

Check for 1.00x(self weight+top vertical dead load)+1.30x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.00	0.00- 0.90	1.25	0.08	1.074	1.100	1.29
Backfill surcharge (live)	Pqx1.30	0.00- 0.90	0.70	0.04	1.118	1.250	0.84
Active earth pressure	Pax1.00	0.90- 1.70	2.95	0.19	0.855	0.359	0.90
Backfill surcharge (live)	Pqx1.30	0.90- 1.70	0.55	0.04	0.867	0.400	0.18
Wall weight	W x1.00		0.00	22.00	0.641	0.769	-14.10
Vert. load on top (dead)	Ngx1.00		0.00	5.00	1.000	1.700	-5.00
Vert. load on top (live)	Nqx1.30		0.00	3.90	1.000	1.700	-3.90
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	1.000	1.700	3.40
Horiz. load on top (live)	Hqx1.30		2.60	0.00	1.000	1.700	4.42
			Sum=	31.25			-11.97

Sum of vertical forces = 31.25 kN/m
Sum of moments at front toe = -11.97 kNm/m
Sum of moments at middle of base = -0.25 kNm/m
Eccentricity ec=-0.25/31.25=-0.008m, ec<=0.750/6=0.125m
Soil pressure q1=0.039 N/mm² q2=0.044 N/mm²



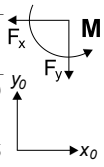
Effective footing L=0.750-2x0.008= 0.734 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.734x(1000x0.20)/1.40= 104.86 kN/m
Bearing resistance check Vd=31.25 < Rd=104.86 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

2.9.3. Failure check due to overturning (GEO)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.250,y=1.700 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	Mo+ [m]	Mo- [kNm/m]	[kNm/m]
Active earth pressure	Pax1.00	0.00- 0.90	1.25	0.08	1.074	1.100	1.38	0.09	
Backfill surcharge (live)	Pqx1.30	0.00- 0.90	0.70	0.04	1.118	1.250	0.88	0.04	
Active earth pressure	Pax1.00	0.90- 1.70	2.95	0.19	0.855	0.359	1.06	0.16	
Backfill surcharge (live)	Pqx1.30	0.90- 1.70	0.55	0.04	0.867	0.400	0.22	0.04	
Wall weight	W x1.00		0.00	22.00	0.641	0.769	0.00	14.10	
Vert. load on top (dead)	Ngx1.00		0.00	5.00	1.000	1.700	0.00	5.00	
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	1.000	1.700	3.40	0.00	
Horiz. load on top (live)	Hqx1.30		2.60	0.00	1.000	1.700	4.42	0.00	
					Sum=		11.36	19.43	

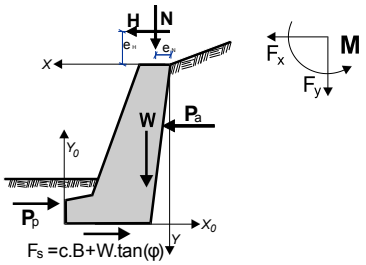


Sum of overturning moments = 11.36 kNm/m
Sum of moments resisting overturning = 19.43 kNm/m
Overturning check Msd=11.36 < Mrd=19.43 kNm/m, Check is verified

2.9.4. Failure check against sliding (GEO)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.00	0.00- 0.90	1.25	0.00	0.08
Backfill surcharge (live)	Pqx1.30	0.00- 0.90	0.70	0.00	0.04
Active earth pressure	Pax1.00	0.90- 1.70	2.95	0.00	0.19
Backfill surcharge (live)	Pqx1.30	0.90- 1.70	0.55	0.00	0.04
Passive earth pressure	Ppx1.00	1.20- 1.70	0.00	3.46	0.00
Wall weight	W x1.00		0.00	0.00	22.00
Vert. load on top (dead)	Ngx1.00		0.00	0.00	5.00
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.00
Horiz. load on top (live)	Hqx1.30		2.60	0.00	0.00
		Sum=	10.05	3.46	27.35



Soil friction Rd=Vd·tanφ/γM= 27.35xtan(30.00°)/1.25= 12.63 kN/m
Soil cohesion Rd=A·cu/γM = 1000x0.750x0.010/1.25= 6.00 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 10.05 kN/m
Sum of resisting forces (3.46+12.63) = 16.09 kN/m
Sliding resistance check Hd=10.05 < Rd=16.09 kN/m, Check is verified

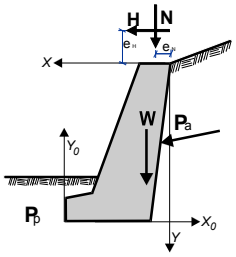
2.10. Seismic design

(EC8 EN1998-5:2004)

Checks of wall stability (with seismic loading)

2.10.1. Forces (driving and resisting) on the wall

Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa 0.00- 0.90	0.74	0.05	0.176	0.600
Backfill surcharge (live)	Pq 0.00- 0.90	0.32	0.02	0.132	0.450
Active earth pressure	Pa 0.90- 1.70	1.78	0.11	0.395	1.341
Backfill surcharge (live)	Pq 0.90- 1.70	0.26	0.02	0.383	1.300
Passive earth pressure	Pp 1.20- 1.70	-4.61	0.00	1.250	1.533
Wall weight	W	0.00	22.00	0.609	0.931
Vert. load on top (dead)	Ng	0.00	5.00	0.250	0.000
Vert. load on top (live)	Nq	0.00	3.00	0.250	0.000
Horiz. load on top (dead)	Hg	2.00	0.00	0.250	0.000
Horiz. load on top (live)	Hq	2.00	0.00	0.250	0.000



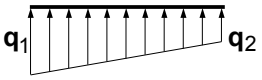
2.10.2. Additional forces due to seismic load

Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa 0.00- 0.90	0.64		0.176	0.600
Backfill surcharge (live)	Pq 0.00- 0.90	0.28		0.132	0.450
Active earth pressure	Pa 0.90- 1.70	1.46		0.395	1.341
Backfill surcharge (live)	Pq 0.90- 1.70	0.21		0.383	1.300
Wall weight	W	0.88	-0.44	0.609	0.931
Vert. load on top (dead)	Ng	0.20	-0.10	0.250	0.000
Vert. load on top (live)	Nq	0.12	-0.06	0.250	0.000

2.10.3. Check of soil bearing capacity (with seismic loading) (EC7 §6.5.2)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.00	0.00- 0.90	1.38	0.05	1.074	1.100	1.46
Backfill surcharge (live)	Pqx1.00	0.00- 0.90	0.60	0.02	1.118	1.250	0.73
Active earth pressure	Pax1.00	0.90- 1.70	3.24	0.11	0.855	0.359	1.08
Backfill surcharge (live)	Pqx1.00	0.90- 1.70	0.47	0.02	0.867	0.400	0.16
Wall weight	W x1.00		0.88	21.56	0.641	0.769	-13.14
Vert. load on top (dead)	Ngx1.00		0.20	4.90	1.000	1.700	-4.56
Vert. load on top (live)	Nqx1.00		0.12	2.94	1.000	1.700	-2.74
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	1.000	1.700	3.40
Horiz. load on top (live)	Hqx1.00		2.00	0.00	1.000	1.700	3.40
			Sum=	29.60			-10.21

Sum of vertical forces = 29.60 kN/m
Sum of moments at front toe = -10.21 kNm/m
Sum of moments at middle of base = 0.89 kNm/m
Eccentricity ec=0.89/29.60=0.030m, ec<=0.750/6=0.125m



Soil pressure q1=0.049 N/mm² q2=0.030 N/mm²
Effective footing L=0.750-2x0.030= 0.690 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=0.690x(1000x0.20)/1.00= 138.00 kN/m
Bearing resistance check Vd=29.60 < Rd=138.00 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

2.10.4. Failure check due to overturning (with seismic loading) (EC7 §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.250,y=1.700 m)

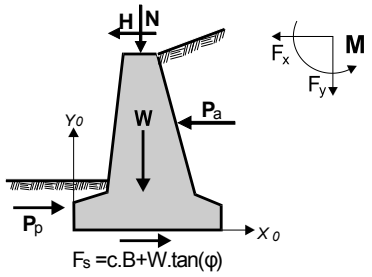
Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.00	0.00- 0.90	1.38	0.05	1.074	1.100	1.51	0.05
Backfill surcharge (live)	Pqx1.00	0.00- 0.90	0.60	0.02	1.118	1.250	0.75	0.02
Active earth pressure	Pax1.00	0.90- 1.70	3.24	0.11	0.855	0.359	1.17	0.09
Backfill surcharge (live)	Pqx1.00	0.90- 1.70	0.47	0.02	0.867	0.400	0.18	0.02
Wall weight	W x1.00		0.88	21.56	0.641	0.769	0.96	14.10*
Vert. load on top (dead)	Ngx1.00		0.20	4.90	1.000	1.700	0.44	5.00*
Vert. load on top (live)	Nqx1.00		0.12	2.94	1.000	1.700	0.26	3.00*
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	1.000	1.700	3.40	0.00
Horiz. load on top (live)	Hqx1.00		2.00	0.00	1.000	1.700	3.40	0.00
					Sum=		12.07	22.28

(*moments of negative seismic vertical loads, are added to the overturning moments)

Sum of overturning moments = 12.07 kNm/m
Sum of moments resisting overturning = 22.28 kNm/m
Overturning check Msd=12.07 < Mrd=22.28 kNm/m, Check is verified

2.10.5. Failure check against sliding (with seismic loading) (EC7 §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.00	0.00- 0.90	1.38	0.00	0.05
Backfill surcharge (live)	Pqx1.00	0.00- 0.90	0.60	0.00	0.02
Active earth pressure	Pax1.00	0.90- 1.70	3.24	0.00	0.11
Backfill surcharge (live)	Pqx1.00	0.90- 1.70	0.47	0.00	0.02
Passive earth pressure	Ppx1.00	1.20- 1.70	0.00	4.61	0.00
Wall weight	W x1.00		0.88	0.00	21.56
Vert. load on top (dead)	Ngx1.00		0.20	0.00	4.90
Vert. load on top (live)	Nqx1.00		0.12	0.00	2.94
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.00
Horiz. load on top (live)	Hqx1.00		2.00	0.00	0.00
		Sum=	10.89	4.61	29.60



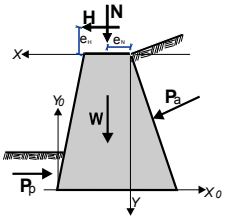
Soil friction Rd=Vd·tanφ/γM= 29.60xtan(30.00°)/1.00= 17.09 kN/m
Soil cohesion Rd=A·cu/γM = 1000x0.750x0.010/1.00= 7.50 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 10.89 kN/m
Sum of resisting forces (4.61+17.09) = 21.70 kN/m
Sliding resistance check Hd=10.89 < Rd=21.70 kN/m, Check is verified

2.11. Design of wall steam

2.11.1. Loading 1.35x(permanent unfavourable)+1.00x(permanent favourable)+1.50x(variable unfav.)

Forces (at centroid of cross section) and stresses at wall steam
x, y:cross section centroid, b:cross section width, e:eccentricity
Fx:horizontal force, Fy:vertical force, M:moment, e/b:relative eccentricity
σ1, σ2: cross section normal stresses, τ:shear stress, Bq:effective cross section width

y [m]	x [m]	b [m]	Fx [kN/m]	Fy [kN/m]	M [kNm/m]	e/b	σ1 [N/mm²]	σ2 [N/mm²]	Bq/B	τ [N/mm²]
0.24	0.335	0.529	5.90	7.49	0.46	-0.117	-0.024	-0.004	1.000	0.011
0.48	0.421	0.559	6.24	10.11	0.78	-0.138	-0.033	-0.003	1.000	0.011
0.72	0.506	0.588	6.72	12.91	0.95	-0.125	-0.038	-0.006	1.000	0.011
0.96	0.591	0.618	7.34	15.84	1.02	-0.104	-0.042	-0.010	1.000	0.012
1.20	0.676	0.647	8.06	18.92	1.00	-0.082	-0.044	-0.015	1.000	0.012



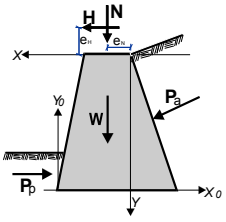
2.11.2. Strength check with allowable stresses

Compression σ max= 0.044 <= σ(allowable)= 3.000 N/mm²
Tension σ max= 0.000 <= σ(allowable)= 0.000 N/mm²
Shear τ max= 0.012 <= τ(allowable)= 0.300 N/mm²

2.11.3. Loading 1.00x(permanent unfav.)+1.00x(permanent favour.)+1.00x(variable)+1.00x(seismic)

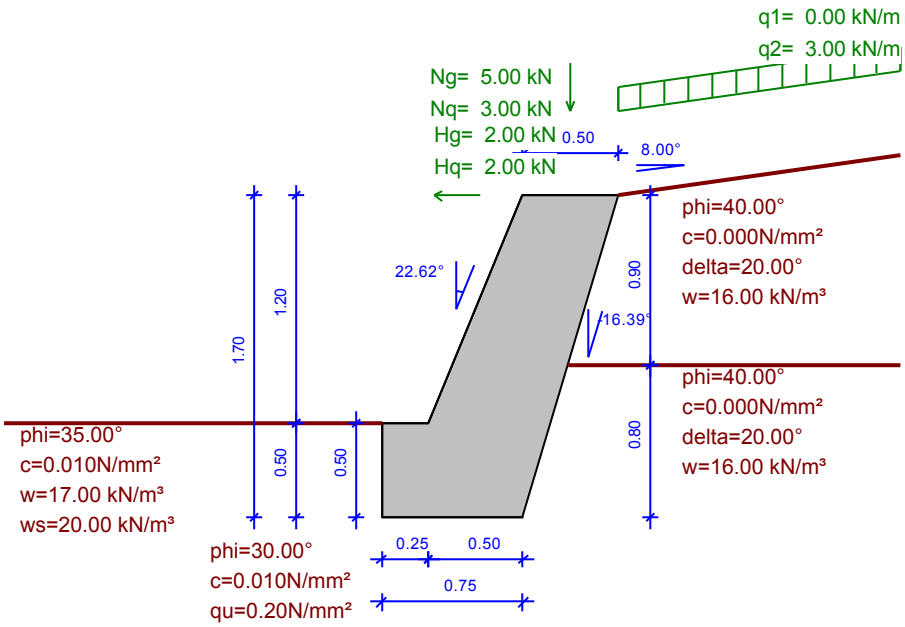
Forces (at centroid of cross section) and stresses at wall steam (with seismic loading)
x, y:cross section centroid, b:cross section width, e:eccentricity
Fx:horizontal force, Fy:vertical force, M:moment, e/b:relative eccentricity
σ1, σ2: cross section normal stresses, τ:shear stress, Bq:effective cross section width

y [m]	x [m]	b [m]	Fx [kN/m]	Fy [kN/m]	M [kNm/m]	e/b	σ1 [N/mm²]	σ2 [N/mm²]	Bq/B	τ [N/mm²]
0.24	0.335	0.529	4.68	10.27	0.30	-0.075	-0.020	-0.008	1.000	0.009
0.48	0.421	0.559	5.23	12.84	0.49	-0.087	-0.028	-0.009	1.000	0.009
0.72	0.506	0.588	6.00	15.57	0.61	-0.081	-0.033	-0.011	1.000	0.010
0.96	0.591	0.618	6.67	18.43	0.57	-0.058	-0.035	-0.017	1.000	0.011
1.20	0.676	0.647	7.74	21.44	0.59	-0.048	-0.038	-0.021	1.000	0.012



2.11.4. Strength check with allowable stresses (with seismic loading)

Compression σ max= 0.038 <= σ(allowable)= 3.000 N/mm²
Tension σ max= 0.000 <= σ(allowable)= 0.000 N/mm²
Shear τ max= 0.012 <= τ(allowable)= 0.300 N/mm²



General information

Wall type : Gravity wall

Wall materials

Allowable compressive stress 3.00 N/mm²

Allowable tensile stress 0.00 N/mm²

Allowable shear stress 0.30 N/mm²

Design codes

Eurocode 0 EN1991-1-1, Basis of structural design

Eurocode 1 EN1991-1-1, Actions on structures

Eurocode 2 EN1992-1-1, Design of concrete structures

Eurocode 7 EN1997-1-1, Geotechnical design

Eurocode 8 EN1998-5, Earthquaqe design

Loads

Vertical : dead Ng=5.00kN, live Nq=3.00kN

Horizontal: dead Hg=2.00kN, live Hq=2.00kN

Surcharge : dead g=0.00kN/m², live q=3.00kN/m²

Seismic coefficients

Design ground acceleration ratio a =0.060

Coefficient for horizontal seismic force kh=0.040

Coefficient for vertical seismic force kv=0.020

Soil properties back-1

phi=40.00°

c=0.000N/mm²

delta=20.00°

w=16.00 kN/m³

Soil properties back-2

phi=40.00°

c=0.000N/mm²

delta=20.00°

w=16.00 kN/m³

Soil properties front

phi=35.00°

c=0.010N/mm²

w=17.00 kN/m³

ws=20.00 kN/m³

Foundation soil properties

phi=30.00°

c=0.010N/mm²

qu=0.20N/mm²

Concrete volume V= 11.00 [m³]

Project: Example of retaining walls

G. WALL-002

Scale : 1:40 **Date:** 12/03/2007

Designer: **Draw.No.:**

Filename: Example of retaining w... **Sign:**

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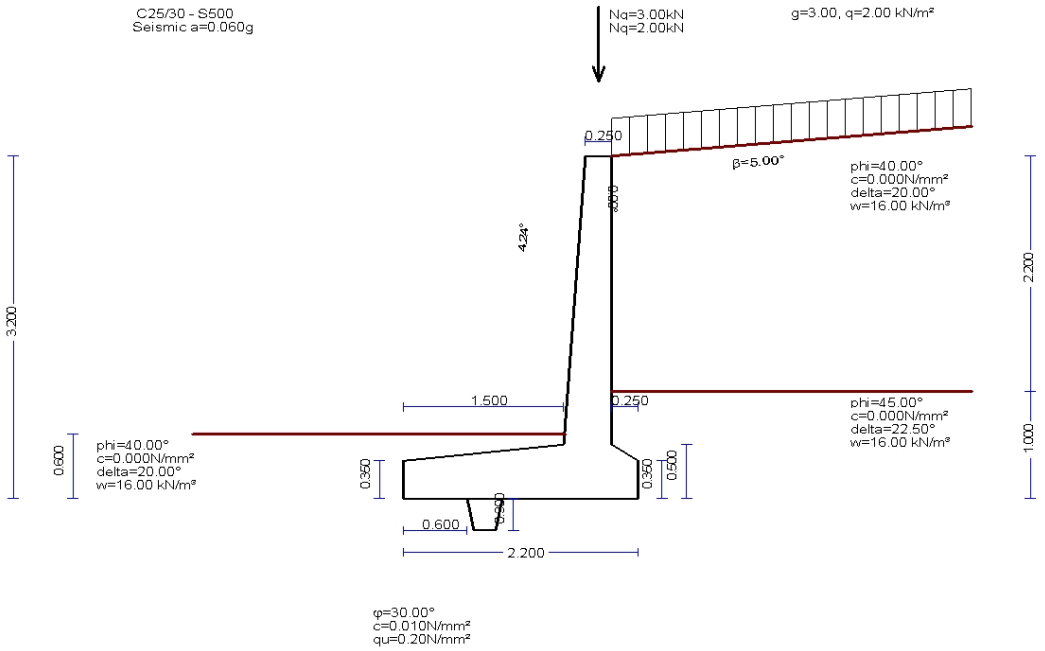
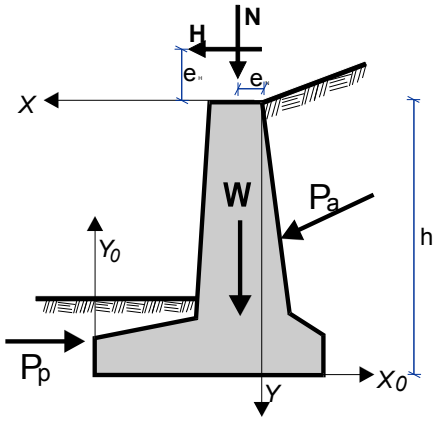
3. C. WALL-001

Cantilever concrete wall

(EC2 EN1992-1-1:2004, EC0 EN1990-1-1:2002, EC7 EN1997-1-1:2004, EC8 EN1998-5:2004)



3.1. Wall properties-Parameters-Code requirements



Dimensions

Height of wall	h=	3.200 m
Transverse length of wall	L=	10.000 m
Steam thickness at top	B1=	0.250 m
Steam thickness at bottom	B2=	0.450 m
Width of wall base	B=	2.200 m
Width of wall toe		1.500 m
Width of wall heel		0.250 m
Height of wall steam		2.700 m
Thickness of wall footing		0.500 m
Front thickness of wall toe		0.350 m
Back thickness of wall heel		0.350 m
Slope (batter) at frontface		4.236° (1:13.5)
Slope (batter) at backface		0.000° (0:1)
Height of wall base key		0.300 m

Loads on wall top

Vertical permanent load	Ng=	3.00 kN/m
Vertical variable load	Nq=	2.00 kN/m
Eccentricity of vertical load	eN=	0.13 kN/m
Horizontal permanent load	Hg=	0.00 kN/m
Horizontal variable load	Hq=	0.00 kN/m
Eccentricity of horizontal load	eH=	0.00 kN/m

Weight of wall

Unit weight of wall material γg=25.000 kN/m³
Cross section area of wall A= 1.914 m²
Self weight per meter of wall W= 1.914x25.000= 47.85 kN/m
Center of gravity of wall at x=0.494 m, y=2.237 m (xo=1.456 m, yo=0.963 m)

Wall materials

Steam : Concrete-Steel class: C25/30-S500 (EN1992-1-1, §3)
: Concrete cover: Cnom=25 mm (EN1992-1-1, §4.4.1)
Footing : Concrete-Steel class: C25/30-S500
: Concrete cover: Cnom=75 mm

Weight of backfill

Weight of backfill per meter Ws=11.14 kN/m
Center of gravity of backfill x=-0.125 m, y=1.382 m

3.2. Partial factors for actions and soil properties

(EC7 Tables A.1-A.4, EC8-5 §3.1)

Equilibrium limit state (EQU), Structural limit state (STR), Geotechnical limit state (GEO)

				(EQU)	(STR)	(GEO)	(SEISMIC)
Actions	Permanent	Unfavourable	γGdst:	1.10	1.35	1.00	1.00
	Permanent	Favourable	γGstb:	0.90	1.00	1.00	1.00
	Variable	Unfavourable	γQdst:	1.50	1.50	1.30	1.00
	Variable	Favourable	γQstb:	0.00	0.00	0.00	0.00
Soil parameters	Angle of shearing resistance		γφ:	1.25	1.00	1.25	1.25
	Effective cohesion		γc:	1.25	1.00	1.25	1.25
	Undrained shear strength		γcu:	1.40	1.00	1.40	1.40
	Unconfined strength		γqu:	1.40	1.00	1.40	1.40
	Weight density		γw:	1.00	1.00	1.00	1.00

3.3. Properties of foundation soil

Bearing capacity of foundation soil qu=0.20 N/mm²
Friction angle between wall footing and soil φ=30.00°, friction coefficient tan(φ)=0.577
Cohesion between wall footing and soil c=0.010 N/mm²

3.4. Seismic coefficients

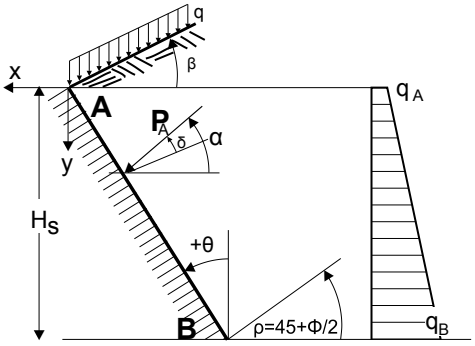
(EC8 EN1998-5:2004, §7.3.2)

Design ground acceleration ratio gh=axg, a=0.06 (EC8-5 §7.3.2)
Reduction factor for seismic coefficient r=1.50 (EC8-5 Table 7.1)
Coefficient for horizontal seismic force kh=0.06/1.500=0.040 (EC8-5 Eq.7.1)
Coefficient for vertical seismic force kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)

Forces due to seismic load (except from earth pressure)

Horizontal seismic force due to self weight Fwx= 47.85x0.040= 1.91 kN/m
Vertical seismic force due to self weight Fwy= 47.85x0.020= 0.96 kN/m
Horizontal seismic force of top loading Ng Fgx= 3.00x0.040= 0.12 kN/m
Vertical seismic force of top loading Ng Fgy= 3.00x0.020= 0.06 kN/m
Horizontal seismic force of top loading Nq Fqx= 2.00x0.040= 0.08 kN/m
Vertical seismic force of top loading Nq Fqy= 2.00x0.020= 0.04 kN/m
Horizontal seismic force of backfill Fwsx= 11.14x0.040= 0.45 kN/m
Vertical seismic force of backfill Fwsy= 11.14x0.020= 0.22 kN/m

3.5. Computation of active earth pressure (Coulomb theory)



3.5.1. Wall part from y=0.000 m to y=2.200 m, Hs=2.200 m

Top point A x= 0.000 m y= 0.000 m
Bottom point B x= 0.000 m y= 2.200 m

Soil properties

Soil type : Mean gravel

Unit weight of soil	γ =16.00 kN/m³
Unit weight of soil (saturated)	γs=20.00 kN/m³
Unit weight of water	γw=10.00 kN/m³
Angle of shearing resistance of ground	φ=40.00°
Cohesion of ground	c=0.000 N/mm²
Slope angle of ground surface	β= 5.00°
Inclination angle of the wall backface	θ= 0.00°
Angle of shear resist. between ground-wall	δ=20.00°

Loads on soil surface

Permanent uniform load	g= 3.00 kN/m²
Variable uniform load	q= 2.00 kN/m²

Earth pressure according to Coulomb theory

$$K_A = \frac{\cos^2(\varphi-\theta)}{\cos^2\theta\,\cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\theta+\delta)\sin(\theta-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$

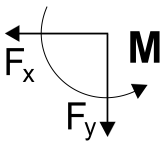
	EQU	STR	GEO
Angle of rupture plane ρ=45°+φ/2 =	61.00	65.00	61.00°
Coefficient of active earth pressure Ka=	0.295	0.209	0.295

Earth pressure q(y)=qA+γ·y·Ka

Permanent actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.88	0.63	0.88	kN/m²
Earth pressure at the bottom (y=yA+ 2.20m)	qB=	11.26	7.99	11.26	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	13.35	9.48	13.35	kN/m
Angle of earth force	α =	16.00	20.00	16.00	°
Earth force in x direction	Pax=	12.54	8.91	12.54	kN/m
Earth force in y direction	Pay=	4.57	3.24	4.57	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-17.73	-12.59	-17.73	kNm/m

Point of application of earth force x= 0.000 m, y= 1.413 m



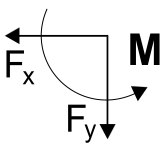
Variable actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.59	0.42	0.59	kN/m²
Earth pressure at the bottom (y=yA+ 2.20m)	qB=	0.59	0.42	0.59	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	1.30	0.92	1.30	kN/m
Angle of earth force	α =	16.00	20.00	16.00	°
Earth force in x direction	Pax=	1.22	0.86	1.22	kN/m
Earth force in y direction	Pay=	0.44	0.31	0.44	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-1.34	-0.95	-1.34	kNm/m

Point of application of earth force x= 0.000 m, y= 1.100 m

Total forces and moments

Forces and moments at bottom point B (x=0.000 m, y=2.200 m)



Permanent actions

	EQU	STR	GEO	
Total horizontal earth force Fsx=	12.54	8.91	12.54	kN/m
Total vertical earth force Fsy=	4.57	3.24	4.57	kN/m
Total moment of earth force Ms =	9.86	7.01	9.86	kNm/m

Variable actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	1.22	0.86	1.22	kN/m
Total vertical earth force	Fsy=	0.44	0.31	0.44	kN/m
Total moment of earth force	Ms =	1.34	0.95	1.34	kNm/m

Seismic loading (EC8 EN1998-5:2004, §7.3.2, Annex E)

Horizontal seismic coefficient kh=0.06/1.500=0.040 (EC8-5 Eq.7.1, T.7.1)
Vertical seismic coefficient kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)
Soil above the water table (EC8-5 Annex E.5)
tan(ω)=kh/(1-kv)=0.040/(1-0.020)=0.041, ω=2.34°

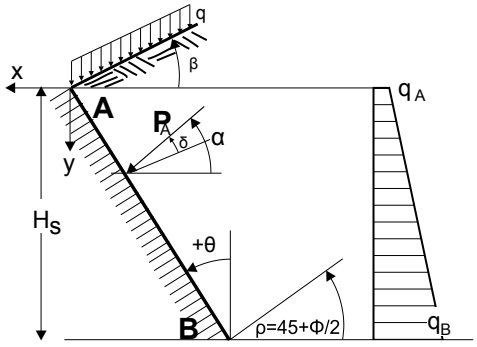
Method Mononobe-Okabe (EC8-5 Annex E.4)
for active earth force during seismic loading
Coefficient of active earth pressure, Ke*= 0.316
Additional earth pressure due to seismic load
over STR load case ξ=(Ke*/Ke-1)=(0.316/0.209-1)=0.512

$$K_E = \frac{\cos^2(\varphi-\omega-\theta)}{\cos\omega\cos^2\theta\cos(\delta+\theta+\omega)\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\omega-\beta)}{\cos(\theta+\omega+\delta)\cos(\theta-\beta)}}\right]^2}$$

Earth force due to seismic load (Permanent actions) Fx=1.512x 8.91=13.47 kN/m
Earth force due to seismic load (Variable actions) Fx=1.512x 0.86= 1.30 kN/m

3.5.2. Wall part from y=2.200 m to y=3.200 m, Hs=1.000 m

Top point A x= 0.000 m y= 2.200 m
Bottom point B x= 0.000 m y= 3.200 m



Soil properties

Soil type : Large gravel

Unit weight of soil	γ	=16.00 kN/m³
Unit weight of soil (saturated)	γs	=20.00 kN/m³
Unit weight of water	γw	=10.00 kN/m³
Angle of shearing resistance of ground	φ	=45.00°
Cohesion of ground	c	=0.000 N/mm²
Slope angle of ground surface	β	= 0.00°
Inclination angle of the wall backface	θ	= 0.00°
Angle of shear resist. between ground-wall	δ	=22.50°

Loads on soil surface

Permanent uniform load	g=	38.20 kN/m²
Variable uniform load	q=	2.00 kN/m²

Earth pressure according to Coulomb theory

$$K_A = \frac{\cos^2(\varphi-\theta)}{\cos^2\theta\cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\theta+\delta)\sin(\theta-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$

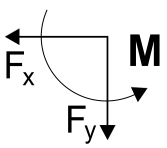
	EQU	STR	GEO
Angle of rupture plane ρ=45°+φ/2 =	63.00	67.50	63.00°
Coefficient of active earth pressure Ka=	0.236	0.160	0.236

Earth pressure q(y)=qA+γ·y·Ka

Permanent actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	9.02	6.11	9.02	kN/m²
Earth pressure at the bottom (y=yA+ 1.00m)	qB=	12.80	8.67	12.80	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	10.91	7.39	10.91	kN/m
Angle of earth force	α =	18.00	22.50	18.00	°
Earth force in x direction	Pax=	10.08	6.83	10.08	kN/m
Earth force in y direction	Pay=	4.18	2.83	4.18	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-27.51	-18.64	-27.51	kNm/m

Point of application of earth force x= 0.000 m, y= 2.729 m



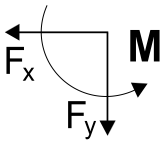
Variable actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.47	0.32	0.47	kN/m²
Earth pressure at the bottom (y=yA+ 1.00m)	qB=	0.47	0.32	0.47	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	0.47	0.32	0.47	kN/m
Angle of earth force	α =	18.00	22.50	18.00	°
Earth force in x direction	Pax=	0.43	0.30	0.43	kN/m
Earth force in y direction	Pay=	0.18	0.12	0.18	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-1.16	-0.81	-1.16	kNm/m

Point of application of earth force x= 0.000 m, y= 2.700 m

Total forces and moments

Forces and moments at bottom point B (x=0.000 m, y=3.200 m)



Permanent actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	22.62	15.74	22.62	kN/m
Total vertical earth force	Fsy=	8.75	6.07	8.75	kN/m
Total moment of earth force	Ms =	27.15	19.14	27.15	kNm/m

Variable actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	1.65	1.16	1.65	kN/m
Total vertical earth force	Fsy=	0.62	0.43	0.62	kN/m
Total moment of earth force	Ms =	2.78	1.96	2.78	kNm/m

Seismic loading (EC8 EN1998-5:2004, §7.3.2, Annex E)

Horizontal seismic coefficient kh=0.06/1.500=0.040 (EC8-5 Eq.7.1, T.7.1)
Vertical seismic coefficient kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)
Soil above the water table (EC8-5 Annex E.5)
tan(ω)=kh/(1-kv)=0.040/(1-0.020)=0.041, ω=2.34°

Method Mononobe-Okabe (EC8-5 Annex E.4)
for active earth force during seismic loading
Coefficient of active earth pressure, Ke*= 0.254
Additional earth pressure due to seismic load
over STR load case ξ=(Ke*/Ke-1)=(0.254/0.160-1)=0.588

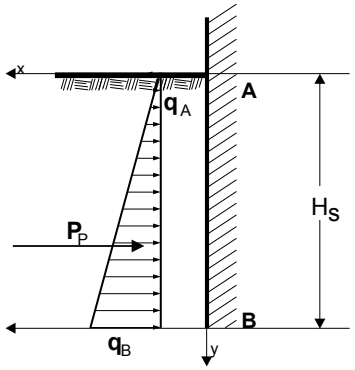
$$K_E = \frac{\cos^2(\varphi-\omega-\theta)}{\cos\omega\cos^2\theta\cos(\delta+\theta+\omega)\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\omega-\beta)}{\cos(\theta+\omega+\delta)\cos(\theta-\beta)}}\right]^2}$$

Earth force due to seismic load (Permanent actions) Fx=1.588x 6.83=10.85 kN/m
Earth force due to seismic load (Variable actions) Fx=1.588x 0.30= 0.48 kN/m

3.6. Computation of passive earth pressure (Rankine theory)

3.6.1. Wall part from y=2.600 m to y=3.500 m, Hs=0.900 m

Top point A x= 1.950 m y= 2.600 m
Bottom point B x= 1.950 m y= 3.500 m



Soil properties

Soil type : Mean gravel

Unit weight of soil	γ =	16.00 kN/m³
Unit weight of soil (saturated)	γs=	20.00 kN/m³
Unit weight of water	γw=	10.00 kN/m³
Angle of shearing resistance of ground	φ=	40.00°
Cohesion of ground	c=	0.000 N/mm²
Slope angle of ground surface	β=	0.00°
Earth pressure on vertical surface	θ=	0.00°
Angle of shear resist. between ground-wall	δ=	0.00°

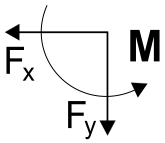
Earth pressure according to Coulomb theory

$$K_p = \frac{\cos^2(\varphi+\theta)}{\cos^2\theta\,\cos(\theta-\delta)\left[1-\sqrt{\frac{\sin(\theta+\delta)\sin(\theta+\beta)}{\cos(\theta-\delta)\cos(\theta-\beta)}}\right]^2}$$

		EQU	STR	GEO
Angle of rupture plane ρ=45°-φ/2	=	29.00	25.00	29.00°
Coefficient of passive earth pressure	Kp=	3.255	4.599	3.255

Earth pressure q(y)=qA+γ·y·Kp

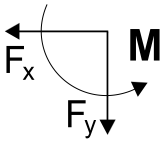
Permanent actions



		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.00	0.00	0.00	kN/m²
Earth pressure at the bottom (y=yA+ 0.90m)	qB=	-46.87	-66.23	-46.87	kN/m²
Earth force Pa=½(qA+qB)H	Pp=	21.09	29.80	21.09	kN/m
Angle of earth force	α =	0.00	0.00	0.00	°
Earth force in x direction	Ppx=	-21.09	-29.80	-21.09	kN/m
Earth force in y direction	Ppy=	0.00	0.00	0.00	kN/m
Moment of earth force at top point (x=0,y=0)	M =	67.49	95.36	67.49	kNm/m

Point of application of earth force x= 1.950 m, y= 3.200 m

Total forces and moments



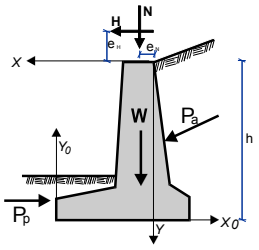
Forces and moments at bottom point B (x=1.950 m, y=3.500 m)

Permanent actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	-21.09	-29.80	-21.09	kN/m
Total vertical earth force	Fsy=	0.00	0.00	0.00	kN/m
Total moment of earth force	Ms =	-6.33	-8.94	-6.33	kNm/m

3.7. Checks of wall stability (EQU)

3.7.1. Forces (driving and resisting) on the wall (EQU)

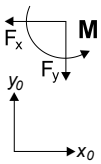


Action		y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa	0.00- 2.20	12.54	4.57	0.000	1.414
Backfill surcharge (live)	Pq	0.00- 2.20	1.22	0.44	0.000	1.100
Active earth pressure	Pa	2.20- 3.20	10.08	4.18	0.000	2.729
Backfill surcharge (live)	Pq	2.20- 3.20	0.43	0.18	0.000	2.700
Passive earth pressure	Pp	2.60- 3.50	-21.09	0.00	1.950	3.200
Wall weight	W		0.00	47.85	0.494	2.237
Backfill weight	Ws		0.00	11.14	-0.125	1.382
Vert. load on top (dead)	Ng		0.00	3.00	0.125	0.000
Vert. load on top (live)	Nq		0.00	2.00	0.125	0.000

3.7.2. Check of soil bearing capacity (EQU)

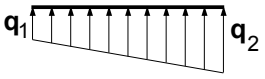
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 0.90x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.10	0.00- 2.20	13.79	5.03	1.950	1.786	14.84
Backfill surcharge (live)	Pqx1.50	0.00- 2.20	1.83	0.66	1.950	2.100	2.55
Active earth pressure	Pax1.10	2.20- 3.20	11.09	4.60	1.950	0.471	-3.74
Backfill surcharge (live)	Pqx1.50	2.20- 3.20	0.64	0.27	1.950	0.500	-0.20
Wall weight	W x0.90		0.00	43.06	1.456	0.963	-62.70
Backfill weight	Wsx0.90		0.00	10.03	2.075	1.818	-20.81
Vert. load on top (dead)	Ngx0.90		0.00	2.70	1.825	3.200	-4.93
			Sum=	66.35			-74.99

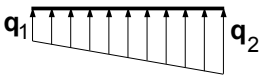
Sum of vertical forces = 66.35 kN/m
Sum of moments at front toe = -74.99 kNm/m
Sum of moments at middle of base = -2.00 kNm/m
Eccentricity ec=-2.00/66.35=-0.030m, ec<=2.200/6=0.367m
Soil pressure q1=0.028 N/mm² q2=0.033 N/mm²
Effective footing L=2.200-2x0.030= 2.140 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=2.140x(1000x0.20)/1.40= 305.71 kN/m
Bearing resistance check Vd=66.35 < Rd=305.71 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)



Check for 1.10x(self weight+top vertical dead load)+1.50x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.10	0.00- 2.20	13.79	5.03	1.950	1.786	14.84
Backfill surcharge (live)	Pqx1.50	0.00- 2.20	1.83	0.66	1.950	2.100	2.55
Active earth pressure	Pax1.10	2.20- 3.20	11.09	4.60	1.950	0.471	-3.74
Backfill surcharge (live)	Pqx1.50	2.20- 3.20	0.64	0.27	1.950	0.500	-0.20
Wall weight	W x1.10		0.00	52.64	1.456	0.963	-76.64
Backfill weight	Wsx1.10		0.00	12.25	2.075	1.818	-25.43
Vert. load on top (dead)	Ngx1.10		0.00	3.30	1.825	3.200	-6.03
Vert. load on top (live)	Nqx1.50		0.00	3.00	1.825	3.200	-5.48
				Sum=	81.75		-100.13

Sum of vertical forces = 81.75 kN/m
Sum of moments at front toe = -100.13 kNm/m
Sum of moments at middle of base = -10.20 kNm/m
Eccentricity ec=-10.20/81.75=-0.125m, ec<=2.200/6=0.367m
Soil pressure q1=0.025 N/mm² q2=0.050 N/mm²
Effective footing L=2.200-2x0.125= 1.950 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.950x(1000x0.20)/1.40= 278.57 kN/m
Bearing resistance check Vd=81.75 < Rd=278.57 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

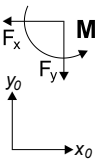


3.7.3. Failure check due to overturning (EQU)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.950,y=3.200 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.10	0.00- 2.20	13.79	5.03	1.950	1.786	24.64	9.80
Backfill surcharge (live)	Pqx1.50	0.00- 2.20	1.83	0.66	1.950	2.100	3.84	1.29
Active earth pressure	Pax1.10	2.20- 3.20	11.09	4.60	1.950	0.471	5.23	8.97
Backfill surcharge (live)	Pqx1.50	2.20- 3.20	0.64	0.27	1.950	0.500	0.33	0.52
Wall weight	W x0.90		0.00	43.06	1.456	0.963	0.00	62.70
Backfill weight	Wsx0.90		0.00	10.03	2.075	1.818	0.00	20.81
Vert. load on top (dead)	Ngx0.90		0.00	2.70	1.825	3.200	0.00	4.93
					Sum=		34.04	109.02

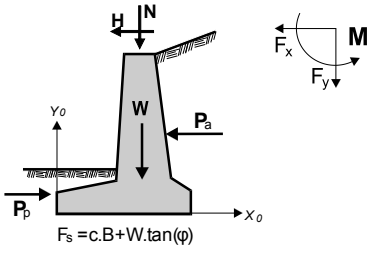


Sum of overturning moments = 34.04 kNm/m
Sum of moments resisting overturning = 109.02 kNm/m
Overturning check Msd=34.04 < Mrd=109.02 kNm/m, Check is verified

3.7.4. Failure check against sliding (EQU)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.10	0.00- 2.20	13.79	0.00	5.03
Backfill surcharge (live)	Pqx1.50	0.00- 2.20	1.83	0.00	0.66
Active earth pressure	Pax1.10	2.20- 3.20	11.09	0.00	4.60
Backfill surcharge (live)	Pqx1.50	2.20- 3.20	0.64	0.00	0.27
Passive earth pressure	Ppx0.90	2.60- 3.50	0.00	18.98	0.00
Wall weight	W x0.90		0.00	0.00	43.06
Backfill weight	Wsx0.90		0.00	0.00	10.03
Vert. load on top (dead)	Ngx0.90		0.00	0.00	2.70
		Sum=	27.35	18.98	66.35

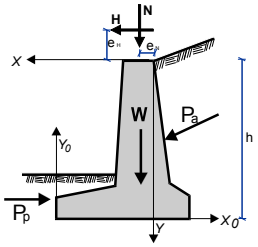


Soil friction Rd=Vd·tanφ/γM= 66.35xtan(30.00°)/1.25= 30.65 kN/m
Soil cohesion Rd=A·cu/γM = 1000x2.200x0.010/1.25= 17.60 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 27.35 kN/m
Sum of resisting forces (18.98+30.65) = 49.63 kN/m
Sliding resistance check Hd=27.35 < Rd=49.63 kN/m, Check is verified

3.8. Checks of wall stability (STR)

3.8.1. Forces (driving and resisting) on the wall (STR)

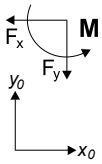
Action		y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa	0.00- 2.20	8.91	3.24	0.000	1.413
Backfill surcharge (live)	Pq	0.00- 2.20	0.86	0.31	0.000	1.100
Active earth pressure	Pa	2.20- 3.20	6.83	2.83	0.000	2.729
Backfill surcharge (live)	Pq	2.20- 3.20	0.30	0.12	0.000	2.700
Passive earth pressure	Pp	2.60- 3.50	-29.80	0.00	1.950	3.200
Wall weight	W		0.00	47.85	0.494	2.237
Backfill weight	Ws		0.00	11.14	-0.125	1.382
Vert. load on top (dead)	Ng		0.00	3.00	0.125	0.000
Vert. load on top (live)	Nq		0.00	2.00	0.125	0.000



3.8.2. Check of soil bearing capacity (STR)

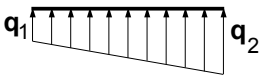
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 1.00x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	M [m]	[kNm/m]
Active earth pressure	Pax1.35	0.00- 2.20	12.03	4.37	1.950	1.787	12.96	
Backfill surcharge (live)	Pqx1.50	0.00- 2.20	1.29	0.46	1.950	2.100	1.82	
Active earth pressure	Pax1.35	2.20- 3.20	9.22	3.82	1.950	0.471	-3.11	
Backfill surcharge (live)	Pqx1.50	2.20- 3.20	0.45	0.18	1.950	0.500	-0.12	
Wall weight	W x1.00		0.00	47.85	1.456	0.963	-69.67	
Backfill weight	Wsx1.00		0.00	11.14	2.075	1.818	-23.12	
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.825	3.200	-5.48	
			Sum=	70.82			-86.72	

Sum of vertical forces = 70.82 kN/m
Sum of moments at front toe = -86.72 kNm/m
Sum of moments at middle of base = -8.82 kNm/m
Eccentricity ec=-8.82/70.82=-0.125m, ec<=2.200/6=0.367m
Soil pressure q1=0.021 N/mm² q2=0.043 N/mm²

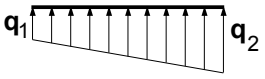


Effective footing L=2.200-2x0.125= 1.951 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.951x(1000x0.20)/1.00= 390.20 kN/m
Bearing resistance check Vd=70.82 < Rd=390.20 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

Check for 1.35x(self weight+top vertical dead load)+1.50x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	M [m]	[kNm/m]
Active earth pressure	Pax1.35	0.00- 2.20	12.03	4.37	1.950	1.787	12.96	
Backfill surcharge (live)	Pqx1.50	0.00- 2.20	1.29	0.46	1.950	2.100	1.82	
Active earth pressure	Pax1.35	2.20- 3.20	9.22	3.82	1.950	0.471	-3.11	
Backfill surcharge (live)	Pqx1.50	2.20- 3.20	0.45	0.18	1.950	0.500	-0.12	
Wall weight	W x1.35		0.00	64.60	1.456	0.963	-94.05	
Backfill weight	Wsx1.35		0.00	15.04	2.075	1.818	-31.21	
Vert. load on top (dead)	Ngx1.35		0.00	4.05	1.825	3.200	-7.40	
Vert. load on top (live)	Nqx1.50		0.00	3.00	1.825	3.200	-5.48	
			Sum=	95.52			-126.59	

Sum of vertical forces = 95.52 kN/m
Sum of moments at front toe = -126.59 kNm/m
Sum of moments at middle of base = -21.52 kNm/m
Eccentricity ec=-21.52/95.52=-0.225m, ec<=2.200/6=0.367m
Soil pressure q1=0.017 N/mm² q2=0.070 N/mm²

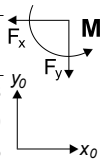


Effective footing L=2.200-2x0.225= 1.749 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.749x(1000x0.20)/1.00= 349.80 kN/m
Bearing resistance check Vd=95.52 < Rd=349.80 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

3.8.3. Failure check due to overturning (STR)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.950,y=3.200 m)



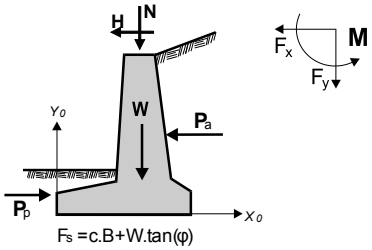
Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.35	0.00- 2.20	12.03	4.37	1.950	1.787	21.49	8.53
Backfill surcharge (live)	Pqx1.50	0.00- 2.20	1.29	0.46	1.950	2.100	2.72	0.90
Active earth pressure	Pax1.35	2.20- 3.20	9.22	3.82	1.950	0.471	4.35	7.45
Backfill surcharge (live)	Pqx1.50	2.20- 3.20	0.45	0.18	1.950	0.500	0.22	0.34
Wall weight	W x1.00		0.00	47.85	1.456	0.963	0.00	69.67
Backfill weight	Wsx1.00		0.00	11.14	2.075	1.818	0.00	23.12
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.825	3.200	0.00	5.48
					Sum=		28.78	115.49

Sum of overturning moments = 28.78 kNm/m
Sum of moments resisting overturning = 115.49 kNm/m
Overturning check Msd=28.78 < Mrd=115.49 kNm/m, Check is verified

3.8.4. Failure check against sliding (STR)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.35	0.00- 2.20	12.03	0.00	4.37
Backfill surcharge (live)	Pqx1.50	0.00- 2.20	1.29	0.00	0.46
Active earth pressure	Pax1.35	2.20- 3.20	9.22	0.00	3.82
Backfill surcharge (live)	Pqx1.50	2.20- 3.20	0.45	0.00	0.18
Passive earth pressure	Ppx1.00	2.60- 3.50	0.00	29.80	0.00
Wall weight	W x1.00		0.00	0.00	47.85
Backfill weight	Wsx1.00		0.00	0.00	11.14
Vert. load on top (dead)	Ngx1.00		0.00	0.00	3.00
		Sum=	22.99	29.80	70.82

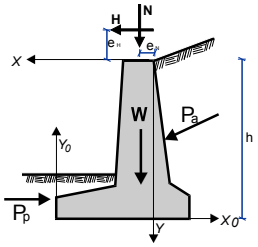


Soil friction Rd=Vd·tanφ/γM= 70.82xtan(30.00°)/1.00= 40.89 kN/m
Soil cohesion Rd=A·cu/γM = 1000x2.200x0.010/1.00= 22.00 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 22.99 kN/m
Sum of resisting forces (29.80+40.89) = 70.69 kN/m
Sliding resistance check Hd=22.99 < Rd=70.69 kN/m, Check is verified

3.9. Checks of wall stability (GEO)

3.9.1. Forces (driving and resisting) on the wall (GEO)

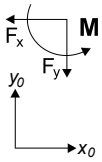
Action		y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa	0.00- 2.20	12.54	4.57	0.000	1.414
Backfill surcharge (live)	Pq	0.00- 2.20	1.22	0.44	0.000	1.100
Active earth pressure	Pa	2.20- 3.20	10.08	4.18	0.000	2.729
Backfill surcharge (live)	Pq	2.20- 3.20	0.43	0.18	0.000	2.700
Passive earth pressure	Pp	2.60- 3.50	-21.09	0.00	1.950	3.200
Wall weight	W		0.00	47.85	0.494	2.237
Backfill weight	Ws		0.00	11.14	-0.125	1.382
Vert. load on top (dead)	Ng		0.00	3.00	0.125	0.000
Vert. load on top (live)	Nq		0.00	2.00	0.125	0.000



3.9.2. Check of soil bearing capacity (GEO)

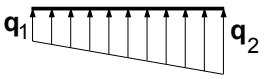
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 1.00x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	M [m]	[kNm/m]
Active earth pressure	Pax1.00	0.00- 2.20	12.54	4.57	1.950	1.786		13.49
Backfill surcharge (live)	Pqx1.30	0.00- 2.20	1.59	0.57	1.950	2.100		2.21
Active earth pressure	Pax1.00	2.20- 3.20	10.08	4.18	1.950	0.471		-3.40
Backfill surcharge (live)	Pqx1.30	2.20- 3.20	0.56	0.23	1.950	0.500		-0.17
Wall weight	W x1.00		0.00	47.85	1.456	0.963		-69.67
Backfill weight	Wsx1.00		0.00	11.14	2.075	1.818		-23.12
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.825	3.200		-5.48
			Sum=	71.54				-86.14

Sum of vertical forces = 71.54 kN/m
Sum of moments at front toe = -86.14 kNm/m
Sum of moments at middle of base = -7.45 kNm/m
Eccentricity ec=-7.45/71.54=-0.104m, ec<=2.200/6=0.367m
Soil pressure q1=0.023 N/mm² q2=0.042 N/mm²

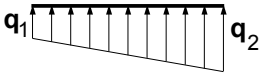


Effective footing L=2.200-2x0.104= 1.992 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.992x(1000x0.20)/1.40= 284.57 kN/m
Bearing resistance check Vd=71.54 < Rd=284.57 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

Check for 1.00x(self weight+top vertical dead load)+1.30x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	M [m]	[kNm/m]
Active earth pressure	Pax1.00	0.00- 2.20	12.54	4.57	1.950	1.786		13.49
Backfill surcharge (live)	Pqx1.30	0.00- 2.20	1.59	0.57	1.950	2.100		2.21
Active earth pressure	Pax1.00	2.20- 3.20	10.08	4.18	1.950	0.471		-3.40
Backfill surcharge (live)	Pqx1.30	2.20- 3.20	0.56	0.23	1.950	0.500		-0.17
Wall weight	W x1.00		0.00	47.85	1.456	0.963		-69.67
Backfill weight	Wsx1.00		0.00	11.14	2.075	1.818		-23.12
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.825	3.200		-5.48
Vert. load on top (live)	Nqx1.30		0.00	2.60	1.825	3.200		-4.74
			Sum=	74.14				-90.88

Sum of vertical forces = 74.14 kN/m
Sum of moments at front toe = -90.88 kNm/m
Sum of moments at middle of base = -9.33 kNm/m
Eccentricity ec=-9.33/74.14=-0.126m, ec<=2.200/6=0.367m
Soil pressure q1=0.022 N/mm² q2=0.045 N/mm²

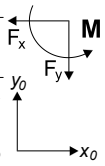


Effective footing L=2.200-2x0.126= 1.948 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.948x(1000x0.20)/1.40= 278.29 kN/m
Bearing resistance check Vd=74.14 < Rd=278.29 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

3.9.3. Failure check due to overturning (GEO)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.950,y=3.200 m)



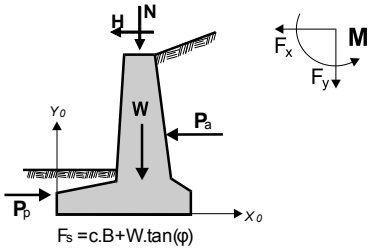
Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.00	0.00- 2.20	12.54	4.57	1.950	1.786	22.40	8.91
Backfill surcharge (live)	Pqx1.30	0.00- 2.20	1.59	0.57	1.950	2.100	3.33	1.12
Active earth pressure	Pax1.00	2.20- 3.20	10.08	4.18	1.950	0.471	4.75	8.15
Backfill surcharge (live)	Pqx1.30	2.20- 3.20	0.56	0.23	1.950	0.500	0.29	0.45
Wall weight	W x1.00		0.00	47.85	1.456	0.963	0.00	69.67
Backfill weight	Wsx1.00		0.00	11.14	2.075	1.818	0.00	23.12
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.825	3.200	0.00	5.48
					Sum=		30.77	116.90

Sum of overturning moments = 30.77 kNm/m
Sum of moments resisting overturning = 116.90 kNm/m
Overturning check Msd=30.77 < Mrd=116.90 kNm/m, Check is verified

3.9.4. Failure check against sliding (GEO)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.00	0.00- 2.20	12.54	0.00	4.57
Backfill surcharge (live)	Pqx1.30	0.00- 2.20	1.59	0.00	0.57
Active earth pressure	Pax1.00	2.20- 3.20	10.08	0.00	4.18
Backfill surcharge (live)	Pqx1.30	2.20- 3.20	0.56	0.00	0.23
Passive earth pressure	Ppx1.00	2.60- 3.50	0.00	21.09	0.00
Wall weight	W x1.00		0.00	0.00	47.85
Backfill weight	Wsx1.00		0.00	0.00	11.14
Vert. load on top (dead)	Ngx1.00		0.00	0.00	3.00
		Sum=	24.77	21.09	71.54



Soil friction Rd=Vd·tanφ/γM= 71.54xtan(30.00°)/1.25= 33.04 kN/m
Soil cohesion Rd=A·cu/γM = 1000x2.200x0.010/1.25= 17.60 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 24.77 kN/m
Sum of resisting forces (21.09+33.04) = 54.13 kN/m
Sliding resistance check Hd=24.77 < Rd=54.13 kN/m, Check is verified

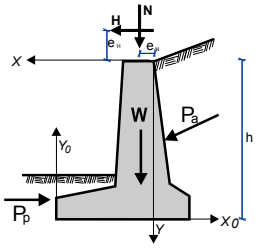
3.10. Seismic design

(EC8 EN1998-5:2004)

Checks of wall stability (with seismic loading)

3.10.1. Forces (driving and resisting) on the wall

Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa 0.00- 2.20	8.91	3.24	0.000	1.413
Backfill surcharge (live)	Pq 0.00- 2.20	0.86	0.31	0.000	1.100
Active earth pressure	Pa 2.20- 3.20	6.83	2.83	0.000	2.729
Backfill surcharge (live)	Pq 2.20- 3.20	0.30	0.12	0.000	2.700
Passive earth pressure	Pp 2.60- 3.50	-29.80	0.00	1.950	3.200
Wall weight	W	0.00	47.85	0.494	2.237
Backfill weight	Ws	0.00	11.14	-0.125	1.382
Vert. load on top (dead)	Ng	0.00	3.00	0.125	0.000
Vert. load on top (live)	Nq	0.00	2.00	0.125	0.000



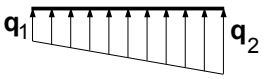
3.10.2. Additional forces due to seismic load

Action		y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa	0.00- 2.20	4.56		0.000	1.413
Backfill surcharge (live)	Pq	0.00- 2.20	0.44		0.000	1.100
Active earth pressure	Pa	2.20- 3.20	4.02		0.000	2.729
Backfill surcharge (live)	Pq	2.20- 3.20	0.18		0.000	2.700
Wall weight	W		1.91	-0.96	0.494	2.237
Backfill weight	Ws		0.45	-0.22	-0.125	1.382
Vert. load on top (dead)	Ng		0.12	-0.06	0.125	0.000
Vert. load on top (live)	Nq		0.08	-0.04	0.125	0.000

3.10.3. Check of soil bearing capacity (with seismic loading) (EC7 §6.5.2)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.00	0.00- 2.20	13.47	3.24	1.950	1.787	17.75
Backfill surcharge (live)	Pqx1.00	0.00- 2.20	1.30	0.31	1.950	2.100	2.14
Active earth pressure	Pax1.00	2.20- 3.20	10.85	2.83	1.950	0.471	-0.41
Backfill surcharge (live)	Pqx1.00	2.20- 3.20	0.48	0.12	1.950	0.500	0.01
Wall weight	W x1.00		1.91	46.89	1.456	0.963	-66.43
Backfill weight	Wsx1.00		0.45	10.92	2.075	1.818	-21.85
Vert. load on top (dead)	Ngx1.00		0.12	2.94	1.825	3.200	-4.99
Vert. load on top (live)	Nqx1.00		0.08	1.96	1.825	3.200	-3.32
				Sum=	69.21		-77.10

Sum of vertical forces = 69.21 kN/m
Sum of moments at front toe = -77.10 kNm/m
Sum of moments at middle of base = -0.97 kNm/m



Eccentricity ec=-0.97/69.21=-0.014m, ec<=2.200/6=0.367m
Soil pressure q1=0.030 N/mm² q2=0.033 N/mm²
Effective footing L=2.200-2x0.014= 2.172 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=2.172x(1000x0.20)/1.00= 434.40 kN/m
Bearing resistance check Vd=69.21 < Rd=434.40 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

3.10.4. Failure check due to overturning (with seismic loading) (EC7 §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.950,y=3.200 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [kN/m]	yo [m]	Mo+ [m]	Mo- [kNm/m]	[kNm/m]
Active earth pressure	Pax1.00	0.00- 2.20	13.47	3.24	1.950	1.787	24.07	6.32	
Backfill surcharge (live)	Pqx1.00	0.00- 2.20	1.30	0.31	1.950	2.100	2.74	0.60	
Active earth pressure	Pax1.00	2.20- 3.20	10.85	2.83	1.950	0.471	5.11	5.52	
Backfill surcharge (live)	Pqx1.00	2.20- 3.20	0.48	0.12	1.950	0.500	0.24	0.23	
Wall weight	W x1.00		1.91	46.89	1.456	0.963	3.24	69.67*	
Backfill weight	Wsx1.00		0.45	10.92	2.075	1.818	1.27	23.12*	
Vert. load on top (dead)	Ngx1.00		0.12	2.94	1.825	3.200	0.49	5.48*	
Vert. load on top (live)	Nqx1.00		0.08	1.96	1.825	3.200	0.33	3.65*	
					Sum=		37.49	114.59	

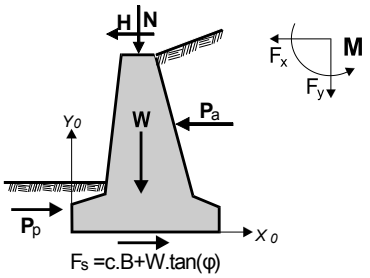
(*moments of negative seismic vertical loads, are added to the overturning moments)

Sum of overturning moments = 37.49 kNm/m
Sum of moments resisting overturning = 114.59 kNm/m
Overturning check Msd=37.49 < Mrd=114.59 kNm/m, Check is verified

3.10.5. Failure check against sliding (with seismic loading)

(EC7 §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.00	0.00- 2.20	13.47	0.00	3.24
Backfill surcharge (live)	Pqx1.00	0.00- 2.20	1.30	0.00	0.31
Active earth pressure	Pax1.00	2.20- 3.20	10.85	0.00	2.83
Backfill surcharge (live)	Pqx1.00	2.20- 3.20	0.48	0.00	0.12
Passive earth pressure	Ppx1.00	2.60- 3.50	0.00	29.80	0.00
Wall weight	W x1.00		1.91	0.00	46.89
Backfill weight	Wsx1.00		0.45	0.00	10.92
Vert. load on top (dead)	Ngx1.00		0.12	0.00	2.94
Vert. load on top (live)	Nqx1.00		0.08	0.00	1.96
		Sum=	28.66	29.80	69.21



Soil friction Rd=Vd·tanφ/γM= 69.21xtan(30.00°)/1.00= 39.96 kN/m
Soil cohesion Rd=A·cu/γM = 1000x2.200x0.010/1.00= 22.00 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 28.66 kN/m
Sum of resisting forces (29.80+39.96) = 69.76 kN/m
Sliding resistance check Hd=28.66 < Rd=69.76 kN/m, Check is verified

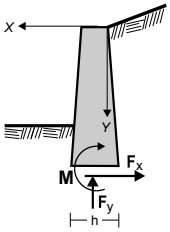
3.11. Design of wall steam

(EC2 EN1992-1-1:2004)

3.11.1. Loading 1.35x(permanent unfavourable)+1.00x(permanent favourable)+1.50x(variable unfav.)

Forces (at cross section centroid) at wall steam

y [m]	h [m]	Fx [kN/m]	Fy [kN/m]	M [kNm/m]
0.50	0.287	1.23	6.80	0.06
1.00	0.324	3.50	11.45	0.84
1.50	0.361	6.85	16.96	2.86
2.00	0.398	11.26	23.31	6.60
2.70	0.450	17.76	33.29	15.46



3.11.2. Design of wall steam in bending

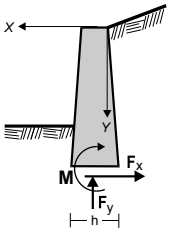
(EC2 §9.6, §6.1)
Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=25 mm (§3, §4.4.1.1)
Vertical reinforcement minimum: 0.0020Ac, maximum: 0.0400Ac (EC2 §9.6.2)

y [m]	Msd [kN/m]	Nsd [kN]	d [mm]	Kd	x/d	ec/es	Ks	As	min reinf. [cm²/m]	[cm²/m]
0.50	0.06	-6.80	257	28.20	0.01	0.2/20.0	2.31	0.00	(2.87)	
1.00	0.84	-11.45	294	19.19	0.01	0.3/20.0	2.31	0.00	(3.24)	
1.50	2.86	-16.96	331	14.24	0.02	0.4/20.0	2.31	0.00	(3.61)	
2.00	6.60	-23.31	368	11.34	0.02	0.5/20.0	2.32	0.13	(3.98)	
2.70	15.46	-33.29	420	8.96	0.03	0.6/20.0	2.32	0.45	(4.50)	

3.11.3. Loading 1.00x(permanent unfav.)+1.00x(permanent favour.)+1.00x(variable)+1.00x(seismic)

Forces (at cross section centroid) at wall steam (with seismic loading)

y [m]	h [m]	Fx [kN/m]	Fy [kN/m]	M [kNm/m]
0.50	0.287	1.73	6.80	0.28
1.00	0.324	4.39	11.45	1.46
1.50	0.361	8.28	16.96	4.14
2.00	0.398	13.37	23.31	8.89
2.70	0.450	20.72	33.29	19.17



3.11.4. Design of wall steam in bending (with seismic loading) (EC2 §9.6, §6.1)

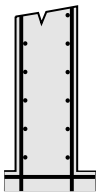
Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=25 mm (§3, §4.4.1.1)
Vertical reinforcement minimum: 0.0020Ac, maximum: 0.0400Ac (EC2 §9.6.2)

y [m]	Msd [kN/m]	Nsd [kN]	d [mm]	Kd	x/d	ec/es	Ks	As	min reinf. [cm²/m]	[cm²/m]
0.50	0.28	-6.80	257	25.08	0.01	0.2/20.0	2.31	0.00	(	2.87)
1.00	1.46	-11.45	294	17.06	0.02	0.3/20.0	2.31	0.00	(	3.24)
1.50	4.14	-16.96	331	12.79	0.02	0.4/20.0	2.32	0.08	(	3.61)
2.00	8.89	-23.31	368	10.28	0.03	0.6/20.0	2.32	0.27	(	3.98)
2.70	19.17	-33.29	420	8.29	0.03	0.7/20.0	2.33	0.66	(	4.50)

3.11.5. Reinforcement of wall steam

Reinforcement at back steam face **Ø10/17.0** (4.62cm²/m)
Secondary transverse reinforcement **Ø8/50.0** (1.01cm²/m)

Reinforcement at front steam face **Ø10/17.0** (4.62cm²/m)
Secondary transverse reinforcement **Ø8/50.0** (1.01cm²/m)



3.11.6. Anchorage of wall steam reinforcement (EC2 §8.4)

Basic required anchorage length lb,rqd=(Φ/4)(σsd/fbd)=(10/4)x(62/1.89)=82mm (EC2 Eq.8.3)
σsd=435.00x66/462=62MPa fbd=2.25x0.70x(fctk0.05/γc)=1.89 MPa (EC2 §8.4.2)
Design anchorage length lbd=1.00x82=82mm, Cnom=25mm<3Ø=30mm (EC2 §8.4.4, T.8.2)
Minimum anchorage length lb,min=max(0.30lbrqd,10Ø,100mm)=100mm
Necessary bend 100mm at lower bar end for anchorage

3.11.7. Shear check of wall steam (EC2 EN1992-1-1:2004, §6.2.2)

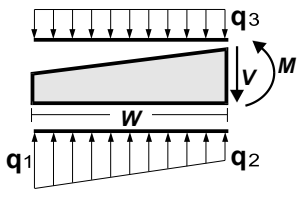
Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=25 mm (§3, §4.4.1.1)
The earth pressure load variation is linear, so the variation of shear
force is parabolic. The variation of steam cross section is linear.
The most unfavourable place for shear check is the base of the steam.

Vsd=17.76 kN/m, Vsd (+seismic)=20.72 kN/m, Nsd=-33.29 kN/m
Shear capacity without shear reinforcement Vrdc (EC2 §6.2.2)
Vrdc=[Crdc·k·(100ρ1·fck)^(0.333)+k1·σcp]·bw·d (EC2 Eq.6.2.a)
Vrdc>=(vmin+k1·σcp)·bw·d (EC2 Eq.6.2.b)
Crdc=0.18/γc=0.18/1.50=0.120, fck=25.00MPa
k=1+(200/d)^½ <=2, k=1.69, k1=0.15
ρ1=As1/(bw·d)=462/(1000x420)=0.0011
σcp=Nsd/Ac=1000x33.29/450000=0.07N/mm²
vmin=0.035·k^(1.50)·fck^½ = 0.38N/mm² (EC2 Eq.6.3N)
Vrd,c(min)=0.001x(0.38+0.15x0.07)x1000x420=164.01kN/m
Vrdc=0.001x[0.120x1.69x(0.11x25.00)^(0.333)+0.15x0.07]x1000x420=123.74, Vrdc=Vrcd(min)=164.01kN/m
Vsd=20.72 kN/m <= Vrdc=164.01 kN/m, shear OK

3.12. Design of wall footing and reinforcement (EC2 EN1992-1-1:2004)

3.12.1. Design of front toe x=1.950 m to x=0.450 m

Sum of vertical forces = 95.52 kN/m
Sum of moments at middle of base = -21.52 kNm/m
q1= 0.017 N/mm², q2= 0.053 N/mm², w= 1.500 m
pressure from self weight q3= 0.013 N/mm²
M= 17.85 kNm/m, V= 32.89 kN/m
V at distance d=425mm from the face of the steam = 18.06 kN/m
Msd= 17.85k Nm/m, Vsd= 18.06 kN/m



3.12.2. Design of front toe x=1.950 m to x=0.450 m (with seismic loading)

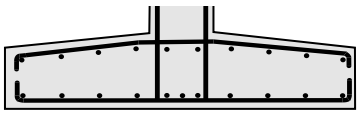
Sum of vertical forces = 69.21 kN/m
Sum of moments at middle of base = -0.97 kNm/m
q1= 0.030 N/mm², q2= 0.032 N/mm², w= 1.500 m
pressure from self weight q3= 0.013 N/mm²
M= 20.03 kNm/m, V= 27.11 kN/m
V at distance d=425mm from the face of the steam = 19.16 kN/m
Msd= 20.03k Nm/m, Vsd= 19.16 kN/m

3.12.3. Design of wall footing in bending

(EC2 EN1992-1-1:2004, §6.1)

Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=75 mm (§3, §4.4.1.1)
Msd= 20.03kNm/m, d=419mm, Kd=9.36 x/d=0.03 εc/εs=0.6/20.0 ks=2.32, **As= 1.11cm²**
Minimum reinforcement As>=0.26bd·Fctm/fyk (As= 5.66cm²/m) (EC2 §9.3.1)
Minimum reinforcement Ø12/19.5(5.79cm²/m)

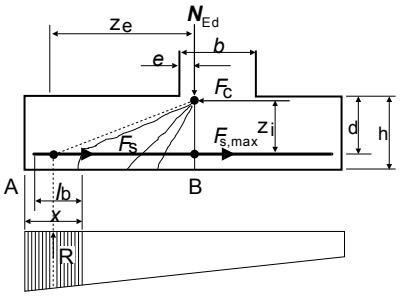
3.12.4. Reinforcement of wall footing



Footing reinforcement at bottom Ø12/19.5 (5.79cm²/m)
Secondary tranverse reinforcement Ø12/40.0 (2.82cm²/m)

3.12.5. Anchorage of footing reinforcement

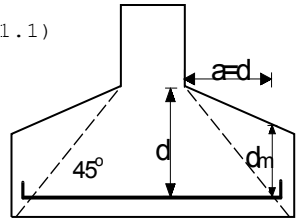
(EC2 EN1992-1-1:2004, §9.8.2.2, §8.4)



x=h/2=0.175m, R=1000x0.053x0.175=9.27 kN/m
e=0.15b=0.067m ze=1.480 m, zi=0.900d=0.377m
Fs=R·ze/zi=9.27x1.480/0.377=36.38 kN/m
σsd=Fs/As=1000x36.38/579=63 MPa
Basic required anchorage length (EC2 Eq.8.3)
lb,rqd=(Φ/4)(σsd/fbd)=(12/4)x(63/2.70)=70mm
fbd=2.25x1.00x(fctk0.05/γc)=2.70 MPa (EC2 §8.4.2)
Design anchorage length (EC2 §8.4.4, T.8.2)
lbd=0.70x70=49mm, Cnom=75mm>3Ø=36mm
Minimum anchorage length lb,min=max(0.30lbrqd,10Ø,100mm)=120mm
Necessary anchorage length of longitudinal reinforcement Lbd=120mm =0.120m
lbd=120mm>(x-Cnom)=100.00. Necessary bends 60mm at bar ends for anchorage

3.12.6. Design of wall footing for shear and punching shear

(EC2 EN1992-1-1:2004, §6.2.2)



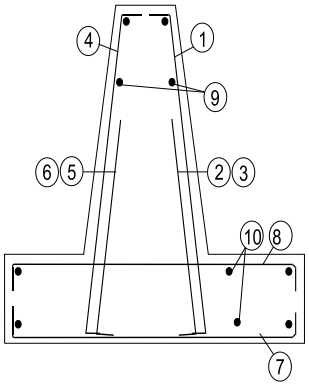
Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=75 mm (§3, §4.4.1.1)
Punching shear capacity without shear reinforcement Vrdc (EC2 §6.4.4)
Vrdc=[Crdc·k·(100ρ1·fck)^(0.333)·(2d/a)]·bw·d (EC2 Eq.6.50)
Vrdc>=[vmin·2d/a]·bw·d, d=dm=377mm, a=419mm
Crdc=0.18/γc=0.18/1.50=0.120, fck=25.00MPa
k=1+(200/d)^½ <=2, k=1.73
ρ1=As1/(bw·d)=579/(1000x377)=0.0015
vmin=0.035·k^(1.50)·fck^½ = 0.40N/mm² (EC2 Eq.6.3N)
Vrd,c(min)=0.001x(0.40x2x377/419)x1000x377=271.51kN/m
Vrdc=0.001x[0.120x1.73x(0.15x25.00)^(0.333)x2x377/419]x1000x377=218.93, Vrdc=Vrcd(min)=271.51kN/m
Vsd=19.16 kN/m <= Vrdc=271.51 kN/m, shear and punching shear OK

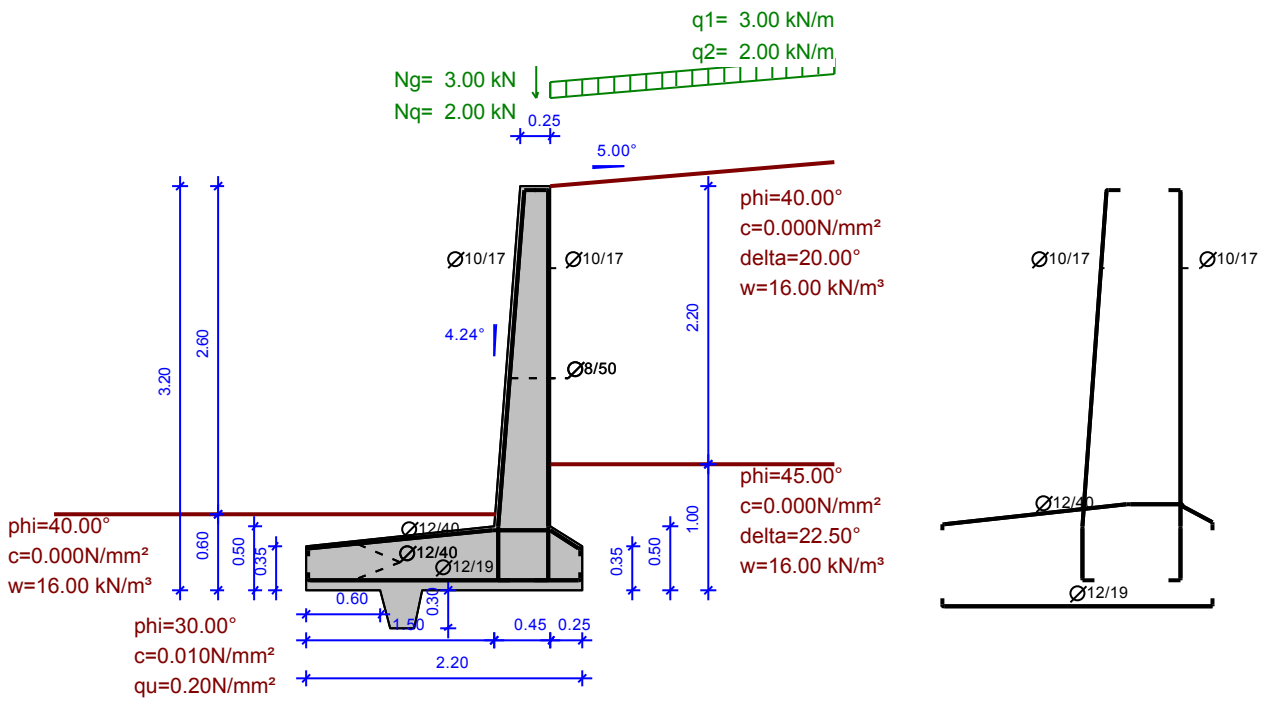
3.13. Material estimate

Concrete per meter of wall length		1.914	m³/m
Reinforcing steel per meter of wall		52.005	kg/m
Total concrete of wall	10.000x	1.914=	19.137 m³
Total reinforcing steel of wall	10.000x	52.005=	520.050 kg

3.14. Reinforcing bar schedule

Num	type	reinforcing bar [mm]	items	∅	g/m [kg/m]	length [m]	weight [kg]
1	1	100 — 3070 — 100	59	10	0.617	3.270	119.04
2	4	100 — 3070 — 100	59	10	0.617	3.270	119.04
3	9	10000	12	8	0.395	10.000	47.40
4	7	60 — 2040 — 60	51	12	0.888	2.160	97.82
5	8	60 — 2040 — 60	25	12	0.888	2.160	47.95
6	10	10000	10	12	0.888	10.000	88.80
		Total weight [kg]					**520.05**





General information

Wall type : Cantilever wall

Concrete and steel class

Steam :C25/30-S500

Footing :C25/30-S500

Design codes

Eurocode 0 EN1991-1-1, Basis of structural design

Eurocode 1 EN1991-1-1, Actions on structures

Eurocode 2 EN1992-1-1, Design of concrete structures

Eurocode 7 EN1997-1-1, Geotechnical design

Eurocode 8 EN1998-5, Earthquaqe design

Loads

Vertical : dead Ng=3.00kN, live Nq=2.00kN

Horizontal: dead Hg=0.00kN, live Hq=0.00kN

Surcharge : dead g=3.00kN/m², live q=2.00kN/m²

Seismic coefficients

Design ground acceleration ratio a =0.060

Coefficient for horizontal seismic force kh=0.040

Coefficient for vertical seismic force kv=0.020

Reinforcing bar schedule

#		reinforcing bar [mm]	items	∅ [mm]	g/m [kg/m]	length [m]	weight [kg]
1	W1	100 — 3070 — 100	59	10	0.617	3.270	119.04
2	W4	100 — 3070 — 100	59	10	0.617	3.270	119.04
3	W9	10000	12	8	0.395	10.000	47.40
4	W7	60 — 2040 — 60	51	12	0.888	2.160	97.82
5	W8	60 — 2040 — 60	25	12	0.888	2.160	47.95
6	W10	10000	10	12	0.888	10.000	88.80

Total weight [kg] **520.05**

Soil properties back-1

phi=40.00°

c=0.000N/mm²

delta=20.00°

w=16.00 kN/m³

Soil properties back-2

phi=45.00°

c=0.000N/mm²

delta=22.50°

w=16.00 kN/m³

Soil properties front

phi=40.00°

c=0.000N/mm²

w=16.00 kN/m³

Foundation soil properties

phi=30.00°

c=0.010N/mm²

qu=0.20N/mm²

Concrete volume V= 19.14 [m³]

Reinforcement weight G=520.05 [kg]

Project: Example of retaining walls

C. WALL-001

Scale : 1:60 **Date:** 12/03/2007

Designer: **Draw.No.:**

Filename: Example of retaining w... **Sign:**

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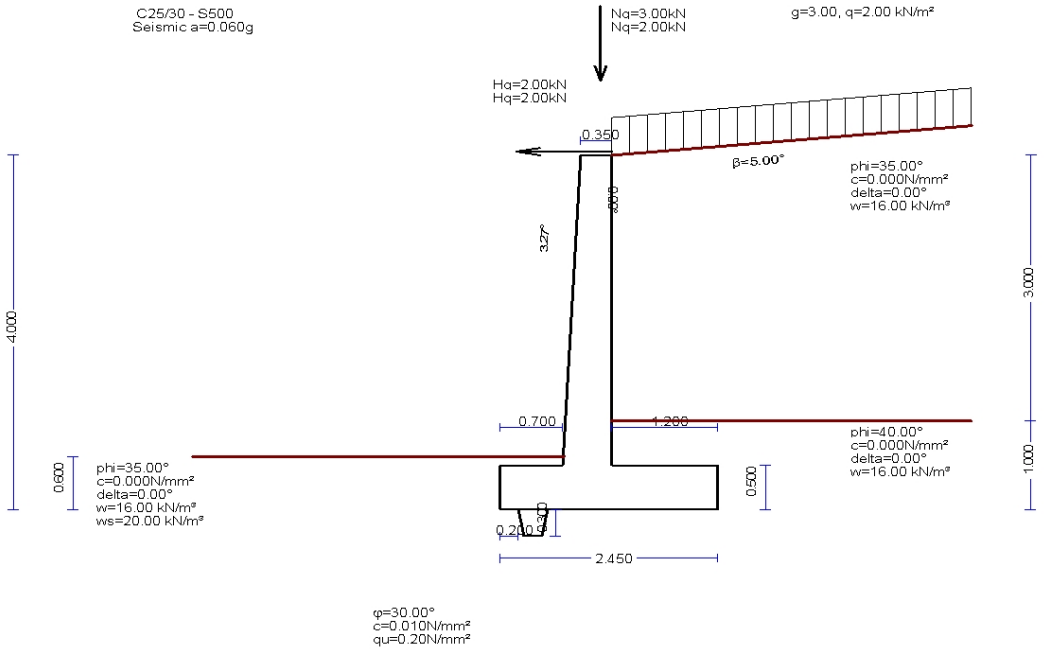
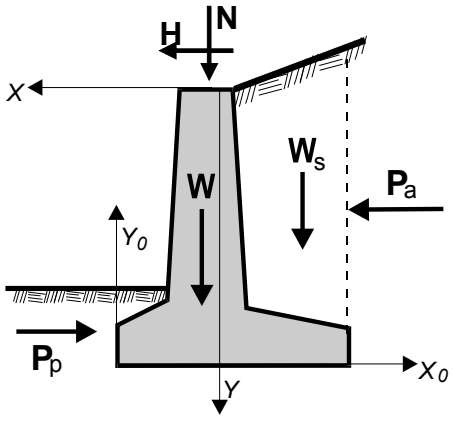
4. C. WALL-002

Cantilever concrete wall

(EC2 EN1992-1-1:2004, EC0 EN1990-1-1:2002, EC7 EN1997-1-1:2004, EC8 EN1998-5:2004)



4.1. Wall properties-Parameters-Code requirements



Dimensions

Height of wall	h=	4.000 m
Transverse length of wall	L=	10.000 m
Steam thickness at top	B1=	0.350 m
Steam thickness at bottom	B2=	0.550 m
Width of wall base	B=	2.450 m
Width of wall toe		0.700 m
Width of wall heel		1.200 m
Height of wall steam		3.500 m
Thickness of wall footing		0.500 m
Front thickness of wall toe		0.500 m
Back thickness of wall heel		0.500 m
Slope (batter) at frontface		3.270° (1:17.5)
Slope (batter) at backface		0.000° (0:1)
Height of wall base key		0.300 m

Loads on wall top

Vertical permanent load	Ng=	3.00 kN/m
Vertical variable load	Nq=	2.00 kN/m
Eccentricity of vertical load	eN=	0.13 kN/m
Horizontal permanent load	Hg=	2.00 kN/m
Horizontal variable load	Hq=	2.00 kN/m
Eccentricity of horizontal load	eH=	0.00 kN/m

Weight of wall

Unit weight of wall material γg=25.000 kN/m³
Cross section area of wall A= 2.800 m²
Self weight per meter of wall W= 2.800x25.000= 70.00 kN/m
Center of gravity of wall at x=0.140 m, y=2.698 m (xo=1.110 m, yo=1.302 m)

Wall materials

Steam : Concrete-Steel class: C25/30-S500 (EN1992-1-1, §3)
: Concrete cover: Cnom=25 mm (EN1992-1-1, §4.4.1)
Footing : Concrete-Steel class: C25/30-S500
: Concrete cover: Cnom=75 mm

Weight of backfill

Weight of backfill per meter Ws=70.22 kN/m
Center of gravity of backfill x=-0.600 m, y=1.776 m

4.2. Partial factors for actions and soil properties

(EC7 Tables A.1-A.4, EC8-5 §3.1)

Equilibrium limit state (EQU), Structural limit state (STR), Geotechnical limit state (GEO)

				(EQU)	(STR)	(GEO)	(SEISMIC)
Actions	Permanent	Unfavourable	γGdst:	1.10	1.35	1.00	1.00
	Permanent	Favourable	γGstb:	0.90	1.00	1.00	1.00
	Variable	Unfavourable	γQdst:	1.50	1.50	1.30	1.00
	Variable	Favourable	γQstb:	0.00	0.00	0.00	0.00
Soil parameters	Angle of shearing resistance		γφ:	1.25	1.00	1.25	1.25
	Effective cohesion		γc:	1.25	1.00	1.25	1.25
	Undrained shear strength		γcu:	1.40	1.00	1.40	1.40
	Unconfined strength		γqu:	1.40	1.00	1.40	1.40
	Weight density		γw:	1.00	1.00	1.00	1.00

4.3. Properties of foundation soil

Bearing capacity of foundation soil qu=0.20 N/mm²
Friction angle between wall footing and soil φ=30.00°, friction coefficient tan(φ)=0.577
Cohesion between wall footing and soil c=0.010 N/mm²

4.4. Seismic coefficients

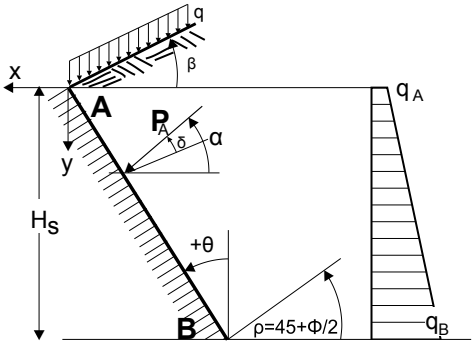
(EC8 EN1998-5:2004, §7.3.2)

Design ground acceleration ratio gh=axg, a=0.06 (EC8-5 §7.3.2)
Reduction factor for seismic coefficient r=1.50 (EC8-5 Table 7.1)
Coefficient for horizontal seismic force kh=0.06/1.500=0.040 (EC8-5 Eq.7.1)
Coefficient for vertical seismic force kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)

Forces due to seismic load (except from earth pressure)

Horizontal seismic force due to self weight Fwx= 70.00x0.040= 2.80 kN/m
Vertical seismic force due to self weight Fwy= 70.00x0.020= 1.40 kN/m
Horizontal seismic force of top loading Ng Fgx= 3.00x0.040= 0.12 kN/m
Vertical seismic force of top loading Ng Fgy= 3.00x0.020= 0.06 kN/m
Horizontal seismic force of top loading Nq Fqx= 2.00x0.040= 0.08 kN/m
Vertical seismic force of top loading Nq Fqy= 2.00x0.020= 0.04 kN/m
Horizontal seismic force of backfill Fwsx= 70.22x0.040= 2.81 kN/m
Vertical seismic force of backfill Fwsy= 70.22x0.020= 1.40 kN/m

4.5. Computation of active earth pressure (Rankine theory)



4.5.1. Wall part from y=-0.105 m to y=3.000 m, Hs=3.105 m

Top point A x=-1.200 m y=-0.105 m
Bottom point B x=-1.200 m y= 3.000 m

Soil properties

Soil type : Thin gravel

Unit weight of soil	γ =16.00 kN/m³
Unit weight of soil (saturated)	γs=20.00 kN/m³
Unit weight of water	γw=10.00 kN/m³
Angle of shearing resistance of ground	φ=35.00°
Cohesion of ground	c=0.000 N/mm²
Slope angle of ground surface	β= 5.00°
Earth pressure on vertical surface	θ= 0.00°
Angle of shear resist. between ground-wall	δ= 0.00°

Loads on soil surface

Permanent uniform load	g= 3.00 kN/m²
Variable uniform load	q= 2.00 kN/m²

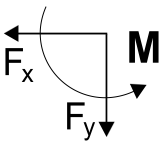
Earth pressure according to Coulomb theory

$$K_A = \frac{\cos^2(\varphi-\theta)}{\cos^2\theta\,\cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\theta+\delta)\sin(\theta-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$

	EQU	STR	GEO
Angle of rupture plane ρ=45°+φ/2 =	59.00	62.50	59.00°
Coefficient of active earth pressure Ka=	0.382	0.284	0.382

Earth pressure q(y)=qA+γ·y·Ka

Permanent actions



		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	1.15	0.85	1.15	kN/m²
Earth pressure at the bottom (y=yA+ 3.10m)	qB=	20.13	14.96	20.13	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	33.04	24.55	33.04	kN/m
Angle of earth force	α =	0.00	0.00	0.00	°
Earth force in x direction	Pax=	33.04	24.55	33.04	kN/m
Earth force in y direction	Pay=	0.00	0.00	0.00	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-63.07	-46.87	-63.07	kNm/m

Point of application of earth force x= -1.200 m, y= 1.909 m

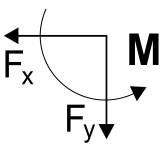
Variable actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.76	0.57	0.76	kN/m²
Earth pressure at the bottom (y=yA+ 3.10m)	qB=	0.76	0.57	0.76	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	2.36	1.77	2.36	kN/m
Angle of earth force	α =	0.00	0.00	0.00	°
Earth force in x direction	Pax=	2.36	1.77	2.36	kN/m
Earth force in y direction	Pay=	0.00	0.00	0.00	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-3.41	-2.56	-3.41	kNm/m

Point of application of earth force x= -1.200 m, y= 1.447 m

Total forces and moments

Forces and moments at bottom point B (x=-1.200 m, y=3.000 m)



Permanent actions

	EQU	STR	GEO	
Total horizontal earth force Fsx=	33.04	24.55	33.04	kN/m
Total vertical earth force Fsy=	0.00	0.00	0.00	kN/m
Total moment of earth force Ms =	36.05	26.78	36.05	kNm/m

Variable actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	2.36	1.77	2.36	kN/m
Total vertical earth force	Fsy=	0.00	0.00	0.00	kN/m
Total moment of earth force	Ms =	3.67	2.75	3.67	kNm/m

Seismic loading (EC8 EN1998-5:2004, §7.3.2, Annex E)

Horizontal seismic coefficient kh=0.06/1.500=0.040 (EC8-5 Eq.7.1, T.7.1)
Vertical seismic coefficient kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)
Soil above the water table (EC8-5 Annex E.5)
tan(ω)=kh/(1-kv)=0.040/(1-0.020)=0.041, ω=2.34°

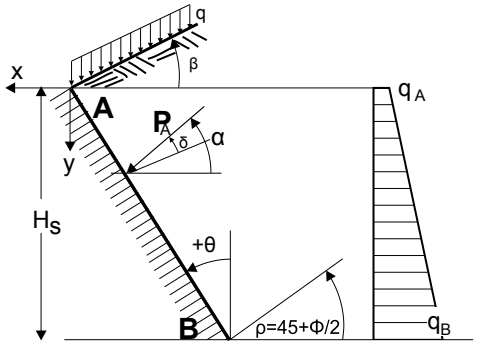
Method Mononobe-Okabe (EC8-5 Annex E.4)
for active earth force during seismic loading
Coefficient of active earth pressure, Ke*= 0.405
Additional earth pressure due to seismic load
over STR load case ξ=(Ke*/Ke-1)=(0.405/0.284-1)=0.426

$$K_E = \frac{\cos^2(\varphi-\omega-\theta)}{\cos\omega\cos^2\theta\cos(\delta+\theta+\omega)\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\omega-\beta)}{\cos(\theta+\omega+\delta)\cos(\theta-\beta)}}\right]^2}$$

Earth force due to seismic load (Permanent actions) Fx=1.426x24.55=35.01 kN/m
Earth force due to seismic load (Variable actions) Fx=1.426x 1.77= 2.52 kN/m

4.5.2. Wall part from y=3.000 m to y=4.000 m, Hs=1.000 m

Top point A x=-1.200 m y= 3.000 m
Bottom point B x=-1.200 m y= 4.000 m



Soil properties

Soil type : Mean gravel

Unit weight of soil	γ	=16.00 kN/m³
Unit weight of soil (saturated)	γs	=20.00 kN/m³
Unit weight of water	γw	=10.00 kN/m³
Angle of shearing resistance of ground	φ	=40.00°
Cohesion of ground	c	=0.000 N/mm²
Slope angle of ground surface	β	= 0.00°
Earth pressure on vertical surface	θ	= 0.00°
Angle of shear resist. between ground-wall	δ	= 0.00°

Loads on soil surface

Permanent uniform load	g=	52.68 kN/m²
Variable uniform load	q=	2.00 kN/m²

Earth pressure according to Coulomb theory

	EQU	STR	GEO	
Angle of rupture plane ρ=45°+φ/2	= 61.00	65.00	61.00	°
Coefficient of active earth pressure Ka=	0.307	0.217	0.307	

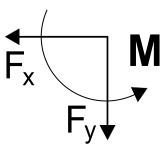
Earth pressure q(y)=qA+γ·y·Ka

$$K_A = \frac{\cos^2(\varphi-\theta)}{\cos^2\theta\cos(\theta+\delta)\left[1+\sqrt{\frac{\sin(\theta+\delta)\sin(\theta-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$

Permanent actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	16.17	11.43	16.17	kN/m²
Earth pressure at the bottom (y=yA+ 1.00m)	qB=	21.08	14.90	21.08	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	18.62	13.16	18.62	kN/m
Angle of earth force	α =	0.00	0.00	0.00	°
Earth force in x direction	Pax=	18.62	13.16	18.62	kN/m
Earth force in y direction	Pay=	0.00	0.00	0.00	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-65.58	-46.35	-65.58	kNm/m

Point of application of earth force x= -1.200 m, y= 3.522 m



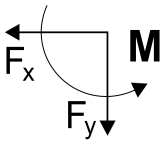
Variable actions

		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.61	0.43	0.61	kN/m²
Earth pressure at the bottom (y=yA+ 1.00m)	qB=	0.61	0.43	0.61	kN/m²
Earth force Pa=½(qA+qB)H	Pa=	0.61	0.43	0.61	kN/m
Angle of earth force	α =	0.00	0.00	0.00	°
Earth force in x direction	Pax=	0.61	0.43	0.61	kN/m
Earth force in y direction	Pay=	0.00	0.00	0.00	kN/m
Moment of earth force at top point (x=0,y=0)	M =	-2.13	-1.50	-2.13	kNm/m

Point of application of earth force x= -1.200 m, y= 3.500 m

Total forces and moments

Forces and moments at bottom point B (x=-1.200 m, y=4.000 m)



Permanent actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	51.66	37.71	51.66	kN/m
Total vertical earth force	Fsy=	0.00	0.00	0.00	kN/m
Total moment of earth force	Ms =	77.99	57.62	77.99	kNm/m

Variable actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	2.97	2.20	2.97	kN/m
Total vertical earth force	Fsy=	0.00	0.00	0.00	kN/m
Total moment of earth force	Ms =	6.34	4.74	6.34	kNm/m

Seismic loading (EC8 EN1998-5:2004, §7.3.2, Annex E)

Horizontal seismic coefficient kh=0.06/1.500=0.040 (EC8-5 Eq.7.1, T.7.1)
Vertical seismic coefficient kv=0.50x0.040=0.020 (EC8-5 Eq.7.2)
Soil above the water table (EC8-5 Annex E.5)
tan(ω)=kh/(1-kv)=0.040/(1-0.020)=0.041, ω=2.34°

Method Mononobe-Okabe (EC8-5 Annex E.4)
for active earth force during seismic loading
Coefficient of active earth pressure, Ke*= 0.326
Additional earth pressure due to seismic load
over STR load case ξ=(Ke*/Ke-1)=(0.326/0.217-1)=0.502

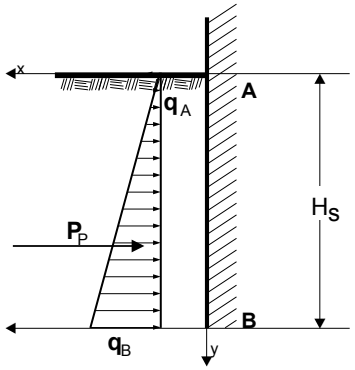
$$K_E = \frac{\cos^2(\varphi-\omega-\theta)}{\cos\omega\cos^2\theta\cos(\delta+\theta+\omega)\left[1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\omega-\beta)}{\cos(\theta+\omega+\delta)\cos(\theta-\beta)}}\right]^2}$$

Earth force due to seismic load (Permanent actions) Fx=1.502x13.16=19.77 kN/m
Earth force due to seismic load (Variable actions) Fx=1.502x 0.43= 0.65 kN/m

4.6. Computation of passive earth pressure (Rankine theory)

4.6.1. Wall part from y=3.400 m to y=4.300 m, Hs=0.900 m

Top point A x= 1.250 m y= 3.400 m
Bottom point B x= 1.250 m y= 4.300 m



Soil properties

Soil type : Thin gravel

Unit weight of soil	γ	=16.00 kN/m³
Unit weight of soil (saturated)	γs	=20.00 kN/m³
Unit weight of water	γw	=10.00 kN/m³
Soil under the water table lever		
Soil weight suspended in water	γo	=10.00 kN/m³
Angle of shearing resistance of ground	φ	=35.00°
Cohesion of ground	c	=0.000 N/mm²
Slope angle of ground surface	β	= 0.00°
Earth pressure on vertical surface	θ	= 0.00°
Angle of shear resist. between ground-wall	δ	= 0.00°

Loads on soil surface

Permanent uniform load g= 0.00 kN/m²
Variable uniform load q= 0.00 kN/m²
Water pressure at the top qw= 0.00 kN/m²

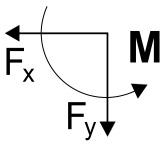
Earth pressure according to Coulomb theory

$$K_p = \frac{\cos^2(\varphi+\theta)}{\cos^2\theta\,\cos(\theta-\delta)\left[1-\sqrt{\frac{\sin(\theta+\delta)\sin(\theta+\beta)}{\cos(\theta-\delta)\cos(\theta-\beta)}}\right]^2}$$

	EQU	STR	GEO
Angle of rupture plane ρ=45°-φ/2 =	31.00	27.50	31.00°
Coefficient of passive earth pressure Kp=	2.770	3.690	2.770

Earth pressure q(y)=qA+γ·y·Kp

Permanent actions



		EQU	STR	GEO	
Earth pressure at the top (y=yA)	qA=	0.00	0.00	0.00	kN/m²
Earth pressure at the bottom (y=yA+ 0.90m)	qB=	-24.93	-33.21	-24.93	kN/m²
Earth force Pa=½(qA+qB)H	Pp=	11.22	14.94	11.22	kN/m
Angle of earth force	α =	0.00	0.00	0.00	°
Earth force in x direction	Ppx=	-11.22	-14.94	-11.22	kN/m
Earth force in y direction	Ppy=	0.00	0.00	0.00	kN/m
Moment of earth force at top point (x=0,y=0)	M =	44.88	59.76	44.88	kNm/m

Point of application of earth force x= 1.250 m, y= 4.000 m

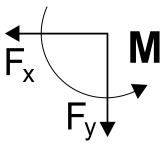
Hydrostatic pressure

Hydrostatic pressure qw=qwA+γw·Hw/cosθ

Hydrostatic pressure at the top (y=yA)	qwA=	0.00	kN/m²
Hydrostatic pressure at the bottom (y=yA+ 0.90m)	qwB=	9.00	kN/m²
Hydrostatic force Pw=½(qwA+qwB)H	Pw =	4.05	kN/m
Angle of hydrostatic force	α =	0.00	°
Hydrostatic force in x direction	Pwx =	4.05	kN/m
Hydrostatic force in y direction	Pwy =	0.00	kN/m
Moment of hydrostatic force at top point (x=0,y=0)	M =	-16.20	kNm/m

Point of application of hydrostatic force x= 1.250 m, y= 4.000 m

Total forces and moments



Forces and moments at bottom point B (x=1.250 m, y=4.300 m)

Permanent actions

		EQU	STR	GEO	
Total horizontal earth force	Fsx=	-11.22	-14.94	-11.22	kN/m
Total vertical earth force	Fsy=	0.00	0.00	0.00	kN/m
Total moment of earth force	Ms =	-3.37	-4.48	-3.37	kNm/m

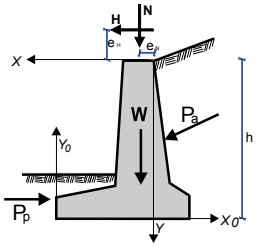
Hydrostatic pressure

Total horizontal hydrostatic force	Fwx=	4.05	kN/m
Total vertical hydrostatic force	Fwy=	0.00	kN/m
Total moment of hydrostatic force	Mw =	1.22	kNm/m

4.7. Checks of wall stability (EQU)

4.7.1. Forces (driving and resisting) on the wall (EQU)

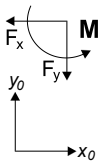
Action		y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa	-0.10- 3.00	33.04	0.00	-1.200	1.909
Backfill surcharge (live)	Pq	-0.10- 3.00	2.36	0.00	-1.200	1.447
Active earth pressure	Pa	3.00- 4.00	18.62	0.00	-1.200	3.522
Backfill surcharge (live)	Pq	3.00- 4.00	0.61	0.00	-1.200	3.500
Passive earth pressure	Pp	3.40- 4.30	-11.22	0.00	1.250	4.000
Wall weight	W		0.00	70.00	0.140	2.698
Backfill weight	Ws		0.00	70.22	-0.600	1.776
Backf. surcharge (dead)	Wsg		0.00	3.60	-0.600	0.000
Backf. surcharge (live)	Wsq		0.00	2.40	-0.600	0.000
Vert. load on top (dead)	Ng		0.00	3.00	0.125	0.000
Vert. load on top (live)	Nq		0.00	2.00	0.125	0.000
Horiz. load on top (dead)	Hg		2.00	0.00	0.175	0.000
Horiz. load on top (live)	Hq		2.00	0.00	0.175	0.000



4.7.2. Check of soil bearing capacity (EQU)

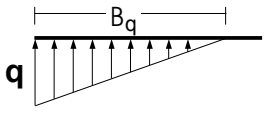
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 0.90x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.10	-0.10- 3.00	36.34	0.00	2.450	2.091	76.00
Backfill surcharge (live)	Pqx1.50	-0.10- 3.00	3.54	0.00	2.450	2.553	9.04
Active earth pressure	Pax1.10	3.00- 4.00	20.48	0.00	2.450	0.478	9.79
Backfill surcharge (live)	Pqx1.50	3.00- 4.00	0.92	0.00	2.450	0.500	0.46
Wall weight	W x0.90		0.00	63.00	1.110	1.302	-69.93
Backfill weight	Wsx0.90		0.00	63.20	1.850	2.224	-116.92
Backf. surcharge (dead)	Wsgx0.90		0.00	3.24	1.850	4.000	-5.99
Vert. load on top (dead)	Ngx0.90		0.00	2.70	1.125	4.000	-3.04
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	1.075	4.000	8.80
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.075	4.000	12.00
			Sum=	132.14			-79.79

Sum of vertical forces = 132.14 kN/m
Sum of moments at front toe = -79.79 kNm/m
Sum of moments at middle of base = 82.08 kNm/m
Eccentricity ec=82.08/132.14=0.621m, ec>2.450/6=0.408m
Soil pressure q=0.146 N/mm² Bq=1.812 m

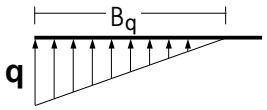


Effective footing L=2.450-2x0.621= 1.208 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.208x(1000x0.20)/1.40= 172.57 kN/m
Bearing resistance check Vd=132.14 < Rd=172.57 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

Check for 1.10x(self weight+top vertical dead load)+1.50x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.10	-0.10- 3.00	36.34	0.00	2.450	2.091	76.00
Backfill surcharge (live)	Pqx1.50	-0.10- 3.00	3.54	0.00	2.450	2.553	9.04
Active earth pressure	Pax1.10	3.00- 4.00	20.48	0.00	2.450	0.478	9.79
Backfill surcharge (live)	Pqx1.50	3.00- 4.00	0.92	0.00	2.450	0.500	0.46
Wall weight	W x1.10		0.00	77.00	1.110	1.302	-85.47
Backfill weight	Wsx1.10		0.00	77.24	1.850	2.224	-142.90
Backf. surcharge (dead)	Wsgx0.90		0.00	3.24	1.850	4.000	-5.99
Backf. surcharge (live)	Wsqx1.50		0.00	3.60	1.850	4.000	-6.66
Vert. load on top (dead)	Ngx1.10		0.00	3.30	1.125	4.000	-3.72
Vert. load on top (live)	Nqx1.50		0.00	3.00	1.125	4.000	-3.38
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	1.075	4.000	8.80
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.075	4.000	12.00
			Sum=	167.38			-132.03

Sum of vertical forces = 167.38 kN/m
Sum of moments at front toe = -132.03 kNm/m
Sum of moments at middle of base = 73.01 kNm/m
Eccentricity ec=73.01/167.38=0.436m, ec>2.450/6=0.408m
Soil pressure q=0.141 N/mm² Bq=2.366 m



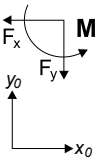
Effective footing L=2.450-2x0.436= 1.578 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.578x(1000x0.20)/1.40= 225.43 kN/m
Bearing resistance check Vd=167.38 < Rd=225.43 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

4.7.3. Failure check due to overturning (EQU)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.250,y=4.000 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.10	-0.10- 3.00	36.34	0.00	2.450	2.091	76.00	0.00
Backfill surcharge (live)	Pqx1.50	-0.10- 3.00	3.54	0.00	2.450	2.553	9.04	0.00
Active earth pressure	Pax1.10	3.00- 4.00	20.48	0.00	2.450	0.478	9.79	0.00
Backfill surcharge (live)	Pqx1.50	3.00- 4.00	0.92	0.00	2.450	0.500	0.46	0.00
Wall weight	W x0.90		0.00	63.00	1.110	1.302	0.00	69.93
Backfill weight	Wsx0.90		0.00	63.20	1.850	2.224	0.00	116.92
Backf. surcharge (dead)	Wsgx0.90		0.00	3.24	1.850	4.000	0.00	5.99
Vert. load on top (dead)	Ngx0.90		0.00	2.70	1.125	4.000	0.00	3.04
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	1.075	4.000	8.80	0.00
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.075	4.000	12.00	0.00
					Sum=		116.09	195.88

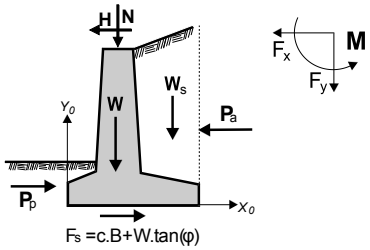


Sum of overturning moments = 116.09 kNm/m
Sum of moments resisting overturning = 195.88 kNm/m
Overturning check Msd=116.09 < Mrd=195.88 kNm/m, Check is verified

4.7.4. Failure check against sliding (EQU)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.10	-0.10- 3.00	36.34	0.00	0.00
Backfill surcharge (live)	Pqx1.50	-0.10- 3.00	3.54	0.00	0.00
Active earth pressure	Pax1.10	3.00- 4.00	20.48	0.00	0.00
Backfill surcharge (live)	Pqx1.50	3.00- 4.00	0.92	0.00	0.00
Passive earth pressure	Ppx0.90	3.40- 4.30	0.00	10.10	0.00
Wall weight	W x0.90		0.00	0.00	63.00
Backfill weight	Wsx0.90		0.00	0.00	63.20
Backf. surcharge (dead)	Wsgx0.90		0.00	0.00	3.24
Vert. load on top (dead)	Ngx0.90		0.00	0.00	2.70
Horiz. load on top (dead)	Hgx1.10		2.20	0.00	0.00
Horiz. load on top (live)	Hqx1.50		3.00	0.00	0.00
		Sum=	66.48	10.10	132.14

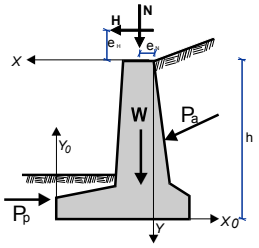


Soil friction Rd=Vd·tanφ/γM= 132.14xtan(30.00°)/1.25= 61.03 kN/m
Soil cohesion Rd=A·cu/γM = 1000x1.812x0.010/1.25= 14.49 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 66.48 kN/m
Sum of resisting forces (10.10+61.03) = 71.13 kN/m
Sliding resistance check Hd=66.48 < Rd=71.13 kN/m, Check is verified

4.8. Checks of wall stability (STR)

4.8.1. Forces (driving and resisting) on the wall (STR)

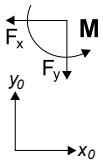
Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa -0.10- 3.00	24.55	0.00	-1.200	1.909
Backfill surcharge (live)	Pq -0.10- 3.00	1.77	0.00	-1.200	1.447
Active earth pressure	Pa 3.00- 4.00	13.16	0.00	-1.200	3.522
Backfill surcharge (live)	Pq 3.00- 4.00	0.43	0.00	-1.200	3.500
Passive earth pressure	Pp 3.40- 4.30	-14.94	0.00	1.250	4.000
Wall weight	W	0.00	70.00	0.140	2.698
Backfill weight	Ws	0.00	70.22	-0.600	1.776
Backf. surcharge (dead)	Wsg	0.00	3.60	-0.600	0.000
Backf. surcharge (live)	Wsq	0.00	2.40	-0.600	0.000
Vert. load on top (dead)	Ng	0.00	3.00	0.125	0.000
Vert. load on top (live)	Nq	0.00	2.00	0.125	0.000
Horiz. load on top (dead)	Hg	2.00	0.00	0.175	0.000
Horiz. load on top (live)	Hq	2.00	0.00	0.175	0.000



4.8.2. Check of soil bearing capacity (STR)

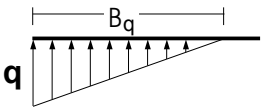
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 1.00x(self weight+top vertical dead load)+0.00x(top vertical live load)



Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.35	-0.10- 3.00	33.14	0.00	2.450	2.091	69.30
Backfill surcharge (live)	Pqx1.50	-0.10- 3.00	2.66	0.00	2.450	2.553	6.78
Active earth pressure	Pax1.35	3.00- 4.00	17.77	0.00	2.450	0.478	8.49
Backfill surcharge (live)	Pqx1.50	3.00- 4.00	0.64	0.00	2.450	0.500	0.33
Wall weight	W x1.00		0.00	70.00	1.110	1.302	-77.70
Backfill weight	Wsx1.00		0.00	70.22	1.850	2.224	-129.91
Backf. surcharge (dead)	Wsgx1.00		0.00	3.60	1.850	4.000	-6.66
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.125	4.000	-3.38
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	1.075	4.000	10.80
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.075	4.000	12.00
			Sum=	146.82			-109.95

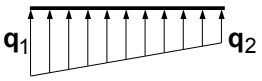
Sum of vertical forces = 146.82 kN/m
Sum of moments at front toe = -109.95 kNm/m
Sum of moments at middle of base = 69.90 kNm/m
Eccentricity ec=69.90/146.82=0.476m, ec>2.450/6=0.408m
Soil pressure q=0.131 N/mm² Bq=2.247 m
Effective footing L=2.450-2x0.476= 1.498 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.498x(1000x0.20)/1.00= 299.60 kN/m
Bearing resistance check Vd=146.82 < Rd=299.60 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)



Check for 1.35x(self weight+top vertical dead load)+1.50x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.35	-0.10- 3.00	33.14	0.00	2.450	2.091	69.30
Backfill surcharge (live)	Pqx1.50	-0.10- 3.00	2.66	0.00	2.450	2.553	6.78
Active earth pressure	Pax1.35	3.00- 4.00	17.77	0.00	2.450	0.478	8.49
Backfill surcharge (live)	Pqx1.50	3.00- 4.00	0.64	0.00	2.450	0.500	0.33
Wall weight	W x1.35		0.00	94.50	1.110	1.302	-104.90
Backfill weight	Wsx1.35		0.00	94.80	1.850	2.224	-175.38
Backf. surcharge (dead)	Wsgx1.00		0.00	3.60	1.850	4.000	-6.66
Backf. surcharge (live)	Wsqx1.50		0.00	3.60	1.850	4.000	-6.66
Vert. load on top (dead)	Ngx1.35		0.00	4.05	1.125	4.000	-4.56
Vert. load on top (live)	Nqx1.50		0.00	3.00	1.125	4.000	-3.38
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	1.075	4.000	10.80
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.075	4.000	12.00
			Sum=	203.55			-193.84

Sum of vertical forces = 203.55 kN/m
Sum of moments at front toe = -193.84 kNm/m
Sum of moments at middle of base = 55.51 kNm/m
Eccentricity ec=55.51/203.55=0.273m, ec<=2.450/6=0.408m
Soil pressure q1=0.139 N/mm² q2=0.028 N/mm²
Effective footing L=2.450-2x0.273= 1.905 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.905x(1000x0.20)/1.00= 381.00 kN/m
Bearing resistance check Vd=203.55 < Rd=381.00 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

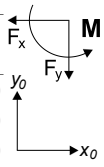


4.8.3. Failure check due to overturning (STR)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.250,y=4.000 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.35	-0.10- 3.00	33.14	0.00	2.450	2.091	69.30	0.00
Backfill surcharge (live)	Pqx1.50	-0.10- 3.00	2.66	0.00	2.450	2.553	6.78	0.00
Active earth pressure	Pax1.35	3.00- 4.00	17.77	0.00	2.450	0.478	8.49	0.00
Backfill surcharge (live)	Pqx1.50	3.00- 4.00	0.64	0.00	2.450	0.500	0.33	0.00
Wall weight	W x1.00		0.00	70.00	1.110	1.302	0.00	77.70
Backfill weight	Wsx1.00		0.00	70.22	1.850	2.224	0.00	129.91
Backf. surcharge (dead)	Wsgx1.00		0.00	3.60	1.850	4.000	0.00	6.66
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.125	4.000	0.00	3.38
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	1.075	4.000	10.80	0.00
Horiz. load on top (live)	Hqx1.50		3.00	0.00	1.075	4.000	12.00	0.00
					Sum=		107.70	217.65

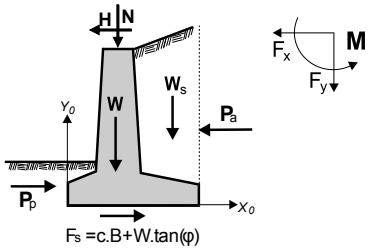


Sum of overturning moments = 107.70 kNm/m
Sum of moments resisting overturning = 217.65 kNm/m
Overturning check Msd=107.70 < Mrd=217.65 kNm/m, Check is verified

4.8.4. Failure check against sliding (STR)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.35	-0.10- 3.00	33.14	0.00	0.00
Backfill surcharge (live)	Pqx1.50	-0.10- 3.00	2.66	0.00	0.00
Active earth pressure	Pax1.35	3.00- 4.00	17.77	0.00	0.00
Backfill surcharge (live)	Pqx1.50	3.00- 4.00	0.64	0.00	0.00
Passive earth pressure	Ppx1.00	3.40- 4.30	0.00	14.94	0.00
Wall weight	W x1.00		0.00	0.00	70.00
Backfill weight	Wsx1.00		0.00	0.00	70.22
Backf. surcharge (dead)	Wsgx1.00		0.00	0.00	3.60
Vert. load on top (dead)	Ngx1.00		0.00	0.00	3.00
Horiz. load on top (dead)	Hgx1.35		2.70	0.00	0.00
Horiz. load on top (live)	Hqx1.50		3.00	0.00	0.00
		Sum=	59.91	14.94	146.82

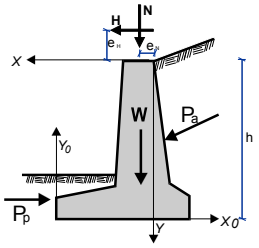


Soil friction Rd=Vd·tanφ/γM= 146.82xtan(30.00°)/1.00= 84.77 kN/m
Soil cohesion Rd=A·cu/γM = 1000x2.247x0.010/1.00= 22.47 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 59.91 kN/m
Sum of resisting forces (14.94+84.77) = 99.71 kN/m
Sliding resistance check Hd=59.91 < Rd=99.71 kN/m, Check is verified

4.9. Checks of wall stability (GEO)

4.9.1. Forces (driving and resisting) on the wall (GEO)

Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa -0.10- 3.00	33.04	0.00	-1.200	1.909
Backfill surcharge (live)	Pq -0.10- 3.00	2.36	0.00	-1.200	1.447
Active earth pressure	Pa 3.00- 4.00	18.62	0.00	-1.200	3.522
Backfill surcharge (live)	Pq 3.00- 4.00	0.61	0.00	-1.200	3.500
Passive earth pressure	Pp 3.40- 4.30	-11.22	0.00	1.250	4.000
Wall weight	W	0.00	70.00	0.140	2.698
Backfill weight	Ws	0.00	70.22	-0.600	1.776
Backf. surcharge (dead)	Wsg	0.00	3.60	-0.600	0.000
Backf. surcharge (live)	Wsq	0.00	2.40	-0.600	0.000
Vert. load on top (dead)	Ng	0.00	3.00	0.125	0.000
Vert. load on top (live)	Nq	0.00	2.00	0.125	0.000
Horiz. load on top (dead)	Hg	2.00	0.00	0.175	0.000
Horiz. load on top (live)	Hq	2.00	0.00	0.175	0.000

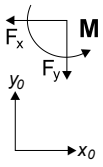


4.9.2. Check of soil bearing capacity (GEO)

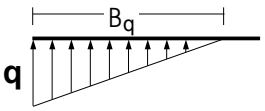
(EC7 EN1997-1-1:2004, §6.5.2)

Check for 1.00x(self weight+top vertical dead load)+0.00x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.00	-0.10- 3.00	33.04	0.00	2.450	2.091	69.09
Backfill surcharge (live)	Pqx1.30	-0.10- 3.00	3.07	0.00	2.450	2.553	7.84
Active earth pressure	Pax1.00	3.00- 4.00	18.62	0.00	2.450	0.478	8.90
Backfill surcharge (live)	Pqx1.30	3.00- 4.00	0.79	0.00	2.450	0.500	0.40
Wall weight	W x1.00		0.00	70.00	1.110	1.302	-77.70
Backfill weight	Wsx1.00		0.00	70.22	1.850	2.224	-129.91
Backf. surcharge (dead)	Wsgx1.00		0.00	3.60	1.850	4.000	-6.66
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.125	4.000	-3.38
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	1.075	4.000	8.00
Horiz. load on top (live)	Hqx1.30		2.60	0.00	1.075	4.000	10.40
			Sum=	146.82			-113.02



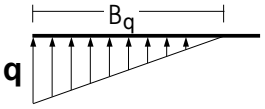
Sum of vertical forces = 146.82 kN/m
Sum of moments at front toe = -113.02 kNm/m
Sum of moments at middle of base = 66.83 kNm/m
Eccentricity ec=66.83/146.82=0.455m, ec>2.450/6=0.408m
Soil pressure q=0.127 N/mm² Bq=2.309 m
Effective footing L=2.450-2x0.455= 1.540 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.540x(1000x0.20)/1.40= 220.00 kN/m
Bearing resistance check Vd=146.82 < Rd=220.00 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)



Check for 1.00x(self weight+top vertical dead load)+1.30x(top vertical live load)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	M [kNm/m]
Active earth pressure	Pax1.00	-0.10- 3.00	33.04	0.00	2.450	2.091	69.09
Backfill surcharge (live)	Pqx1.30	-0.10- 3.00	3.07	0.00	2.450	2.553	7.84
Active earth pressure	Pax1.00	3.00- 4.00	18.62	0.00	2.450	0.478	8.90
Backfill surcharge (live)	Pqx1.30	3.00- 4.00	0.79	0.00	2.450	0.500	0.40
Wall weight	W x1.00		0.00	70.00	1.110	1.302	-77.70
Backfill weight	Wsx1.00		0.00	70.22	1.850	2.224	-129.91
Backf. surcharge (dead)	Wsgx1.00		0.00	3.60	1.850	4.000	-6.66
Backf. surcharge (live)	Wsqx1.30		0.00	3.12	1.850	4.000	-5.77
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.125	4.000	-3.38
Vert. load on top (live)	Nqx1.30		0.00	2.60	1.125	4.000	-2.92
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	1.075	4.000	8.00
Horiz. load on top (live)	Hqx1.30		2.60	0.00	1.075	4.000	10.40
			Sum=	152.54			-121.71

Sum of vertical forces = 152.54 kN/m
Sum of moments at front toe = -121.71 kNm/m
Sum of moments at middle of base = 65.15 kNm/m
Eccentricity ec=65.15/152.54=0.427m, ec>2.450/6=0.408m
Soil pressure q=0.127 N/mm² Bq=2.394 m
Effective footing L=2.450-2x0.427= 1.596 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.596x(1000x0.20)/1.40= 228.00 kN/m
Bearing resistance check Vd=152.54 < Rd=228.00 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

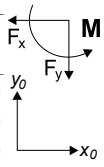


4.9.3. Failure check due to overturning (GEO)

(EC7 EN1997-1-1:2004, §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.250,y=4.000 m)

Action	(γ)	y1 - y2	Fx [kN/m]	Fy [kN/m]	xo [m]	yo [m]	Mo+ [kNm/m]	Mo- [kNm/m]
Active earth pressure	Pax1.00	-0.10- 3.00	33.04	0.00	2.450	2.091	69.09	0.00
Backfill surcharge (live)	Pqx1.30	-0.10- 3.00	3.07	0.00	2.450	2.553	7.84	0.00
Active earth pressure	Pax1.00	3.00- 4.00	18.62	0.00	2.450	0.478	8.90	0.00
Backfill surcharge (live)	Pqx1.30	3.00- 4.00	0.79	0.00	2.450	0.500	0.40	0.00
Wall weight	W x1.00		0.00	70.00	1.110	1.302	0.00	77.70
Backfill weight	Wsx1.00		0.00	70.22	1.850	2.224	0.00	129.91
Backf. surcharge (dead)	Wsgx1.00		0.00	3.60	1.850	4.000	0.00	6.66
Vert. load on top (dead)	Ngx1.00		0.00	3.00	1.125	4.000	0.00	3.38
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	1.075	4.000	8.00	0.00
Horiz. load on top (live)	Hqx1.30		2.60	0.00	1.075	4.000	10.40	0.00
					Sum=		104.63	217.65

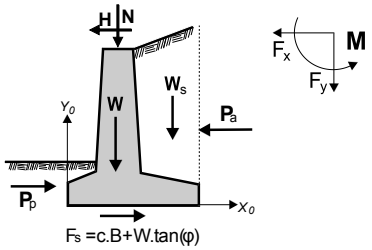


Sum of overturning moments = 104.63 kNm/m
Sum of moments resisting overturning = 217.65 kNm/m
Overturning check Msd=104.63 < Mrd=217.65 kNm/m, Check is verified

4.9.4. Failure check against sliding (GEO)

(EC7 EN1997-1-1:2004, §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]
Active earth pressure	Pax1.00	-0.10- 3.00	33.04	0.00	0.00
Backfill surcharge (live)	Pqx1.30	-0.10- 3.00	3.07	0.00	0.00
Active earth pressure	Pax1.00	3.00- 4.00	18.62	0.00	0.00
Backfill surcharge (live)	Pqx1.30	3.00- 4.00	0.79	0.00	0.00
Passive earth pressure	Ppx1.00	3.40- 4.30	0.00	11.22	0.00
Wall weight	W x1.00		0.00	0.00	70.00
Backfill weight	Wsx1.00		0.00	0.00	70.22
Backf. surcharge (dead)	Wsgx1.00		0.00	0.00	3.60
Vert. load on top (dead)	Ngx1.00		0.00	0.00	3.00
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.00
Horiz. load on top (live)	Hqx1.30		2.60	0.00	0.00
		Sum=	60.12	11.22	146.82



Soil friction Rd=Vd·tanφ/γM= 146.82xtan(30.00°)/1.25= 67.81 kN/m
Soil cohesion Rd=A·cu/γM = 1000x2.309x0.010/1.25= 18.48 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 60.12 kN/m
Sum of resisting forces (11.22+67.81) = 79.03 kN/m
Sliding resistance check Hd=60.12 < Rd=79.03 kN/m, Check is verified

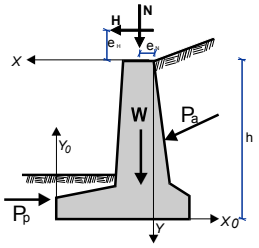
4.10. Seismic design

(EC8 EN1998-5:2004)

Checks of wall stability (with seismic loading)

4.10.1. Forces (driving and resisting) on the wall

Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa -0.10- 3.00	24.55	0.00	-1.200	1.909
Backfill surcharge (live)	Pq -0.10- 3.00	1.77	0.00	-1.200	1.447
Active earth pressure	Pa 3.00- 4.00	13.16	0.00	-1.200	3.522
Backfill surcharge (live)	Pq 3.00- 4.00	0.43	0.00	-1.200	3.500
Passive earth pressure	Pp 3.40- 4.30	-14.94	0.00	1.250	4.000
Wall weight	W	0.00	70.00	0.140	2.698
Backfill weight	Ws	0.00	70.22	-0.600	1.776
Backf. surcharge (dead)	Wsg	0.00	3.60	-0.600	0.000
Backf. surcharge (live)	Wsq	0.00	2.40	-0.600	0.000
Vert. load on top (dead)	Ng	0.00	3.00	0.125	0.000
Vert. load on top (live)	Nq	0.00	2.00	0.125	0.000
Horiz. load on top (dead)	Hg	2.00	0.00	0.175	0.000
Horiz. load on top (live)	Hq	2.00	0.00	0.175	0.000



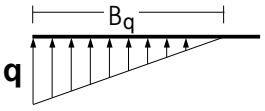
4.10.2. Additional forces due to seismic load

Action	y1 - y2	Fx [kN/m]	Fy [kN/m]	x [m]	y [m]
Active earth pressure	Pa -0.10- 3.00	10.46		-1.200	1.909
Backfill surcharge (live)	Pq -0.10- 3.00	0.75		-1.200	1.447
Active earth pressure	Pa 3.00- 4.00	6.61		-1.200	3.522
Backfill surcharge (live)	Pq 3.00- 4.00	0.22		-1.200	3.500
Wall weight	W	2.80	-1.40	0.140	2.698
Backfill weight	Ws	2.81	-1.40	-0.600	1.776
Backf. surcharge (dead)	Wsg	0.14	-0.07	-0.600	0.000
Backf. surcharge (live)	Wsq	0.10	-0.05	-0.600	0.000
Vert. load on top (dead)	Ng	0.12	-0.06	0.125	0.000
Vert. load on top (live)	Nq	0.08	-0.04	0.125	0.000

4.10.3. Check of soil bearing capacity (with seismic loading) (EC7 §6.5.2)

Action	(γ)	y1 - y2	Fx	Fy	xo	yo	M	
				[kN/m]	[kN/m]	[m]	[m]	[kNm/m]
Active earth pressure	Pax1.00	-0.10- 3.00		35.01	0.00	2.450	2.091	73.20
Backfill surcharge (live)	Pqx1.00	-0.10- 3.00		2.52	0.00	2.450	2.553	6.45
Active earth pressure	Pax1.00	3.00- 4.00		19.77	0.00	2.450	0.478	9.45
Backfill surcharge (live)	Pqx1.00	3.00- 4.00		0.65	0.00	2.450	0.500	0.33
Wall weight	W x1.00			2.80	68.60	1.110	1.302	-72.50
Backfill weight	Wsx1.00			2.81	68.82	1.850	2.224	-121.07
Backf. surcharge (dead)	Wsgx1.00			0.14	3.53	1.850	4.000	-5.97
Backf. surcharge (live)	Wsqx1.00			0.10	2.35	1.850	4.000	-3.95
Vert. load on top (dead)	Ngx1.00			0.12	2.94	1.125	4.000	-2.83
Vert. load on top (live)	Nqx1.00			0.08	1.96	1.125	4.000	-1.89
Horiz. load on top (dead)	Hgx1.00			2.00	0.00	1.075	4.000	8.00
Horiz. load on top (live)	Hqx1.00			2.00	0.00	1.075	4.000	8.00
				Sum=	148.20			-102.78

Sum of vertical forces = 148.20 kN/m
Sum of moments at front toe = -102.78 kNm/m
Sum of moments at middle of base = 78.77 kNm/m
Eccentricity ec=78.77/148.20=0.532m, ec>2.450/6=0.408m
Soil pressure q=0.142 N/mm² Bq=2.080 m



Effective footing L=2.450-2x0.532= 1.387 m (EC7 Annex D)
Soil bearing capacity Rd=L·qu/γM=1.387x(1000x0.20)/1.00= 277.40 kN/m
Bearing resistance check Vd=148.20 < Rd=277.40 kN/m, Check is verified (EC7 Eq.2.2, Eq.6.1)

4.10.4. Failure check due to overturning (with seismic loading) (EC7 §9.7.4)

Overturning with respect to the toe (xo=0,yo=0) (x=1.250,y=4.000 m)

Action	(γ)	y1 - y2	Fx	Fy	xo	yo	Mo+	Mo-	
				[kN/m]	[kN/m]	[m]	[m]	[kNm/m]	[kNm/m]
Active earth pressure	Pax1.00	-0.10- 3.00		35.01	0.00	2.450	2.091	73.20	0.00
Backfill surcharge (live)	Pqx1.00	-0.10- 3.00		2.52	0.00	2.450	2.553	6.45	0.00
Active earth pressure	Pax1.00	3.00- 4.00		19.77	0.00	2.450	0.478	9.45	0.00
Backfill surcharge (live)	Pqx1.00	3.00- 4.00		0.65	0.00	2.450	0.500	0.33	0.00
Wall weight	W x1.00			2.80	68.60	1.110	1.302	5.20	77.70*
Backfill weight	Wsx1.00			2.81	68.82	1.850	2.224	8.84	129.91*
Backf. surcharge (dead)	Wsgx1.00			0.14	3.53	1.850	4.000	0.69	6.66*
Backf. surcharge (live)	Wsqx1.00			0.10	2.35	1.850	4.000	0.49	4.44*
Vert. load on top (dead)	Ngx1.00			0.12	2.94	1.125	4.000	0.55	3.38*
Vert. load on top (live)	Nqx1.00			0.08	1.96	1.125	4.000	0.36	2.25*
Horiz. load on top (dead)	Hgx1.00			2.00	0.00	1.075	4.000	8.00	0.00
Horiz. load on top (live)	Hqx1.00			2.00	0.00	1.075	4.000	8.00	0.00
						Sum=		121.56	224.34

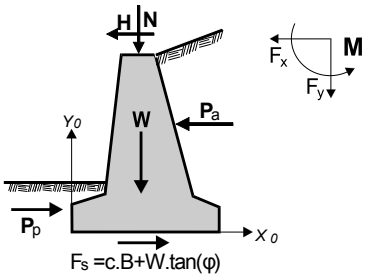
(*moments of negative seismic vertical loads, are added to the overturning moments)

Sum of overturning moments = 121.56 kNm/m
Sum of moments resisting overturning = 224.34 kNm/m
Overturning check Msd=121.56 < Mrd=224.34 kNm/m, Check is verified

4.10.5. Failure check against sliding (with seismic loading)

(EC7 §9.7.3, §6.5.3)

Action	(γ)	y1 - y2	Fx+ [kN/m]	Fx- [kN/m]	Fy [kN/m]	
Active earth pressure	Pax1.00	-0.10- 3.00	35.01	0.00	0.00	
Backfill surcharge (live)	Pqx1.00	-0.10- 3.00	2.52	0.00	0.00	
Active earth pressure	Pax1.00	3.00- 4.00	19.77	0.00	0.00	
Backfill surcharge (live)	Pqx1.00	3.00- 4.00	0.65	0.00	0.00	
Passive earth pressure	Ppx1.00	3.40- 4.30	0.00	14.94	0.00	
Wall weight	W x1.00		2.80	0.00	68.60	
Backfill weight	Wsx1.00		2.81	0.00	68.82	
Backf. surcharge (dead)	Wsgx1.00		0.14	0.00	3.53	
Backf. surcharge (live)	Wsqx1.00		0.10	0.00	2.35	
Vert. load on top (dead)	Ngx1.00		0.12	0.00	2.94	
Vert. load on top (live)	Nqx1.00		0.08	0.00	1.96	
Horiz. load on top (dead)	Hgx1.00		2.00	0.00	0.00	
Horiz. load on top (live)	Hqx1.00		2.00	0.00	0.00	
		Sum=	68.00	14.94	148.20	



Soil friction Rd=Vd·tanφ/γM= 148.20xtan(30.00°)/1.00= 85.56 kN/m
Soil cohesion Rd=A·cu/γM = 1000x2.080x0.010/1.00= 20.80 kN/m
(resisting forces from effective cohesion are neglected) (EC7 §6.5.3. 10)
Sum of driving forces = 68.00 kN/m
Sum of resisting forces (14.94+85.56) = 100.50 kN/m
Sliding resistance check Hd=68.00 < Rd=100.50 kN/m, Check is verified

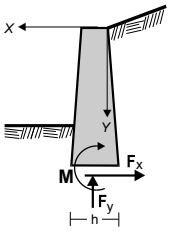
4.11. Design of wall steam

(EC2 EN1992-1-1:2004)

4.11.1. Loading 1.35x(permanent unfavourable)+1.00x(permanent favourable)+1.50x(variable unfav.)

Forces (at cross section centroid) at wall steam

y [m]	h [m]	Fx [kN/m]	Fy [kN/m]	M [kNm/m]
0.50	0.379	8.03	7.55	3.01
1.00	0.407	11.67	12.46	7.70
1.50	0.436	16.81	17.73	14.49
2.00	0.464	23.51	23.36	24.18
2.50	0.493	31.73	29.34	37.51
3.00	0.521	41.48	35.68	55.23
3.50	0.550	50.13	42.37	77.50



4.11.2. Design of wall steam in bending

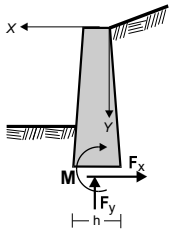
(EC2 §9.6, §6.1)
Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=25 mm (§3, §4.4.1.1)
Vertical reinforcement minimum: 0.0020Ac, maximum: 0.0400Ac (EC2 §9.6.2)

y [m]	Msd [kN/m]	Nsd [kN]	d [mm]	Kd	x/d	ec/es	Ks	As	min reinf. [cm²/m]	[cm²/m]
0.50	3.01	-7.55	349	16.97	0.02	0.3/20.0	2.31	0.11	(3.79)	
1.00	7.70	-12.46	377	12.01	0.02	0.5/20.0	2.32	0.32	(4.07)	
1.50	14.49	-17.73	406	9.61	0.03	0.6/20.0	2.32	0.61	(4.36)	
2.00	24.18	-23.36	434	8.08	0.03	0.7/20.0	2.33	1.01	(4.64)	
2.50	37.51	-29.34	463	6.99	0.04	0.8/20.0	2.33	1.53	(4.93)	
3.00	55.23	-35.68	491	6.17	0.05	1.0/20.0	2.34	2.20	(5.21)	
3.50	77.50	-42.37	520	5.55	0.05	1.1/20.0	2.34	2.98	(5.50)	

4.11.3. Loading 1.00x(permanent unfav.)+1.00x(permanent favour.)+1.00x(variable)+1.00x(seismic)

Forces (at cross section centroid) at wall steam (with seismic loading)

y [m]	h [m]	Fx [kN/m]	Fy [kN/m]	M [kNm/m]
0.50	0.379	7.46	7.55	2.62
1.00	0.407	11.83	12.46	7.19
1.50	0.436	17.81	17.73	14.27
2.00	0.464	25.45	23.36	24.69
2.50	0.493	34.72	29.34	39.24
3.00	0.521	45.61	35.68	58.74
3.50	0.550	55.09	42.37	81.93



4.11.4. Design of wall steam in bending (with seismic loading)

(EC2 §9.6, §6.1)

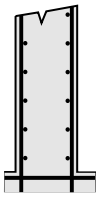
Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=25 mm (§3, §4.4.1.1)
Vertical reinforcement minimum: 0.0020Ac, maximum: 0.0400Ac (EC2 §9.6.2)

y [m]	Msd [kN/m]	Nsd [kN]	d [mm]	Kd	x/d	ec/es	Ks	As	min reinf. [cm²/m]	[cm²/m]
0.50	2.62	-7.55	349	17.84	0.02	0.3/20.0	2.31	0.08	(3.79)	
1.00	7.19	-12.46	377	12.33	0.02	0.5/20.0	2.32	0.29	(4.07)	
1.50	14.27	-17.73	406	9.67	0.03	0.6/20.0	2.32	0.60	(4.36)	
2.00	24.69	-23.36	434	8.01	0.03	0.7/20.0	2.33	1.04	(4.64)	
2.50	39.24	-29.34	463	6.85	0.04	0.9/20.0	2.33	1.62	(4.93)	
3.00	58.74	-35.68	491	6.00	0.05	1.0/20.0	2.34	2.37	(5.21)	
3.50	81.93	-42.37	520	5.41	0.05	1.1/20.0	2.34	3.19	(5.50)	

4.11.5. Reinforcement of wall steam

Reinforcement at back steam face **Ø10/14.0** (5.61cm²/m)
Secondary transverse reinforcement **Ø8/50.0** (1.01cm²/m)

Reinforcement at front steam face **Ø10/14.0** (5.61cm²/m)
Secondary transverse reinforcement **Ø8/50.0** (1.01cm²/m)



4.11.6. Anchorage of wall steam reinforcement

(EC2 §8.4)

Basic required anchorage length lb,rqd=(Φ/4)(σsd/fbd)=(10/4)x(247/1.89)=327mm (EC2 Eq.8.3)
σsd=435.00x319/561=247MPa fbd=2.25x0.70x(fctk0.05/γc)=1.89 MPa (EC2 §8.4.2)
Design anchorage length lbd=1.00x327=327mm, Cnom=25mm<3Ø=30mm (EC2 §8.4.4, T.8.2)
Minimum anchorage length lb,min=max(0.30lbrqd,10Ø,100mm)=100mm
Necessary bend 100mm at lower bar end for anchorage

4.11.7. Shear check of wall steam

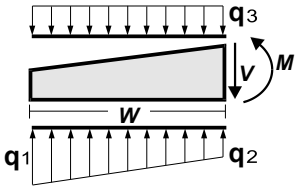
(EC2 EN1992-1-1:2004, §6.2.2)

Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=25 mm (§3, §4.4.1.1)
The earth pressure load variation is linear, so the variation of shear force is parabolic. The variation of steam cross section is linear.
The most unfavourable place for shear check is the base of the steam.

Vsd=50.13 kN/m, Vsd (+seismic)=55.09 kN/m, Nsd=-42.37 kN/m
Shear capacity without shear reinforcement Vrdc (EC2 §6.2.2)
Vrdc=[Crdc·k·(100ρ1·fck)^(0.333)+k1·σcp]·bw·d (EC2 Eq.6.2.a)
Vrdc>=(vmin+k1·σcp)·bw·d (EC2 Eq.6.2.b)
Crdc=0.18/γc=0.18/1.50=0.120, fck=25.00MPa
k=1+(200/d)^½ <=2, k=1.62, k1=0.15
ρ1=As1/(bw·d)=561/(1000x520)=0.0011
σcp=Nsd/Ac=1000x42.37/550000=0.08N/mm²
vmin=0.035·k^(1.50)·fck^½ = 0.36N/mm² (EC2 Eq.6.3N)
Vrd,c(min)=0.001x(0.36+0.15x0.08)x1000x520=193.44kN/m
Vrdc=0.001x[0.120x1.62x(0.11x25.00)^(0.333)+0.15x0.08]x1000x520=147.87, Vrdc=Vrcd(min)=193.44kN/m
Vsd=55.09 kN/m <= Vrdc=193.44 kN/m, shear OK

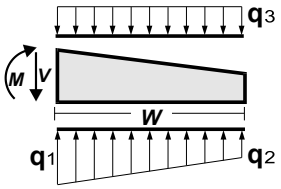
4.12. Design of wall footing and reinforcement (EC2 EN1992-1-1:2004)

4.12.1. Design of front toe x=1.250 m to x=0.550 m



Sum of vertical forces = 203.55 kN/m
Sum of moments at middle of base = 55.51 kNm/m
q1= 0.139 N/mm², q2= 0.107 N/mm², w= 0.700 m
pressure from self weight q3= 0.013 N/mm²
M= 28.17 kNm/m, V= 76.80 kN/m
V at distance d=425mm from the face of the steam = 32.72 kN/m
Msd= 28.17k Nm/m, Vsd= 32.72 kN/m

4.12.2. Design of back heel x=-1.200 m to x=0.000 m



Sum of vertical forces = 203.55 kN/m
Sum of moments at middle of base = 55.51 kNm/m
q1= 0.082 N/mm², q2= 0.028 N/mm², w= 1.200 m
pressure from backfill and self weight q3= 0.071 N/mm²
M= -18.21 kNm/m, V= 19.47 kN/m
V at distance d=425mm from the face of the steam = 18.86 kN/m
Msd= -18.21k Nm/m, Vsd= 18.86 kN/m

4.12.3. Design of front toe x=1.250 m to x=0.550 m (with seismic loading)

Sum of vertical forces = 148.20 kN/m
Sum of moments at middle of base = 78.77 kNm/m
q1= 0.142 N/mm², q2= 0.095 N/mm², w= 0.700 m
pressure from self weight q3= 0.013 N/mm²
M= 27.80 kNm/m, V= 73.85 kN/m
V at distance d=425mm from the face of the steam = 32.94 kN/m
Msd= 27.80k Nm/m, Vsd= 32.94 kN/m

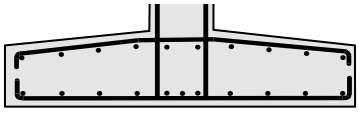
4.12.4. Design of back heel x=-1.200 m to x=0.000 m (with seismic loading)

Sum of vertical forces = 148.20 kN/m
Sum of moments at middle of base = 78.77 kNm/m
q1= 0.057 N/mm², q2= 0.000 N/mm², w= 0.830 m
pressure from backfill and self weight q3= 0.097 N/mm²
M= -26.98 kNm/m, V= 56.94 kN/m
V at distance d=425mm from the face of the steam = 33.74 kN/m
Msd= -26.98k Nm/m, Vsd= 33.74 kN/m

4.12.5. Design of wall footing in bending (EC2 EN1992-1-1:2004, §6.1)

Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=75 mm (§3, §4.4.1.1)
Msd= 28.17kNm/m, d=419mm, Kd=7.89 x/d=0.04 εc/εs=0.7/20.0 ks=2.33, **As= 1.56cm²**
Msd=-26.98kNm/m, d=419mm, Kd=8.07 x/d=0.03 εc/εs=0.7/20.0 ks=2.33, **As= 1.50cm²**
Minimum reinforcement As>=0.26bd·Fctm/fyk (As= 5.66cm²/m) (EC2 §9.3.1)
Minimum reinforcement Ø12/19.5(5.79cm²/m)

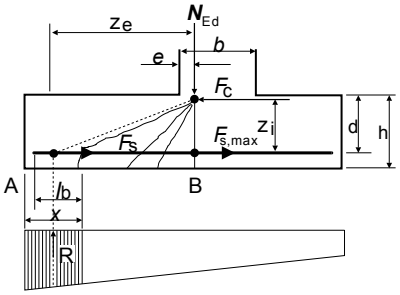
4.12.6. Reinforcement of wall footing



Footing reinforcement at bottom **Ø12/19.5** (5.79cm²/m)
Footing reinforcement at top **Ø12/19.5** (5.79cm²/m)
Secondary tranverse reinforcement **Ø12/40.0** (2.82cm²/m)

4.12.7. Anchorage of footing reinforcement

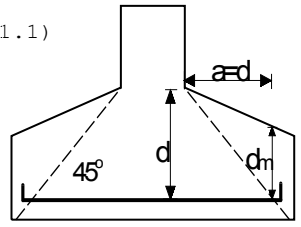
(EC2 EN1992-1-1:2004, §9.8.2.2, §8.4)



x=h/2=0.250m, R=1000x0.142x0.250=35.50 kN/m
e=0.15b=0.083m ze=1.158 m, zi=0.900d=0.377m
Fs=R·ze/zi=35.50x1.158/0.377=108.97 kN/m
σsd=Fs/As=1000x108.97/579=188 MPa
Basic required anchorage length (EC2 Eq.8.3)
lb,rqd=(Φ/4)(σsd/fbd)=(12/4)x(188/2.70)=209mm
fbd=2.25x1.00x(fctk0.05/γc)=2.70 MPa (EC2 §8.4.2)
Design anchorage length (EC2 §8.4.4, T.8.2)
lbd=0.70x209=146mm, Cnom=75mm>3Ø=36mm
Minimum anchorage length lb,min=max(0.30lbrqd,10Ø,100mm)=120mm
Necessary anchorage length of longitudinal reinforcement Lbd=150mm =0.150m
lbd=150mm<(x-Cnom)=175.00. Sufficient length is available

4.12.8. Design of wall footing for shear and punching shear

(EC2 EN1992-1-1:2004, §6.2.2)



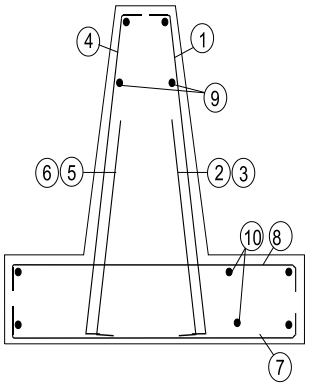
Concrete-Steel class: C25/30-S500, Concrete cover: Cnom=75 mm (§3, §4.4.1.1)
Punching shear capacity without shear reinforcement Vrdc (EC2 §6.4.4)
Vrdc=[Crdc·k·(100ρ1·fck)^(0.333)·(2d/a)]·bw·d (EC2 Eq.6.50)
Vrdc>=[vmin·2d/a]·bw·d, d=dm=419mm, a=419mm
Crdc=0.18/γc=0.18/1.50=0.120, fck=25.00MPa
k=1+(200/d)^½ <=2, k=1.69
ρ1=As1/(bw·d)=579/(1000x419)=0.0014
vmin=0.035·k^(1.50)·fck^½ = 0.38N/mm² (EC2 Eq.6.3N)
Vrd,c(min)=0.001x(0.38x2x419/419)x1000x419=318.44kN/m
Vrdc=0.001x[0.120x1.69x(0.14x25.00)^(0.333)x2x419/419]x1000x419=258.03, Vrdc=Vrcd(min)=318.44kN/m
Vsd=33.74 kN/m <= Vrdc=318.44 kN/m, shear and punching shear OK

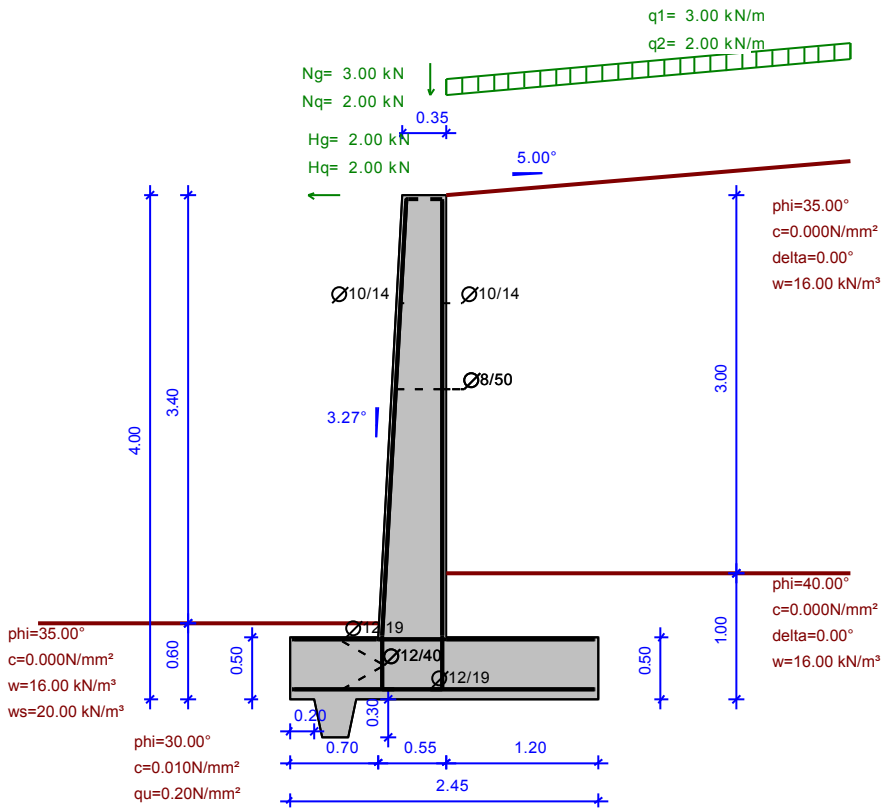
4.13. Material estimate

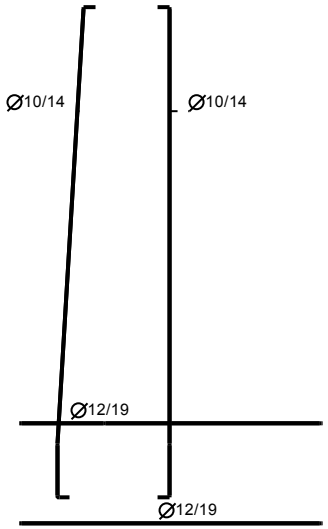
Concrete per meter of wall length 2.800 m³/m
Reinforcing steel per meter of wall 73.376 kg/m
Total concrete of wall 10.000x 2.800= 27.999 m³
Total reinforcing steel of wall 10.000x 73.376= 733.760 kg

4.14. Reinforcing bar schedule

Num	type	reinforcing bar [mm]	items	∅	g/m [kg/m]	length [m]	weight [kg]
7	1	100 — 3870 — 100	71	10	0.617	4.070	178.29
8	4	100 — 3870 — 100	71	10	0.617	4.070	178.29
9	9	10000	16	8	0.395	10.000	63.20
10	7	2290	51	12	0.888	2.290	103.71
11	8	2290	51	12	0.888	2.290	103.71
12	10	10000	12	12	0.888	10.000	106.56
		Total weight [kg]					**733.76**







General information

Wall type : Cantilever wall

Concrete and steel class

Steam :C25/30-S500

Footing :C25/30-S500

Design codes

Eurocode 0 EN1991-1-1, Basis of structural design

Eurocode 1 EN1991-1-1, Actions on structures

Eurocode 2 EN1992-1-1, Design of concrete structures

Eurocode 7 EN1997-1-1, Geotechnical design

Eurocode 8 EN1998-5, Earthquaqe design

Loads

Vertical : dead Ng=3.00kN, live Nq=2.00kN

Horizontal: dead Hg=2.00kN, live Hq=2.00kN

Surcharge : dead g=3.00kN/m², live q=2.00kN/m²

Seismic coefficients

Design ground acceleration ratio a =0.060

Coefficient for horizontal seismic force kh=0.040

Coefficient for vertical seismic force kv=0.020

Soil properties back-1

phi=35.00°

c=0.000N/mm²

delta=0.00°

w=16.00 kN/m³

Soil properties back-2

phi=40.00°

c=0.000N/mm²

delta=0.00°

w=16.00 kN/m³

Soil properties front

phi=35.00°

c=0.000N/mm²

w=16.00 kN/m³

ws=20.00 kN/m³

Foundation soil properties

phi=30.00°

c=0.010N/mm²

qu=0.20N/mm²

Concrete volume V= 28.00 [m³]

Reinforcement weight G=733.76 [kg]

Reinforcing bar schedule

#		reinforcing bar [mm]	items	∅ [mm]	g/m [kg/m]	length [m]	weight [kg]
1	W1	100 — 3870 — 100	71	10	0.617	4.070	178.29
2	W4	100 — 3870 — 100	71	10	0.617	4.070	178.29
3	W9	10000	16	8	0.395	10.000	63.20
4	W7	2290	51	12	0.888	2.290	103.71
5	W8	2290	51	12	0.888	2.290	103.71
6	W10	10000	12	12	0.888	10.000	106.56

Total weight [kg] **733.76**

Project: Example of retaining walls

C. WALL-002

Scale : 1:60 **Date:** 12/03/2007

Designer: **Draw.No.:**

Filename: Example of retaining wall **Sign:**

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