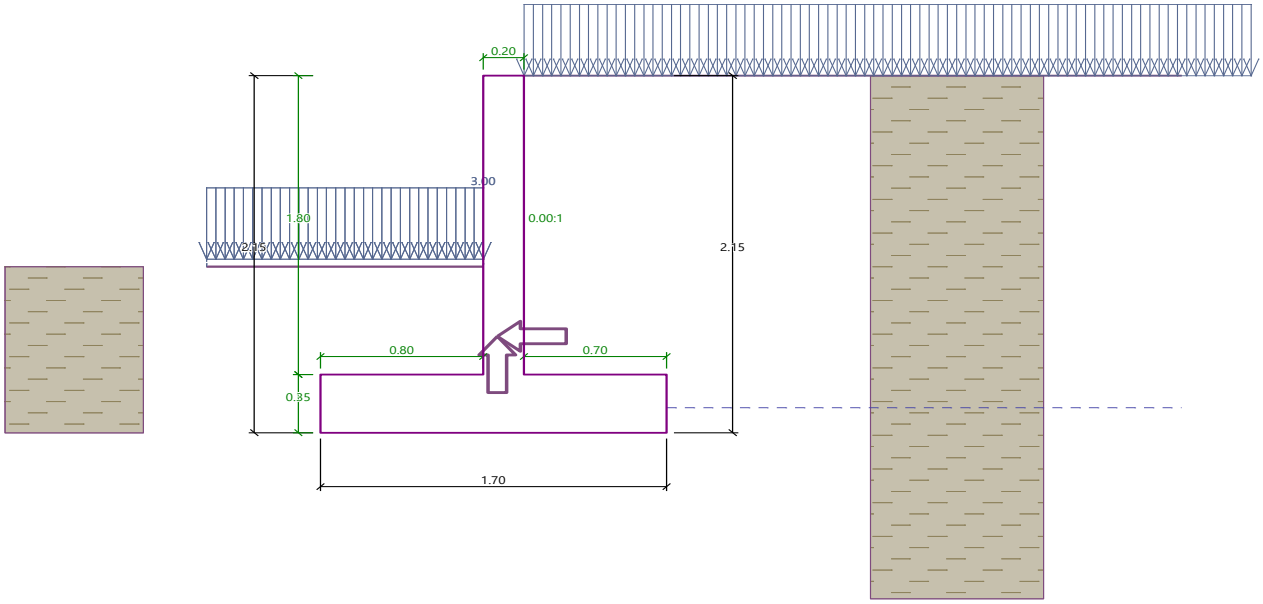
MEMORIAS DE CALCULO ESTRUCTURAL

PROYECTO

MURO DE CONTENCIÓN CANCHA MÚLTIPLE EL CARMELO

CARTAGENA, DEPARTAMENTO DE BOLÍVAR.



Responsable

Jorge Andrés Ruiz Arboleda

Ingeniero Civil-Especialista en Estructuras

Máster en Análisis y Cálculo de Estructuras (c)

M.P. 13202-310617 BLV

La Ceja - Antioquia

Octubre de 2023

Diseño estructural graderías y muro de contención Cancha Múltiple El Carmelo

Calculó: Ing. Jorge Ruiz A. – Ing. Roxana Quesada

Aprobó: Ing. Jorge Ruiz A.

Cantilever wall analysis

Input data

Project

Date : 17/10/2023

Settings

(input for current task)

Materials and standards

Concrete structures : ACI 318-19

Coefficients according to SNiP			
Combination coefficient :	γ_k =	1.00	[–]
Coefficient of action conditions :	γ_c =	0.90	[–]
Coefficient of importance of structure :	γ_n =	1.10	[–]

Wall analysis

Active earth pressure calculation :	Coulomb
Passive earth pressure calculation :	Caquot-Kerisel
Earthquake analysis :	Mononobe-Okabe
Shape of earth wedge :	Calculate as skew
Base key :	The base key is considered as front face resistance
Allowable eccentricity :	0.333
Verification methodology :	Safety factors (ASD)

Safety factors			
Permanent design situation			
Safety factor for overturning :	SF_o =	1.60	[–]
Safety factor for sliding resistance :	SF_s =	1.60	[–]
Safety factor for bearing capacity :	SF_b =	3.00	[–]

Material of structure

Unit weight γ = 24.00 kN/m^3
Analysis of concrete structures carried out according to the standard ACI 318-11.
Concrete : f'c=28 MPa
Compressive strength f_c' = 28.00 MPa

Longitudinal steel : Fy=420 MPa (user defined)
Tensile strength f_y = 420.00 MPa

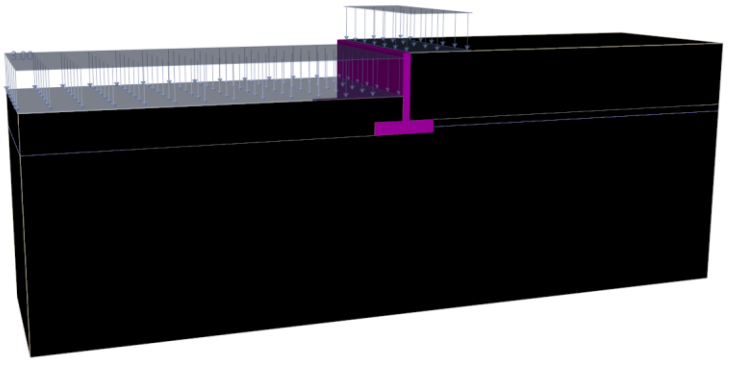
[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Geometry of structure

No.	Coordinate X [m]	Depth Z [m]
1	0.00	0.00
2	0.00	1.80
3	0.70	1.80
4	0.70	2.15
5	-1.00	2.15
6	-1.00	1.80
7	-0.20	1.80
8	-0.20	0.00

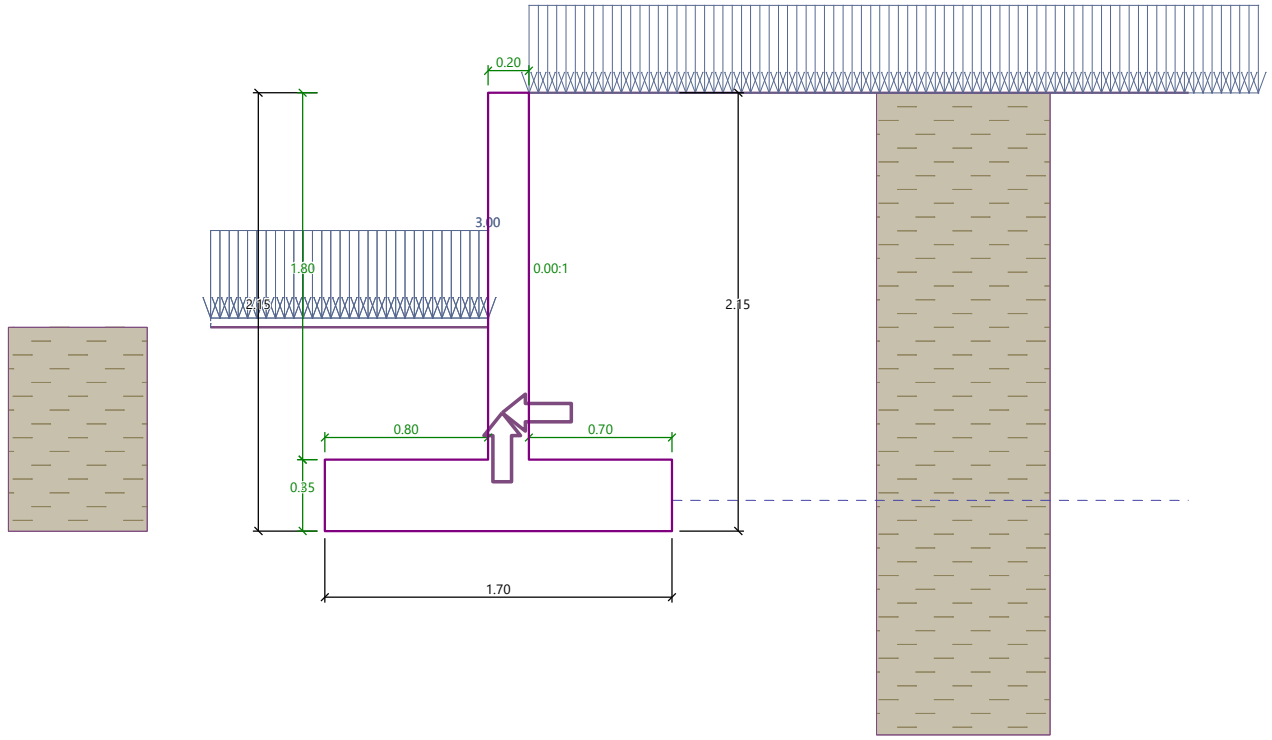
The origin [0,0] is located at the most upper right point of the wall.
Wall section area = 0.95 m^2.

Name : Geometry	Stage - analysis : 1 - 0
Description : Wall Geometry	



[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Name : Geometry	Stage - analysis : 1 - 0



Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]	γ_{su} [kN/m^3]	δ [°]
1	CH		11.00	20.00	18.00	10.00	11.00

Soil parameters to compute pressure at rest

No.	Name	Pattern	Type calculation	φ_{ef} [°]	ν [–]	OCR [–]	K_r [–]
1	CH		cohesive	-	0.42	-	-

Soil parameters

CH

Unit weight : γ = 18.00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 11.00 °
Cohesion of soil : c_{ef} = 20.00 kPa
Angle of friction struc.-soil : δ = 11.00 °
Soil : cohesive

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Poisson's ratio : $\nu = 0.42$
Saturated unit weight : $\gamma_{sat} = 20.00$ kN/m^3

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	-	0.00 .. ∞	CH	

Foundation

Type of foundation : soil from geological profile

Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 2.00 m
Uplift in foot. bottom due to different pressures is not considered.
The evolution of tensile cracks is considered in the analyses. Depth of cracks is 2.00 m.

Input surface surcharges

No.	Surcharge new	Surcharge change	Action	Mag.1 [kN/m^2]	Mag.2 [kN/m^2]	Ord.x x [m]	Length l [m]	Depth z [m]
1	Yes		permanent	3.00				on terrain

Resistance on front face of the structure

Resistance on front face of the structure: passive
Soil on front face of the structure - CH
Angle of friction struc.-soil $\delta = 0.00$ °
Soil thickness in front of structure $h = 1.00$ m
Terrain surcharge $f = 3.00$ kN/m^2

Terrain in front of structure is flat.

Earthquake

Factor of horizontal acceleration $K_h = 0.1000$
Factor of vertical acceleration $K_v = 0.0500$

Water below the GWT is restricted.

Settings of the stage of construction

Design situation : permanent
The wall is free to move. Active earth pressure is therefore assumed.

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Verification No. 1

Passive pressure on front face of the structure - partial results

Layer No.	Thickness [m]	α [°]	φ_d [°]	c_d [kPa]	γ [kN/m^3]	δ_d [°]	K_p	Comment
1	0.65	0.00	11.00	20.00	18.00	0.00	1.481	
2	0.00	89.90(11.00)	11.00	20.00	18.00	0.00	1.344	MODIFIED
3	0.35	0.00	11.00	20.00	18.00	0.00	1.481	

Passive pressure distribution on front face of the structure

Layer No.	Start [m] End [m]	σ_Z [kPa]	σ_W [kPa]	Pressure [kPa]	Hor. comp. [kPa]	Vert. comp. [kPa]
1	0.00	0.00	0.00	48.68	48.68	0.00
	0.65	11.70	0.00	66.00	66.00	0.00
2	0.65	11.70	0.00	62.09	0.10	62.09
	0.65	11.72	0.00	62.12	0.10	62.12
3	0.65	11.72	0.00	66.04	66.04	0.00
	1.00	18.00	0.00	75.33	75.33	0.00

Active pressure behind the structure - partial results

Layer No.	Thickness [m]	α [°]	φ_d [°]	c_d [kPa]	γ [kN/m^3]	δ_d [°]	K_a	Comment
1	0.95	0.00	11.00	20.00	18.00	11.00	0.609	
2	0.05	39.50	11.00	20.00	18.00	11.00	1.068	
3	0.09	39.50	11.00	20.00	18.00	11.00	1.068	
4	0.71	39.50	11.00	20.00	18.00	11.00	1.068	
5	0.20	0.00	11.00	20.00	18.00	11.00	0.609	
6	0.15	0.00	11.00	20.00	10.00	11.00	0.609	

Active pressure distribution behind the structure (without surcharge)

Layer No.	Start [m] End [m]	σ_Z [kPa]	σ_W [kPa]	Pressure [kPa]	Hor. comp. [kPa]	Vert. comp. [kPa]
1	0.00	0.00	0.00	0.00	0.00	0.00
	0.95	17.11	0.00	0.00	0.00	0.00
2	0.95	17.11	0.00	0.00	0.00	0.00
	1.00	18.00	0.00	0.00	0.00	0.00
3	1.00	18.00	0.00	0.00	0.00	0.00
	1.09	19.56	0.00	0.00	0.00	0.00

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Layer No.	Start [m] End [m]	σ_z [kPa]	σ_w [kPa]	Pressure [kPa]	Hor. comp. [kPa]	Vert. comp. [kPa]
4	1.09	19.56	0.00	0.00	0.00	0.00
	1.80	32.40	0.00	13.71	8.72	10.58
5	1.80	32.40	0.00	0.00	0.00	0.00
	2.00	36.00	0.00	0.00	0.00	0.00
6	2.00	36.00	0.00	0.00	0.00	0.00
	2.15	37.50	1.50	0.00	0.00	0.00

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-0.58	22.92	0.87	1.000
Earthq.- constr.	2.29	-0.58	-1.15	0.87	1.000
FF resistance	-61.91	-0.46	0.08	0.40	1.000
Resistance on front face	-4.44	-0.50	0.01	0.40	1.000
Earthq.- face	1.27	-0.67	0.00	0.80	1.000
Weight - earth wedge	0.00	-0.63	5.35	1.23	1.000
Earthquake - soil wedge	0.54	-0.63	-0.27	1.23	1.000
Active pressure	3.11	-0.59	3.77	1.50	1.000
Water pressure	0.11	-0.05	0.00	1.00	1.000
Tensile crack	20.00	-0.82	0.00	1.00	1.000
Uplift pressure	0.00	-2.15	0.00	1.00	1.000
Earthq.- act.pressure	4.94	-1.45	2.34	1.20	1.000
Surch.1 - surface	1.62	-0.75	2.55	1.32	1.000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 30.34 kNm/m

Overturning moment M_{ovr} = -1.93 kNm/m

Safety factor = 1000.00 > 1.60

Wall for overturning is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 33.48 kN/m

Active horizontal force H_{act} = -32.47 kN/m

Safety factor = 1000.00 > 1.60

Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Warning - allowable range of input data exceeded during earthquake analysis!

The analysis is carried out with the modified value of terrain inclination β.

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Bearing capacity of foundation soil

Design load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]	Eccentricity [–]	Stress [kPa]
1	-8.75	35.61	-32.47	0.000	20.95

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	-8.75	35.61	-32.47

Verification of foundation soil

Stress in the footing bottom : rectangle

Eccentricity verification

Max. eccentricity of normal force $e = 0.000$

Maximum allowable eccentricity $e_{alw} = 0.333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom $\sigma = 20.95$ kPa

Bearing capacity of foundation soil $R_d = 277.50$ kPa

Safety factor = 13.25 > 3.00

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Dimensioning No. 1

Wall stem check - front reinf.

Passive pressure on front face of the structure - partial results

Layer No.	Thickness [m]	α [°]	φ_d [°]	c_d [kPa]	γ [kN/m^3]	δ_d [°]	K_p	Comment
1	0.65	0.00	11.00	20.00	18.00	0.00	1.481	

Passive pressure distribution on front face of the structure

Layer No.	Start [m] End [m]	σ_z [kPa]	σ_w [kPa]	Pressure [kPa]	Hor. comp. [kPa]	Vert. comp. [kPa]
1	0.00	0.00	0.00	48.68	48.68	0.00
	0.65	11.68	0.00	65.97	65.97	0.00

Pressure at rest behind the structure - partial results

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Layer No.	Thickness [m]	α [°]	φ_d [°]	c_d [kPa]	γ [kN/m³]	K_r	Comment
1	1.00	0.00	11.00	20.00	18.00	0.724	
2	0.80	0.00	11.00	20.00	18.00	0.724	

Pressure at rest distribution behind the structure (without surcharge)

Layer No.	Start [m] End [m]	σ_z [kPa]	σ_w [kPa]	Pressure [kPa]	Hor. comp. [kPa]	Vert. comp. [kPa]
1	0.00	0.00	0.00	0.00	0.00	0.00
	1.00	18.00	0.00	13.03	13.03	0.00
2	1.00	18.00	0.00	13.03	13.03	0.00
	1.80	32.38	0.00	23.45	23.45	0.00

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-0.90	8.63	0.10	1.000
Earthq.- constr.	0.86	-0.90	-0.43	0.10	1.000
FF resistance	-37.19	-0.31	0.00	0.00	1.000
Resistance on front face	-2.88	-0.32	0.00	0.00	1.000
Earthq.- face	0.53	-0.43	0.00	0.00	1.000
Pressure at rest	21.09	-0.60	0.00	0.20	1.000
Water pressure	0.00	-1.80	0.00	0.20	1.000
Tensile crack	16.18	-0.60	0.00	0.20	1.000
Earthquake - pressure at rest	5.53	-0.90	0.00	0.20	1.000
Surch.1 - surface	3.91	-0.90	0.00	0.20	1.000

Wall stem check - front reinf.

Front reinforcement is not required.

Wall stem check - back reinf.

Passive pressure on front face of the structure - partial results

Layer No.	Thickness [m]	α [°]	φ_d [°]	c_d [kPa]	γ [kN/m³]	δ_d [°]	K_p	Comment
1	0.65	0.00	11.00	20.00	18.00	0.00	1.481	

Passive pressure distribution on front face of the structure

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Layer No.	Start [m] End [m]	σ_z [kPa]	σ_w [kPa]	Pressure [kPa]	Hor. comp. [kPa]	Vert. comp. [kPa]
1	0.00	0.00	0.00	48.68	48.68	0.00
	0.65	11.68	0.00	65.97	65.97	0.00

Pressure at rest behind the structure - partial results

Layer No.	Thickness [m]	α [°]	φ_d [°]	c_d [kPa]	γ [kN/m^3]	K_r	Comment
1	1.00	0.00	11.00	20.00	18.00	0.724	
2	0.80	0.00	11.00	20.00	18.00	0.724	

Pressure at rest distribution behind the structure (without surcharge)

Layer No.	Start [m] End [m]	σ_z [kPa]	σ_w [kPa]	Pressure [kPa]	Hor. comp. [kPa]	Vert. comp. [kPa]
1	0.00	0.00	0.00	0.00	0.00	0.00
	1.00	18.00	0.00	13.03	13.03	0.00
2	1.00	18.00	0.00	13.03	13.03	0.00
	1.80	32.38	0.00	23.45	23.45	0.00

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-0.90	8.63	0.10	1.000
Earthq.- constr.	0.86	-0.90	-0.43	0.10	1.000
FF resistance	-37.19	-0.31	0.00	0.00	1.000
Resistance on front face	-2.88	-0.32	0.00	0.00	1.000
Earthq.- face	0.53	-0.43	0.00	0.00	1.000
Pressure at rest	21.09	-0.60	0.00	0.20	1.000
Water pressure	0.00	-1.80	0.00	0.20	1.000
Tensile crack	16.18	-0.60	0.00	0.20	1.000
Earthquake - pressure at rest	5.53	-0.90	0.00	0.20	1.000
Surch.1 - surface	3.91	-0.90	0.00	0.20	1.000

Wall stem check - back reinf.

Wall check at the construction joint 1.80 m from the wall crest
Reinforcement and dimensions of the cross-section
4 prof. No. 4, cover 75.0 mm
Inputted reinforcement area = 506.7 mm^2
Required reinforcement area = 448.6 mm^2
Cross-section width = 1.00 m

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Cross-section height = 0.20 m

Reinforcement ratio	ρ	=	0.43	%	>	0.33	%	=	ρ_{min}
Position of neutral axis	c	=	0.02	m	<	0.05	m	=	c_{max}
Ultimate shear force	ϕV_n	=	78.20	kN	>	8.03	kN	=	V_u
Ultimate moment	ϕM_n	=	34.88	kNm	>	19.45	kNm	=	M_u

Cross-section is SATISFACTORY.

Wall stem check - back reinf. - V_u

Wall check at the construction joint 1.16 m from the wall crest
Reinforcement and dimensions of the cross-section
4 prof. No. 4, cover 75.0 mm
Inputted reinforcement area = 506.7 mm^2
Required reinforcement area = 448.6 mm^2
Cross-section width = 1.00 m
Cross-section height = 0.20 m

Ultimate shear force ϕV_n = 78.20 kN > 20.25 kN = V_u
Cross-section is SATISFACTORY.

Wall jump check

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-0.58	22.92	0.87	1.000
Earthq.- constr.	2.29	-0.58	-1.15	0.87	1.000
FF resistance	-61.91	-0.46	0.08	0.40	1.000
Resistance on front face	-4.44	-0.50	0.01	0.40	1.000
Earthq.- face	1.27	-0.67	0.00	0.80	1.000
Weight - earth wedge	0.00	-0.63	5.35	1.23	1.000
Earthquake - soil wedge	0.54	-0.63	-0.27	1.23	1.000
Active pressure	3.11	-0.59	3.77	1.50	1.000
Water pressure	0.11	-0.05	0.00	1.00	1.000
Tensile crack	20.00	-0.82	0.00	1.00	1.000
Uplift pressure	0.00	-2.15	0.00	1.00	1.000
Earthq.- act.pressure	4.94	-1.45	2.34	1.20	1.000
Surch.1 - surface	1.62	-0.75	2.55	1.32	1.000

Wall jump check

Reinforcement and dimensions of the cross-section
4 prof. No. 4, cover 75.0 mm
Inputted reinforcement area = 506.7 mm^2

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Required reinforcement area = 52.6 mm^2
Cross-section width = 1.00 m
Cross-section height = 0.35 m

Reinforcement ratio	ρ	=	0.19	%	>	0.02	%	=	ρ_{min}
Position of neutral axis	c	=	0.01	m	<	0.12	m	=	c_{max}
Ultimate shear force	ϕV_n	=	177.06	kN	>	10.04	kN	=	V_u
Ultimate moment	ϕM_n	=	50.60	kNm	>	4.01	kNm	=	M_u

Cross-section is SATISFACTORY.

Wall heel check

Passive pressure on front face of the structure - partial results

Layer No.	Thickness [m]	α [°]	φ_d [°]	c_d [kPa]	γ [kN/m³]	δ_d [°]	K_p	Comment
1	0.65	0.00	11.00	20.00	18.00	0.00	1.481	
2	0.00	89.90(11.00)	11.00	20.00	18.00	0.00	1.344	MODIFIED
3	0.35	0.00	11.00	20.00	18.00	0.00	1.481	

Passive pressure distribution on front face of the structure

Layer No.	Start [m] End [m]	σ_z [kPa]	σ_w [kPa]	Pressure [kPa]	Hor. comp. [kPa]	Vert. comp. [kPa]
1	0.00	0.00	0.00	48.68	48.68	0.00
	0.65	11.70	0.00	66.00	66.00	0.00
2	0.65	11.70	0.00	62.09	0.10	62.09
	0.65	11.72	0.00	62.12	0.10	62.12
3	0.65	11.72	0.00	66.04	66.04	0.00
	1.00	18.00	0.00	75.33	75.33	0.00

Active pressure behind the structure - partial results

Layer No.	Thickness [m]	α [°]	φ_d [°]	c_d [kPa]	γ [kN/m³]	δ_d [°]	K_a	Comment
1	0.95	0.00	11.00	20.00	18.00	11.00	0.609	
2	0.05	39.50	11.00	20.00	18.00	11.00	1.068	
3	0.09	39.50	11.00	20.00	18.00	11.00	1.068	
4	0.71	39.50	11.00	20.00	18.00	11.00	1.068	
5	0.20	0.00	11.00	20.00	18.00	11.00	0.609	
6	0.15	0.00	11.00	20.00	10.00	11.00	0.609	

Active pressure distribution behind the structure (without surcharge)

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Layer No.	Start [m] End [m]	σ_z [kPa]	σ_w [kPa]	Pressure [kPa]	Hor. comp. [kPa]	Vert. comp. [kPa]
1	0.00	0.00	0.00	0.00	0.00	0.00
	0.95	17.11	0.00	0.00	0.00	0.00
2	0.95	17.11	0.00	0.00	0.00	0.00
	1.00	18.00	0.00	0.00	0.00	0.00
3	1.00	18.00	0.00	0.00	0.00	0.00
	1.09	19.56	0.00	0.00	0.00	0.00
4	1.09	19.56	0.00	0.00	0.00	0.00
	1.80	32.40	0.00	13.71	8.72	10.58
5	1.80	32.40	0.00	0.00	0.00	0.00
	2.00	36.00	0.00	0.00	0.00	0.00
6	2.00	36.00	0.00	0.00	0.00	0.00
	2.15	37.50	1.50	0.00	0.00	0.00

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-0.17	5.88	1.35	1.000
Weight - earth wedge	0.00	-0.63	5.35	1.23	1.000
Active pressure	3.11	-0.59	3.77	1.50	1.000
Tensile crack	20.00	-0.82	0.00	1.00	1.000
Surch.1 - surface	1.62	-0.75	2.55	1.32	1.000
Contact stress	0.00	0.00	-22.14	1.38	1.000

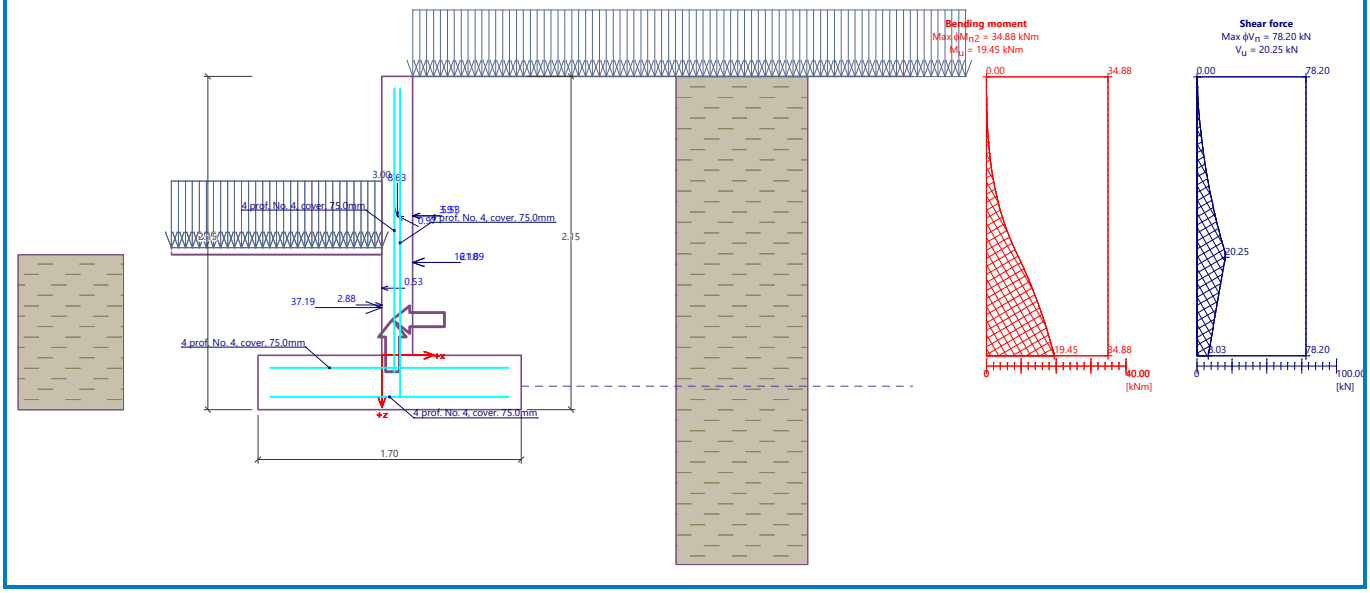
Wall heel check

Reinforcement and dimensions of the cross-section
4 prof. No. 4, cover 75.0 mm
Inputted reinforcement area = 506.7 mm^2
Required reinforcement area = 0.0 mm^2
Cross-section width = 1.00 m
Cross-section height = 0.35 m

Fibers loaded in tension are on the front side of the cross-section, the cross-section cannot be checked using this program.

[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]

Name : Dimensioning	Stage - analysis : 1 - 1



[GEO5 - Cantilever Wall | version 5.2020.40.0 | Copyright © 2020 Fine spol. s r.o. All Rights Reserved | www.finesoftware.eu]