Cantilever wall analysis

Input data

Material of structure

Unit weight γ = 25.00 kN/m^3
Analysis of concrete structures carried out according to the standard GB 50010-2010.

Concrete: C35

Compressive strength	f_{ck} =	23.40 MPa
Tensile strength	f_{tk} =	2.20 MPa

Longitudinal steel: RRB400

Yield strength	f_{yk} =	400.00 MPa
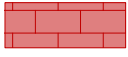
Geometry of structure

No.	Coordinate X [m]	Depth Z [m]
1	0.00	0.00
2	0.00	4.00
3	2.50	4.00
4	2.50	4.60
5	-1.80	4.60
6	-1.80	4.00
7	-0.80	4.00
8	-0.60	0.00

The origin [0,0] is located at the most upper right point of the wall.
Wall section area = 5.38 m^2.

Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]	γ_{su} [kN/m^3]	δ [°]
1	□ □ □ □		35.00	0.00	20.00	10.00	17.50
2	□ □		10.00	5.00	17.00	7.00	0.00
3	□ □ □ □		0.00	1000.00	23.00	13.00	0.00

All soils are considered as cohesionless for at rest pressure analysis.

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	5.00	0.00 .. 5.00	□ □ □ □	
2	-	5.00 .. ∞	□ □	

Terrain profile

Terrain behind construction has the slope 1: 1.51 (slope angle is 33.45 °).
Embankment height is 0.74 m, embankment length is 1.12 m.

Verification No. 1 (Stage of construction 1)

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	-1.45	134.50	1.78	1.000
Weight - earth wedge	0.00	-2.26	129.56	2.67	1.000
Active pressure	73.91	-1.78	105.70	3.63	1.000

Verification of complete wall

Check for overturning stability
Resisting moment M_{res} = 969.97 kNm/m
Overturning moment M_{ovr} = 131.89 kNm/m

Safety factor = 7.35 > 1.60
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force H_{res} = 172.42 kN/m
Active horizontal force H_{act} = 73.91 kN/m

Safety factor = 2.33 > 1.30
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Bearing capacity of foundation soil (Stage of construction 1)

Design load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]	Eccentricity [−]
1	-43.11	369.76	73.91	0.000

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	-43.11	369.76	73.91

Dimensioning No. 1 (Stage of construction 1)

Wall stem check - back reinf.

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Coeff. moment	Coeff. norm.force	Coeff. shear for.
Weight - wall	0.00	-1.90	69.98	0.45	1.000	1.350	1.000
Active pressure	50.27	-1.46	15.85	0.80	1.350	1.350	1.350

Wall stem check - back reinf.

Wall check at the construction joint 4.00 m from the wall crest
Reinforcement and dimensions of the cross-section
5 prof. 20.0 mm, cover 30.0 mm
Inputted reinforcement area   = 1570.8 mm^2
Required reinforcement area = 1519.9 mm^2
Cross-section width   =   1.00 m
Cross-section height   =   0.80 m

Reinforcement ratio ρ =   0.21 %   >   0.20 %   = ρ_{min}
Position of neutral axis x/β_1 =   0.04 m   <   0.49 m   = $\xi_b h_0/\beta_1$
Ultimate shear force V_u = 835.93 kN   > 67.86 kN   = V
Ultimate moment M_u = 420.17 kNm > 87.24 kNm = M

Cross-section is SATISFACTORY.

Input data (Stage of construction 2)

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	5.00	0.00 .. 5.00	□ □ □ □	
2	-	5.00 .. ∞	□ □	

Foundation

Type of foundation : pile foundation
Unit weight γ = 25.00 kN/m^3
Geometry
Length   l   = 18.50 m
Offset   d   = 0.50 m
Diameter x   = 0.80 m
Spacing   b   = 2.30 m

Terrain profile

Terrain behind construction has the slope 1: 1.51 (slope angle is 33.45 °).

Embankment height is 0.74 m, embankment length is 1.12 m.
Water influence

Ground water table is located below the structure.
Resistance on front face of the structure

Resistance on front face of the structure is not considered.
Settings of the stage of construction

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

Verification No. 1 (Stage of construction 2)

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	-1.45	134.50	1.78	1.000
Weight - earth wedge	0.00	-2.26	129.56	2.67	1.000
Active pressure	73.91	-1.78	105.70	3.63	1.000

Verification of complete wall

Overall check - WALL is SATISFACTORY

Bearing capacity of foundation soil (Stage of construction 2)

Loading length (0.00 m) is not set correctly (minimum 1.50 m)

Dimensioning No. 1 (Stage of construction 2)

Wall stem check - back reinf.

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Coeff. moment	Coeff. norm.force	Coeff. shear for.
Weight - wall	0.00	-1.90	69.98	0.45	1.000	1.350	1.000
Active pressure	50.27	-1.46	15.85	0.80	1.350	1.350	1.350

Wall stem check - back reinf.

Wall check at the construction joint 4.00 m from the wall crest
Reinforcement and dimensions of the cross-section
5 prof. 20.0 mm, cover 30.0 mm
Inputted reinforcement area   = 1570.8 mm²
Required reinforcement area = 1519.9 mm²
Cross-section width   =   1.00 m
Cross-section height   =   0.80 m

Reinforcement ratio ρ =   0.21 %   >   0.20 %   = ρ_{min}
Position of neutral axis x/β_1 =   0.04 m   <   0.49 m   = $\xi_b h_0/\beta_1$
Ultimate shear force V_u = 835.93 kN   > 67.86 kN   = V
Ultimate moment M_u = 420.17 kNm > 87.24 kNm = M

Cross-section is SATISFACTORY.

Analysis of reinforced slopes

Input data

Project

Task   : □ □ □
Part   : □ □ □
Author : □ □ □
Date   : 2014/8/28

Settings

China - National standards (GB)

Materials and standards

Concrete structures : GB 50010-2010

Wall analysis

Active earth pressure calculation :   Coulomb
Passive earth pressure calculation :   Mazindrani (Rankine)
Earthquake analysis :   GB 50330 - 2013
Shape of earth wedge :   Calculate as skew
Allowable eccentricity :   0.250
Internal stability :   JTG D30 - 2015 Highway China Code
Verification methodology :   according to Chinese standards
Partial factors on dimensioning of RC and Masonry : Standard

Safety factors			
Permanent design situation			
Safety factor for overturning :	SF_o =	1.60	[–]
Safety factor for sliding resistance :	SF_s =	1.30	[–]
Safety factor for sliding along geo-reinforcement :	SF_{sr} =	1.50	[–]
Safety factor for geo-reinforcement strength :	SF_{st} =	1.50	[–]
Safety factor for pull out resistance of geo-reinf. :	SF_{po} =	1.50	[–]
Safety factor for connection strength :	SF_{con} =	1.50	[–]

Stability analysis

Verification methodology : according to Chinese standards

Safety factors		
Permanent design situation		
Safety factor for circular slip surface :	SF_{circ} =	1.35 [–]

Geometry of structure

Embankment height h_n = 4.60 m
Embankment length l_n = 0.50 m
Cover thickness t_c = 0.20 m

Material

Cover material
Unit weight γ = 23.00 kN/m^3
Shear resistance R_s =   0.00 kPa

Types of reinforcements

No.	Name	Type of reinforcement	Line type	Reinforcement strength		Coefficient	
				T_{ult}[kN/m]	R_t[kN/m]	C_{ds}[−]	C_i[−]
1	□ □ □ □ □ (user)	user-defined	————	500.00	60.00	0.60	0.40

Reinforcement details

1. □ □ □ □ □ (user)
Short-term char. strength T_{ult} = 500.00 kN/m
Long-term design strength R_t = 60.00 kN/m

Reinforcement

No.	Number of reinforcements	Type of nforceme	Spacing of reinforcements h_r[m]	Height of first reinforcement y[m]	Reinforcements geometry
1	3	□ □ □ □ □ (user)	0.50	1.00	identical length of reinforcements

Installation type

No.	Number of reinforcements	Type of reinforcement	Installation type	a [m]	b [m]	k_{cr} [−]	α [−]
1	3	□ □ □ □ □ (user)	continuous				

Reinforcement details

Reinforcement No. 1
Reinforcement type : □ □ □ □ □ (user)
Number of reinforcements 3
Reinforcement geometry : identical length of reinforcements
Reinforcement length : 4.00 m

No.	Origin l_1[m]	End l_2[m]	Height from bottom y[m]	Length l[m]
1	-0.39	3.61	1.00	4.00
2	-0.34	3.66	1.50	4.00
3	-0.28	3.72	2.00	4.00

Soil parameters

□ □ □ □
Unit weight : γ =   20.00 kN/m³
Angle of internal friction : φ_{ef} =   35.00 °
Cohesion of soil : c_{ef} =   0.00 kPa
Angle of friction struc.-soil : δ =   17.50 °
Saturated unit weight : γ_{sat} =   20.00 kN/m³

□ □
Unit weight : γ =   17.00 kN/m³
Angle of internal friction : φ_{ef} =   10.00 °
Cohesion of soil : c_{ef} =   5.00 kPa
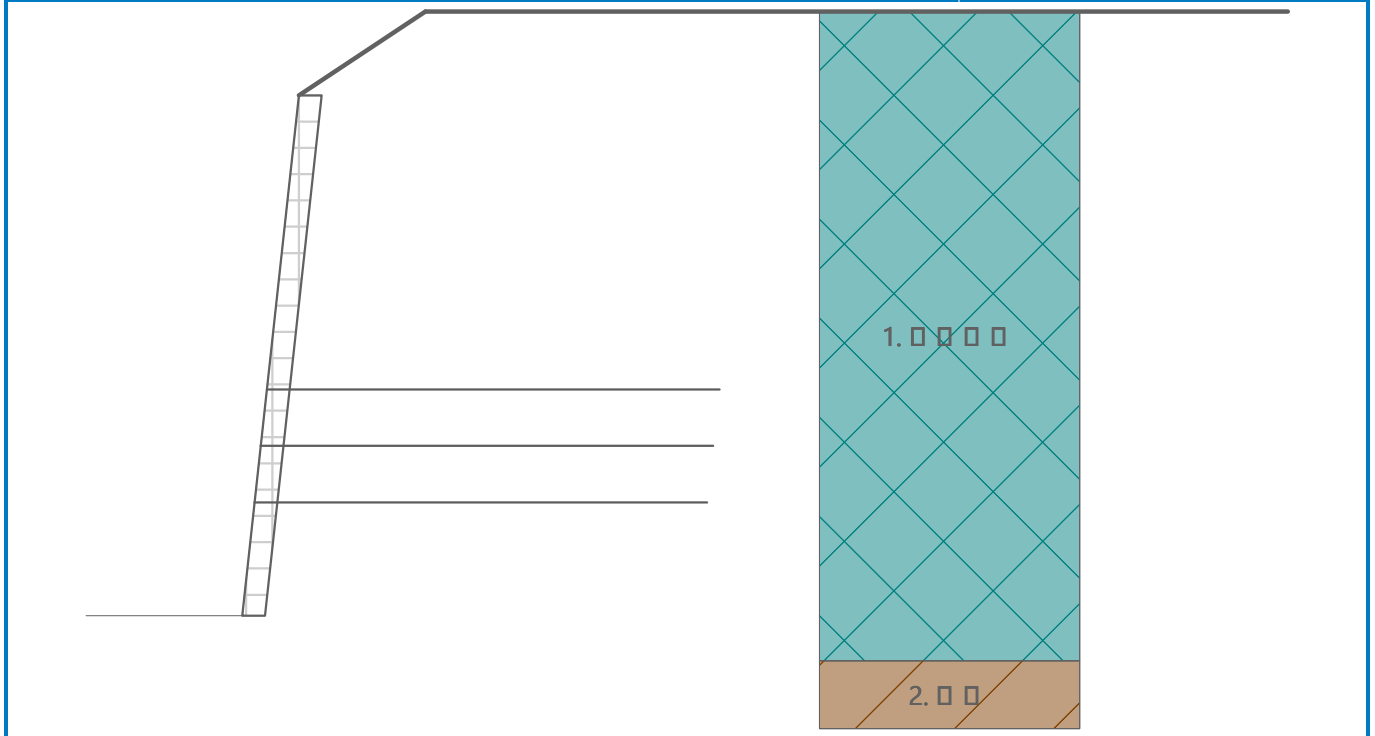Angle of friction struc.-soil : δ =   0.00 °
Saturated unit weight : γ_{sat} =   17.00 kN/m³

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	5.00	0.00 .. 5.00	□ □ □ □	
2	-	5.00 .. ∞	□ □	

Name : Profile and assignment	Stage - analysis : 1 - 0

Terrain profile

Terrain behind construction has the slope 1: 1.51 (slope angle is 33.45 °).
Embankment height is 0.74 m, embankment length is 1.12 m.

Water influence

Ground water table is not considered.

Resistance on front face of the structure

Resistance on front face of the structure is not considered.

Settings of the stage of construction

Design situation : permanent

Verification No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - reinforced soil	0.00	-2.58	407.38	2.26	1.000
Active pressure	53.97	-1.85	33.10	4.16	1.000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 1056.45 kNm/m
Overturning moment M_{ovr} = 99.80 kNm/m

Safety factor = 10.59 > 1.60
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force H_{res} = 308.43 kN/m
Active horizontal force H_{act} = 53.97 kN/m

Safety factor = 5.71 > 1.30
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY
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 [–]
1	-75.68	440.48	53.97	0.000

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	-75.68	440.48	53.97

Verification of slip on georeinforcement No. 1
Forces acting on construction (verification of most utilized reinforcement)

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Active pressure	38.51	-1.45	26.97	4.00	1.000
Weight - reinforced soil	0.00	-2.08	318.95	2.15	1.000
Reinforcement	-2.34	-0.50	0.00	4.00	1.000
Reinforcement	-4.07	-1.00	0.00	4.00	1.000

Check for slip along geo-reinforcement with the maximal utilization (Reinforc. No.: 1)

Inclination of slip surface = 90.00 °
Overall normal force acting on reinforcement = 345.92 kN/m
Coefficient of reduction of slip along geo-textile = 0.60
Resistance along geo-reinforcement = 145.33 kN/m
Wall resistance = 0.00 kN/m
Overall bearing capacity of reinforcements = 6.41 kN/m

Check for slip:
Resisting horizontal force H_{res} = 151.73 kN/m
Active horiz. force H_{act} = 38.51 kN/m

Factor of safety = 3.94 > 1.50
Slip along geotextile is SATISFACTORY
Calculation of internal stability No. 1
Calculated forces and strength of reinforcements

No.	Name	F_x [kN/m]	Depth z[m]	R_t [kN/m]	Utiliz. [%]	T_p [kN/m]	Utiliz. [%]
1	☐ ☐ ☐ ☐ ☐ (user)	-30.66	3.61	60.00	76.65	171.65	26.79
2	☐ ☐ ☐ ☐ ☐ (user)	-10.58	3.11	60.00	26.46	141.51	11.22
3	☐ ☐ ☐ ☐ ☐ (user)	-37.08	2.61	60.00	92.71	114.07	48.76

Check for tensile strength (reinforcement No.3)

Tension strength R_t = 60.00 kN/m

Force in reinforcement F_x = 37.08 kN/m

Safety factor = 1.62 > 1.50

Reinforcement for tensile strength is SATISFACTORY

Check for pull out resistance (reinforcement No.3)

Pull out resistance T_p = 114.07 kN/m

Force in reinforcement F_x = 37.08 kN/m

Safety factor = 3.08 > 1.50

Reinforcement for pull out resistance is SATISFACTORY

Overall verification - reinforcement is SATISFACTORY

Global stability analysis No. 1

Parameters of input slip surface

Center S = (-4.43;-2.00) m

Radius r = 9.29 m

Angle α_1 = -44.73 °

α_2 = 82.20 °

Analysis has not been performed.