Prosheet

C. Examples

1. Cantilever wall

1.1. Description

This example shows a cantilever wall in a multilayer soil (gravel – sand – clays). An excavation is planned on the front side of the wall over a height of 4.0 m. Top level of the sheet pile is considered at 30.0 m, so excavation level is at 26.00 m. The water table is at 22.50 m. Constant permanent load (20 kPa) must be taken into account at the top level of the back side. PU 32 section has been chosen in the design.

Prosheet may help to deduce minimum embedment required to ensure global wall equilibrium.

Calculation will be done according to Classical and Eurocode 7-1 methods.

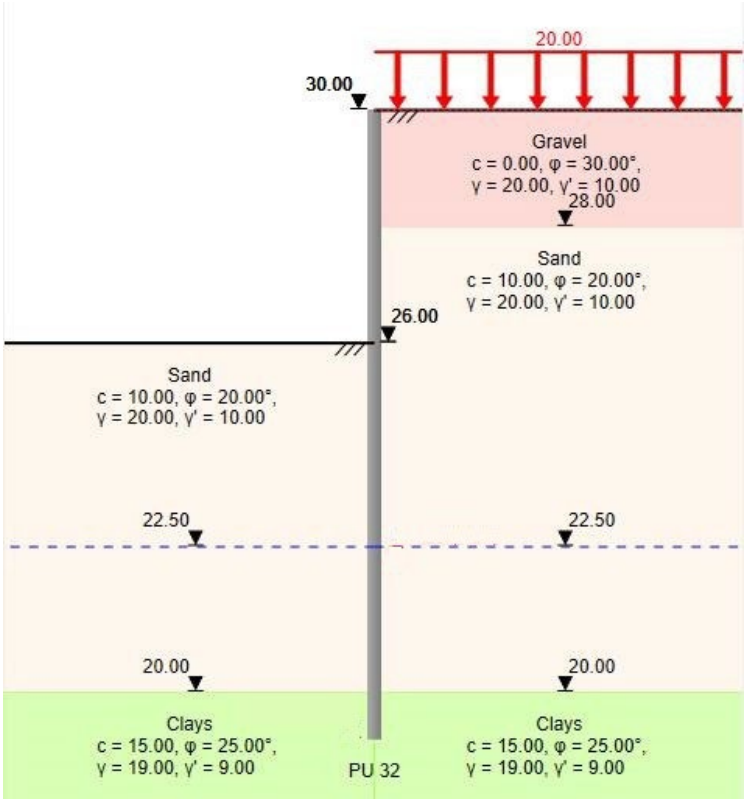

Figure 1. Cross-section

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1.2. Classical method

The classical method aims to get the wall equilibrium with no ponderation on actions but with possible global safety on passive earth pressure (S_f factor). No local standard is used in this method.

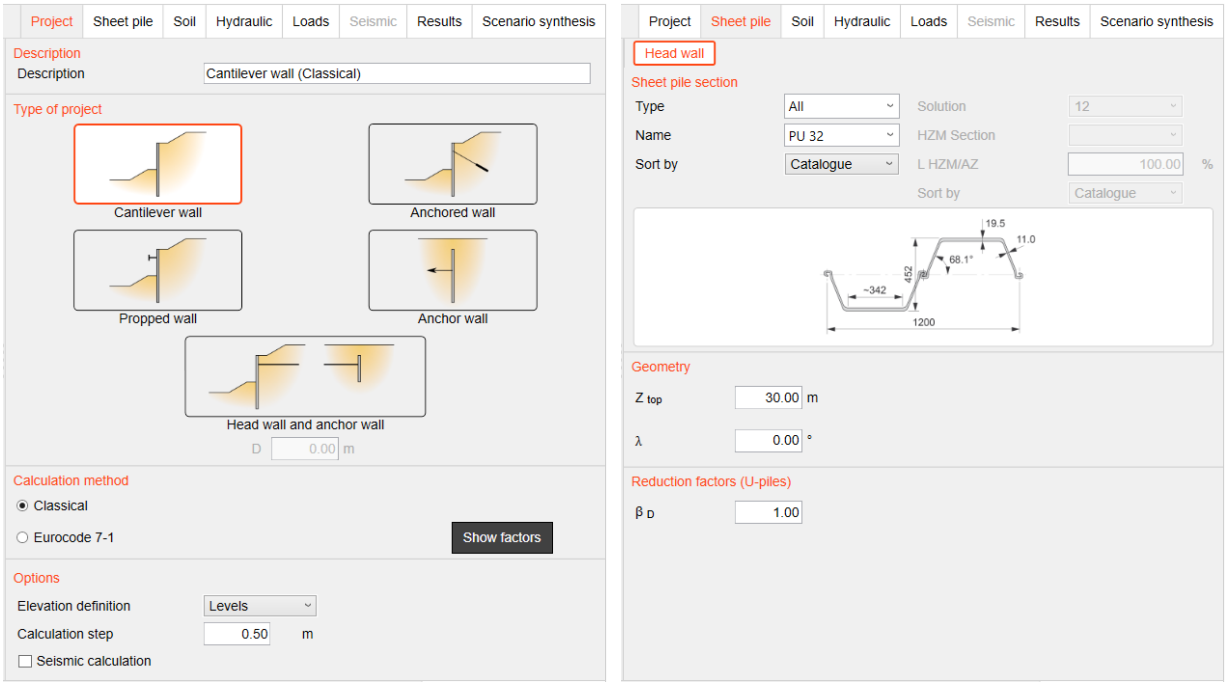

Figure 2. Project and Sheet pile tabs

First, one has to choose type of project: Cantilever wall for this project. Our calculation will be made with Classical method. We choose to define the cross-section with levels (depths option is also available). Calculation step is defined equal to 0.50 m, it means that results will be provided every 0.50 m without no impact on the bottom level of the sheet pile.

In this project, we aim for a global safety on passive earth pressure of at least 1.90. No over-length for the moment.

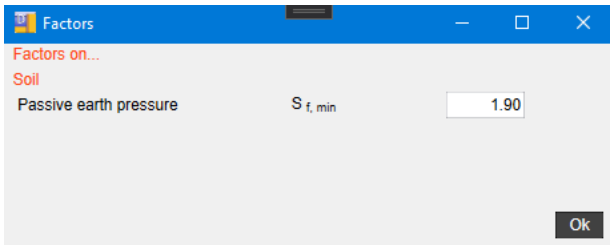

Figure 3. Global safety on passive earth pressure

Then, soil geometry and materials must be defined in both sides of the wall. Natural ground level (NGL) may be horizontal, inclined or berm. According to the cross section, we choose horizontal and define z_0 = 25.50 m for the front side. At the back, we also define a horizontal soil at z_0 = 30.0 m.

Please, input following soil parameters. Active and passive earth pressures coefficients may be calculated automatically by Prosheet according to Kérisel-Absi tables. They may be also defined by the user with “Custom” mode.

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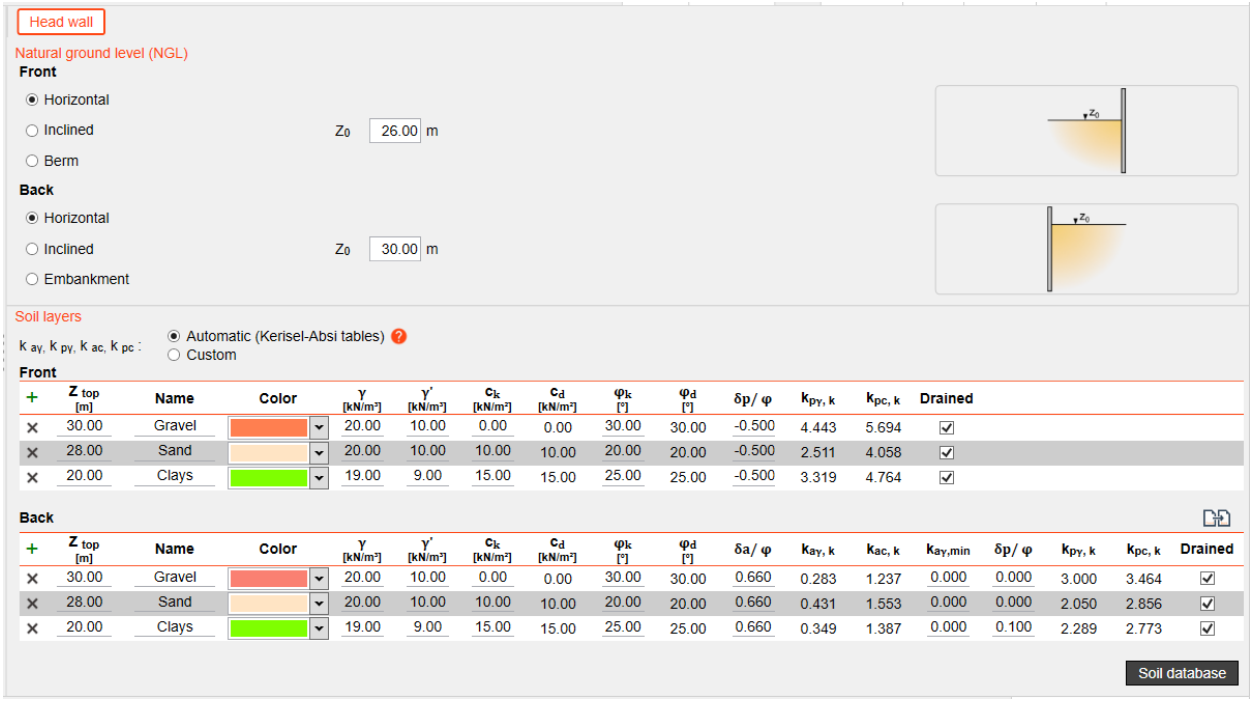

Figure 4. Soil tab

After that, one must define hydraulic conditions. Two possibilities exist: phreatic level and custom pore pressure diagram. In this project, we define the same condition and the same level for both sides: phreatic level at z_w=22.60m.

Several loads may be defined in the same project: Caquot and Boussinesq loads applied on the soil, linear and distributed loads and wave load applied on the wall.

Uniform permanent load will be modelled as Caquot load: 20 kPa at z = 30.0m.

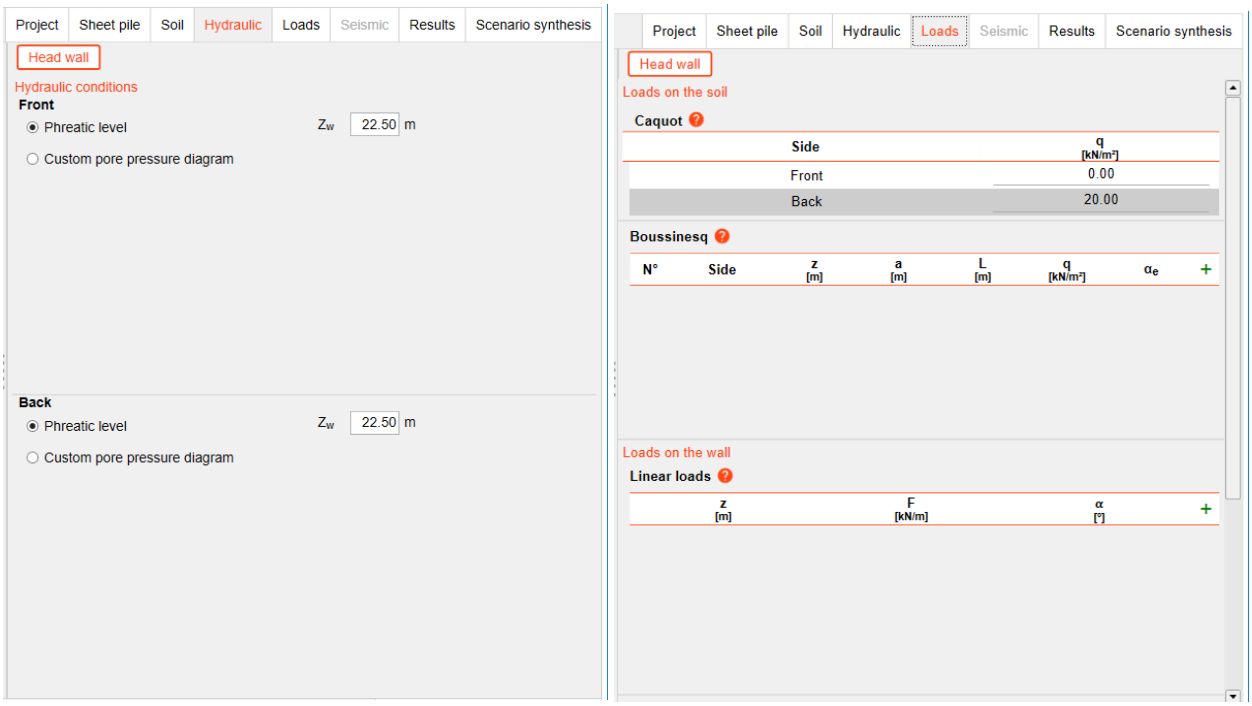

Figure 5. Hydraulic tab (left) and Loads tab (right)

Prosheet launch calculation automatically every time new input data is available.

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In Results tab we can find following information:

- Graphs : displacement, bending moment, shear, earth and water pressures diagrams.
- Tables: numerical values of every diagram.
- Details: intermediate and final results and some checks.

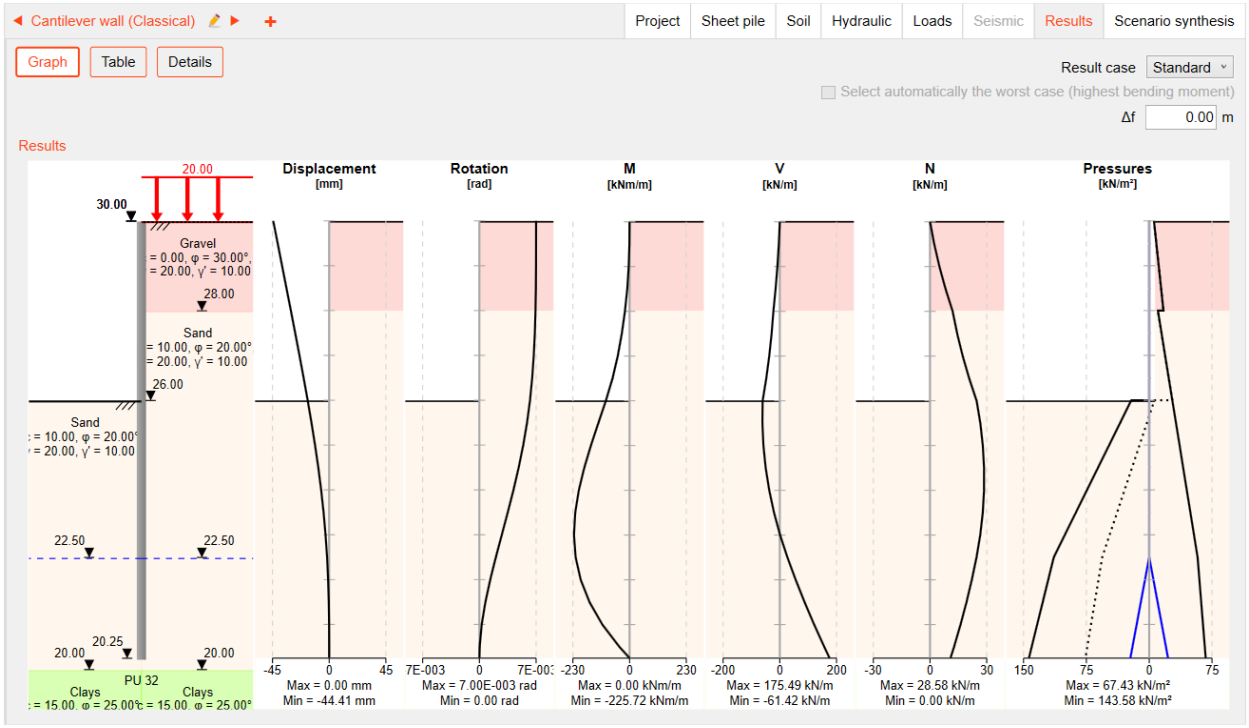
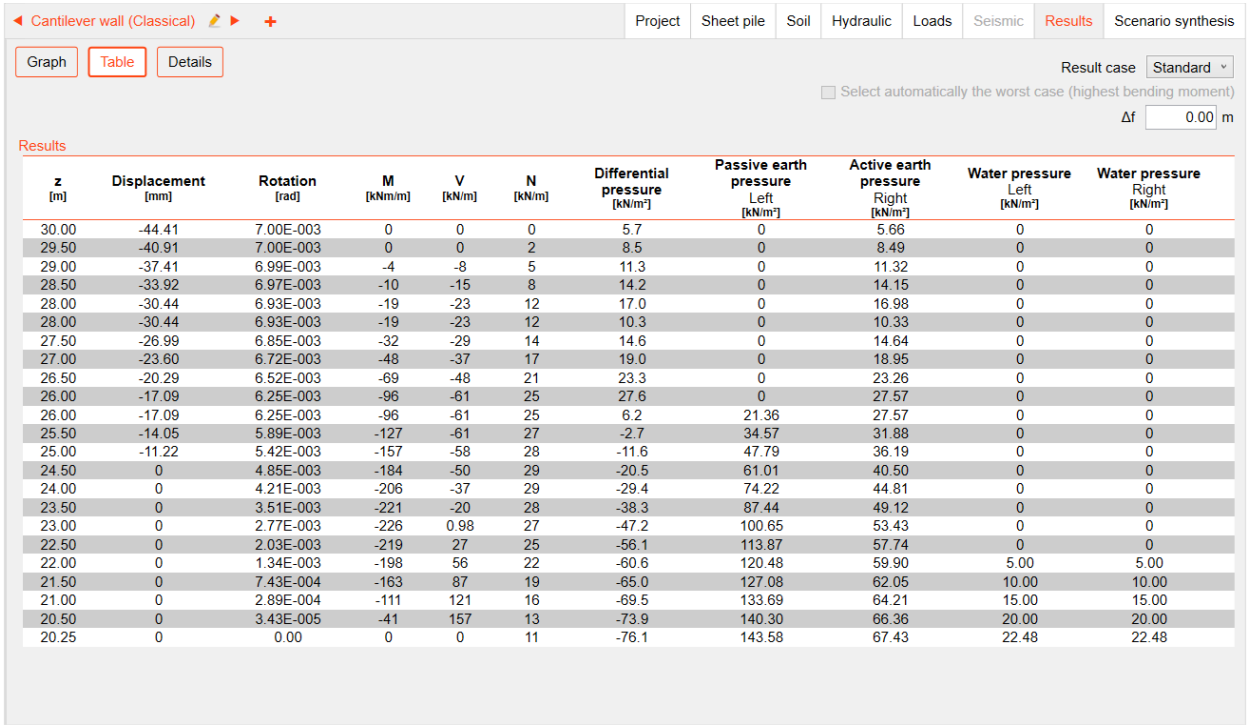


Figure 6. Results tab (graph)



z [m]	Displacement [mm]	Rotation [rad]	M [kNm/m]	V [kN/m]	N [kN/m]	Differential pressure [kN/m²]	Passive earth pressure Left [kN/m²]	Active earth pressure Right [kN/m²]	Water pressure Left [kN/m²]	Water pressure Right [kN/m²]
30.00	-44.41	7.00E-003	0	0	0	5.7	0	5.66	0	0
29.50	-40.91	7.00E-003	0	0	2	8.5	0	8.49	0	0
29.00	-37.41	6.99E-003	-4	-8	5	11.3	0	11.32	0	0
28.50	-33.92	6.97E-003	-10	-15	8	14.2	0	14.15	0	0
28.00	-30.44	6.93E-003	-19	-23	12	17.0	0	16.98	0	0
28.00	-30.44	6.93E-003	-19	-23	12	10.3	0	10.33	0	0
27.50	-26.99	6.85E-003	-32	-29	14	14.6	0	14.64	0	0
27.00	-23.60	6.72E-003	-48	-37	17	19.0	0	18.95	0	0
26.50	-20.29	6.52E-003	-69	-48	21	23.3	0	23.26	0	0
26.00	-17.09	6.25E-003	-96	-61	25	27.6	0	27.57	0	0
26.00	-17.09	6.25E-003	-96	-61	25	6.2	21.36	27.57	0	0
25.50	-14.05	5.89E-003	-127	-61	27	-2.7	34.57	31.88	0	0
25.00	-11.22	5.42E-003	-157	-58	28	-11.6	47.79	36.19	0	0
24.50	0	4.85E-003	-184	-50	29	-20.5	61.01	40.50	0	0
24.00	0	4.21E-003	-206	-37	29	-29.4	74.22	44.81	0	0
23.50	0	3.51E-003	-221	-20	28	-38.3	87.44	49.12	0	0
23.00	0	2.77E-003	-226	0.98	27	-47.2	100.65	53.43	0	0
22.50	0	2.03E-003	-219	27	25	-56.1	113.87	57.74	0	0
22.00	0	1.34E-003	-198	56	22	-60.6	120.48	59.90	5.00	5.00
21.50	0	7.43E-004	-163	87	19	-65.0	127.08	62.05	10.00	10.00
21.00	0	2.89E-004	-111	121	16	-69.5	133.69	64.21	15.00	15.00
20.50	0	3.43E-005	-41	157	13	-73.9	140.30	66.36	20.00	20.00
20.25	0	0.00	0	0	11	-76.1	143.58	67.43	22.48	22.48

Figure 7. Results tab (table)

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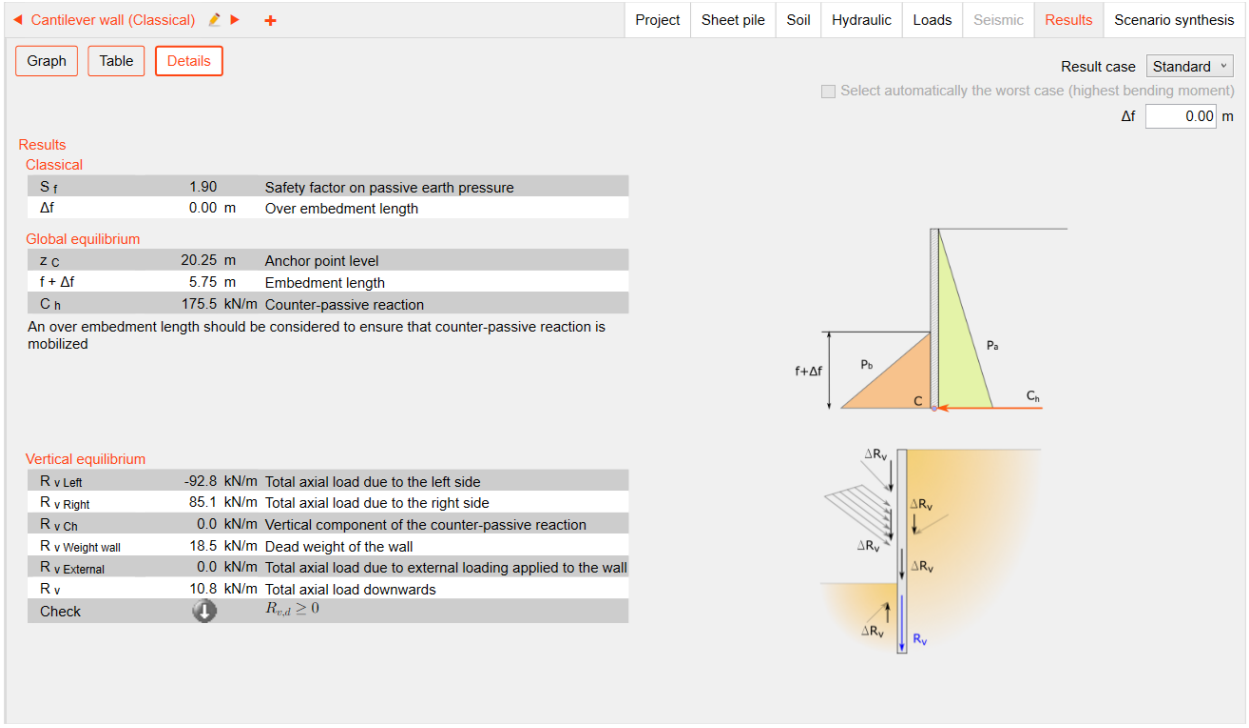

Figure 8. Results tab (details)

Required embedment to ensure global wall equilibrium with global safety on passive earth pressure equal to 1.90 is 5.75 m, that is bottom level at 20.25 m. Required counter-passive earth reaction is 175.5 kN/m to ensure global equilibrium. An overlength should be considered to ensure that counter-passive reaction is mobilized.

Finally, vertical resultant force is downwards (positive value) so vertical equilibrium is coherent. Bearing capacity has to be checked with 10.8 kN/m at the bottom level of the sheet pile wall.

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1.3. Eurocode method

Prosheet allows to switch quickly from one calculation method to another one. Please, choose Eurocode method in the Project tab and take a look to the partial factors set for Approach 2*

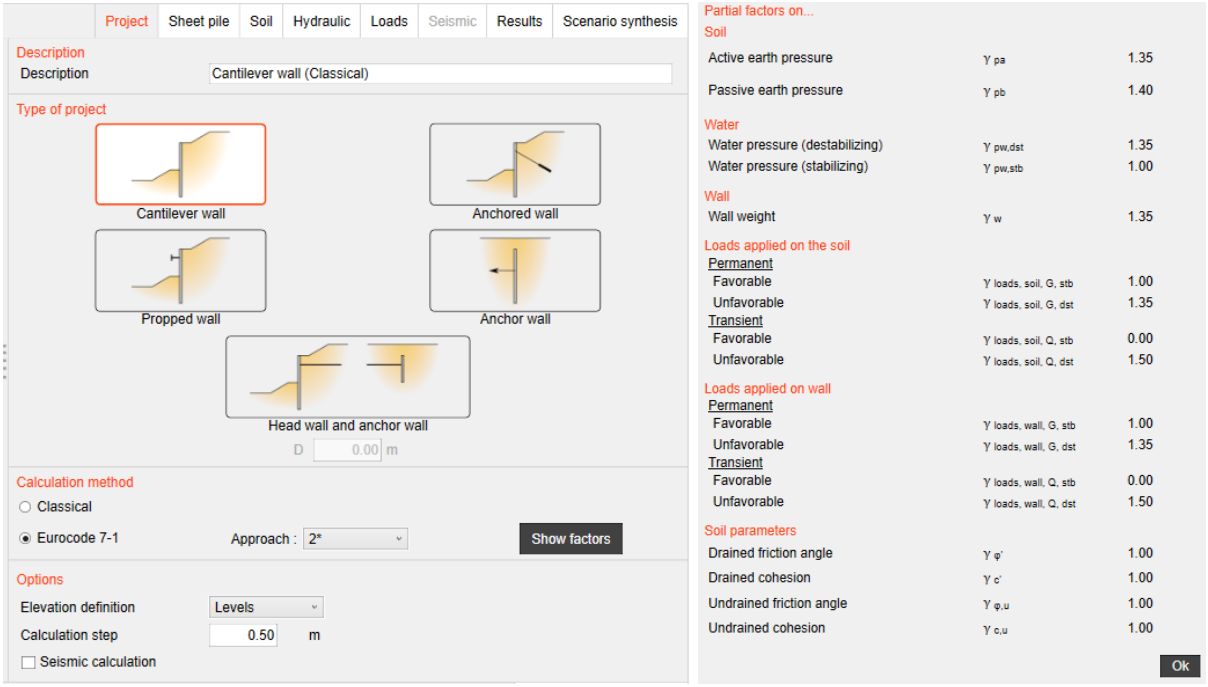

Figure 9. Sheet pile tab and partial factors for Approach 2*

Results are immediately available in Results tab in ULS and SLS.

Figure 10. Results tab (ULS results graphs)

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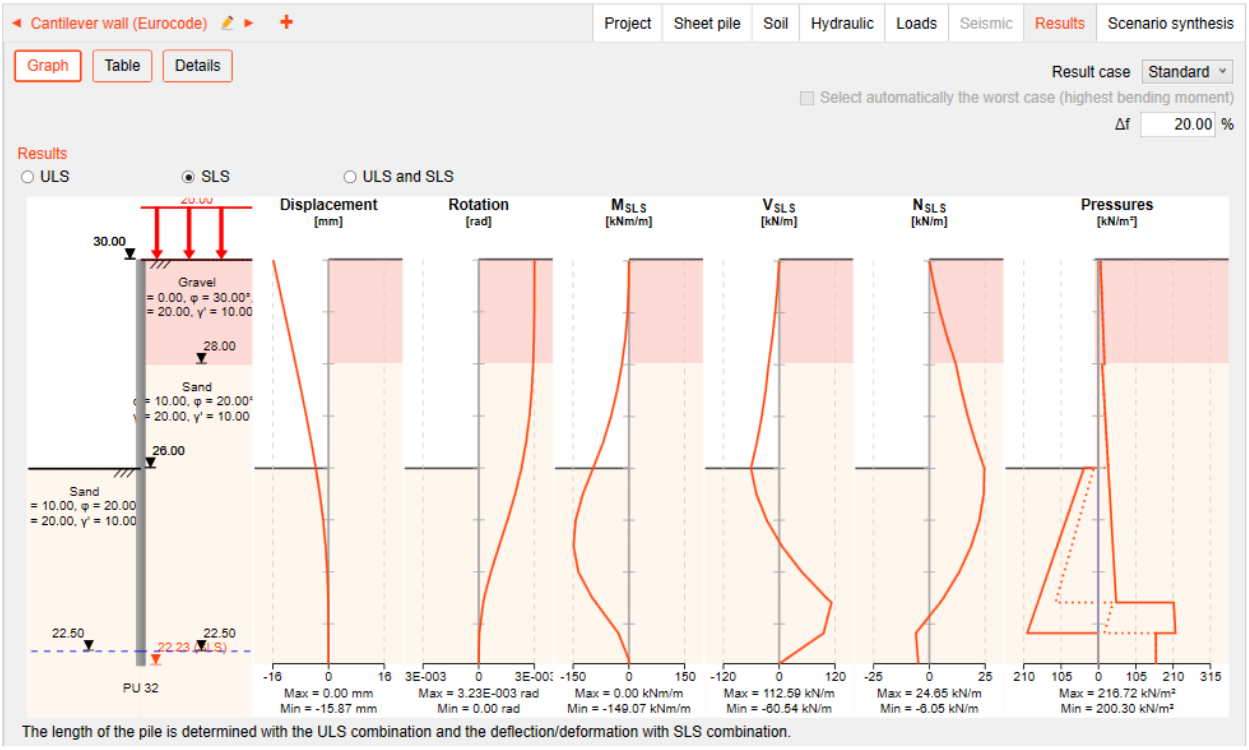

Figure 11. Results tab (SLS results graph)

According to Eurocode 7-1, embedment is calculated from ULS calculation considering partial factors, active and passive earth pressure. Eurocode 7-1 (NF P94-282) requires to check embedment length and counter-passive reaction). An overlength of Δf = 20% of the embedment length has been considered to ensure the mobilization of the counter-passive earth pressure

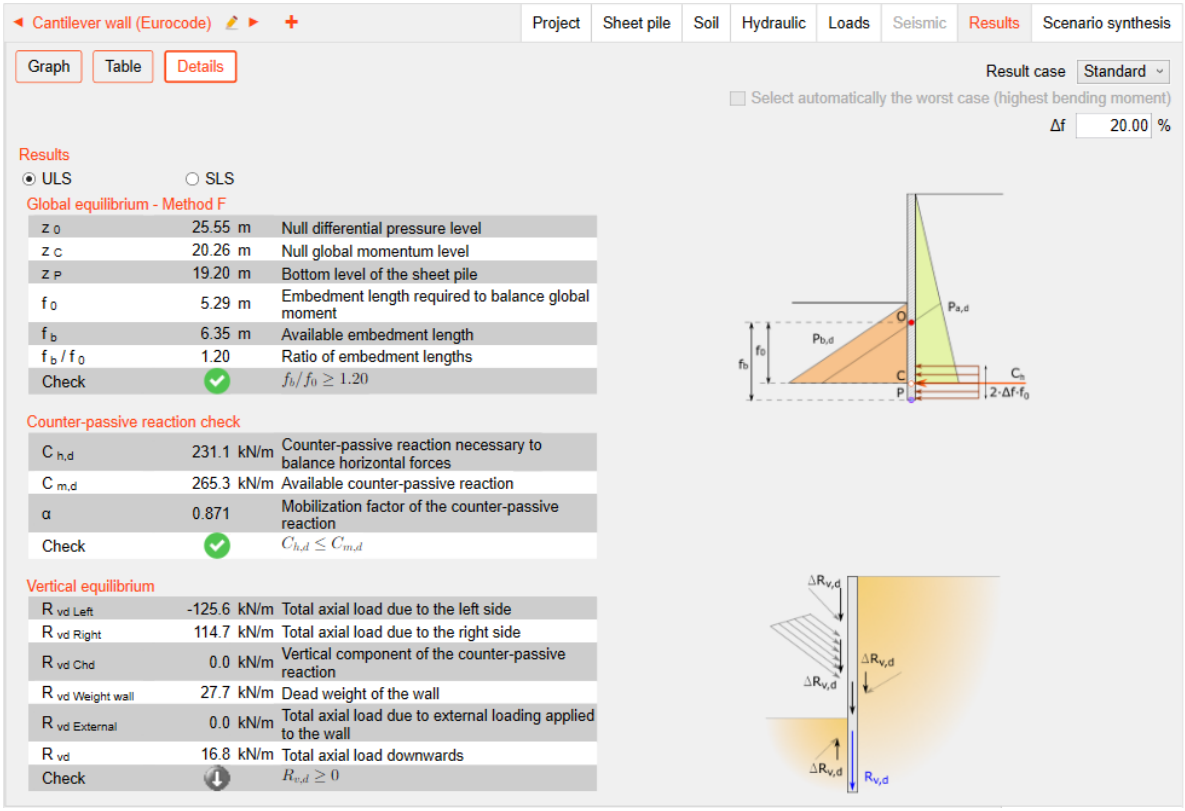

Figure 12. Results tab (ULS Details)

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2. Anchored wall

2.1. Description

This example shows an anchored wall in a multilayer soil. An excavation is planned on the front side of the wall over a height of 12.0 m. Top level of the sheet pile is considered at 30.0 m, so excavation level is at 18.0 m. The water table is assumed to be very deep in relation to the project. Uniform permanent load (20 kPa) must be considered at the top level of the back side. AZ 32-750 section has been chosen in the design.

Anchors level is at 25.0 m, inclined of 30° with 10.0 m of free length and 7.0 m of embedment length.

Calculation will be done according to Classical method considering a fixed earth support. In this case, Prosheet ensures global equilibrium horizontal forces as well as global momentum equilibrium using Blum assumption, which consists of to assume that null differential pressure level matches with null bending moment level.

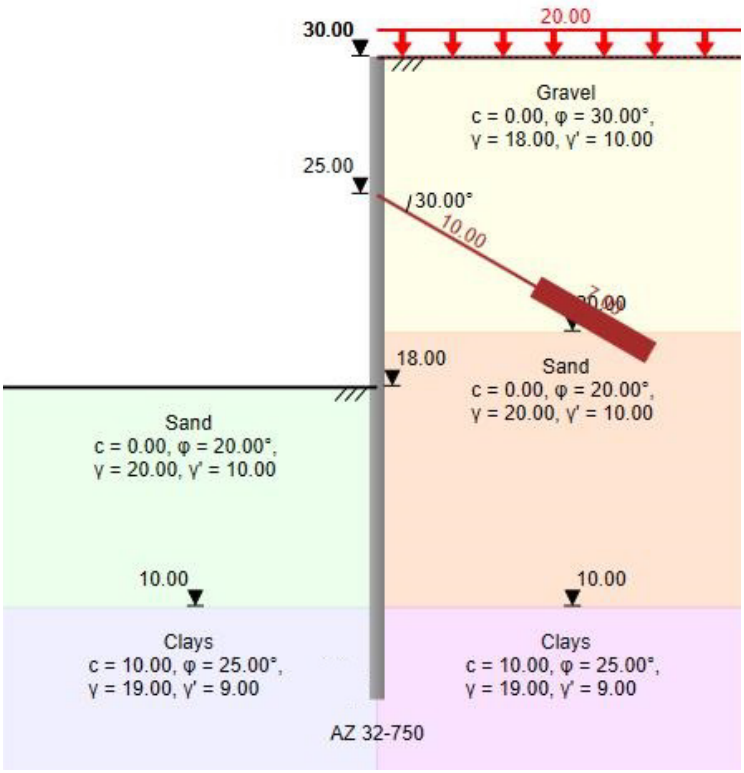

Figure 13. Cross-section

2.2. Classical method

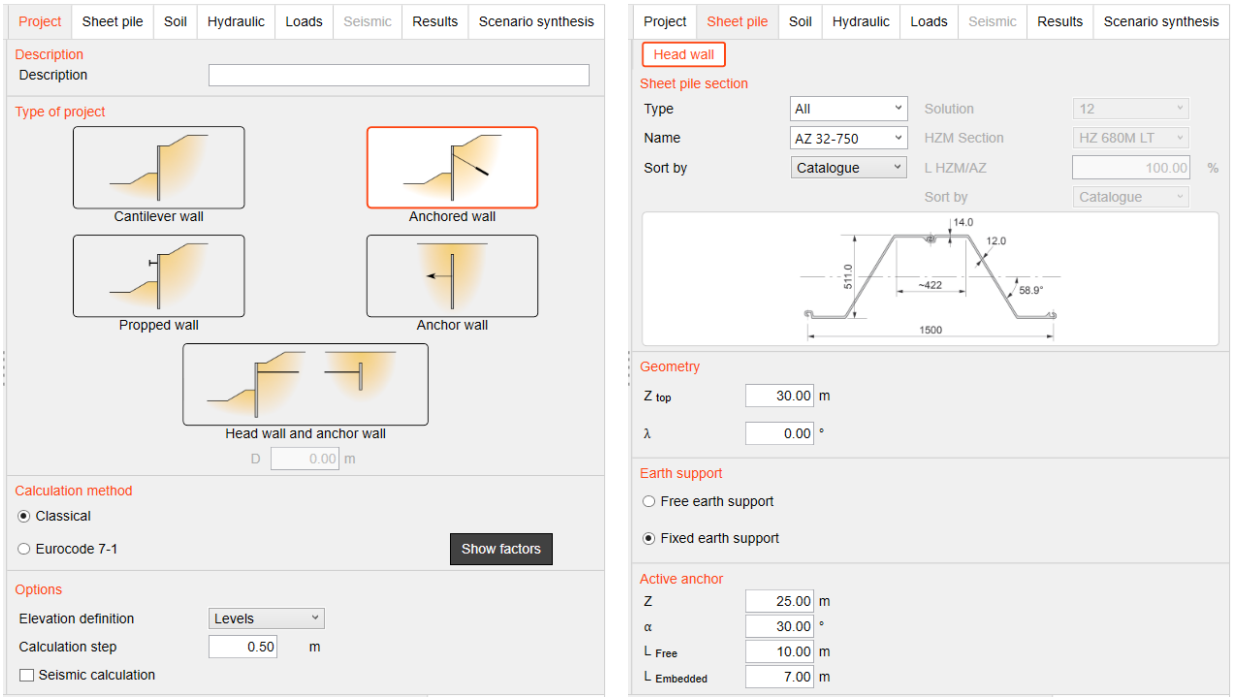

Figure 14. Project tab (left) and sheet pile tab (right)

In this project, we aim for a global safety on passive earth pressure of at least 1.50.

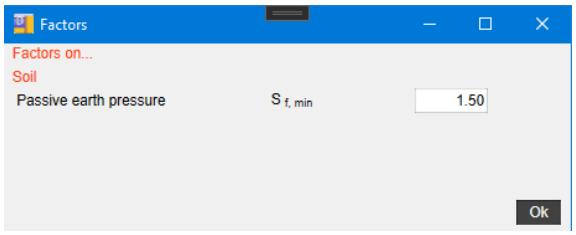

Figure 15. Project tab and global safety factor on passive earth pressure

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Soil definition is given on the following figure:

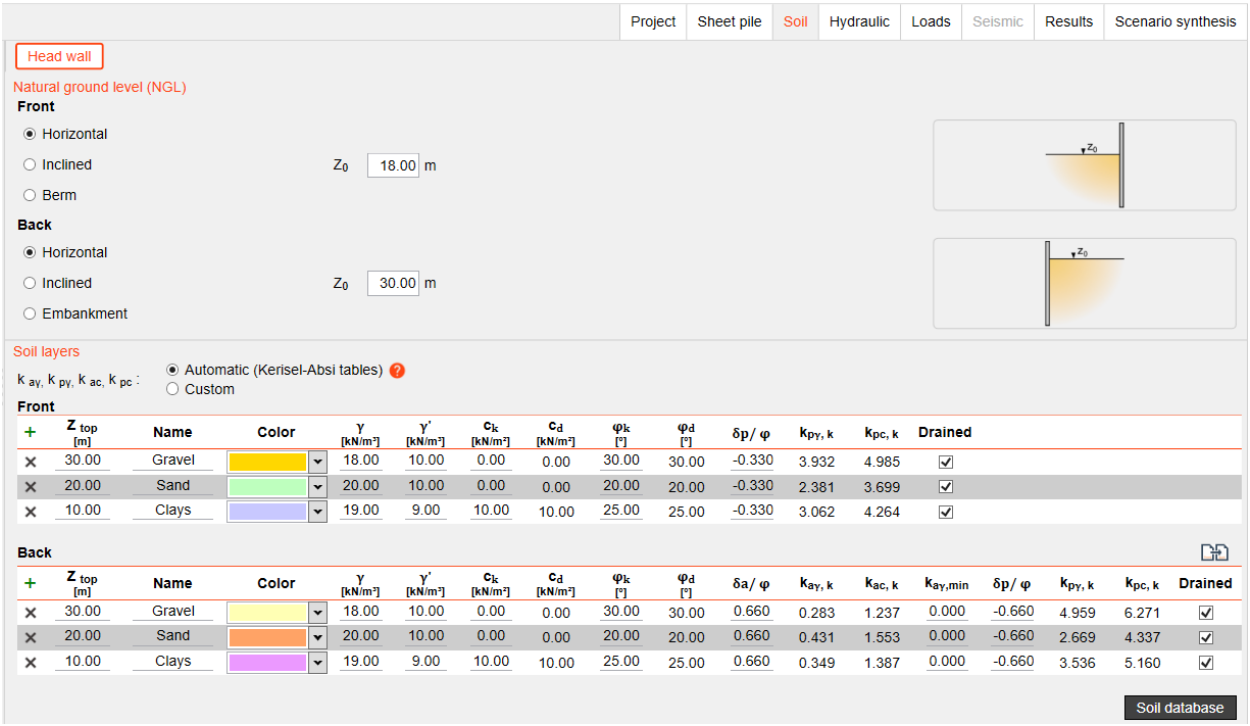


Figure 16. Soil tab

Loads definition is given in the following figure:

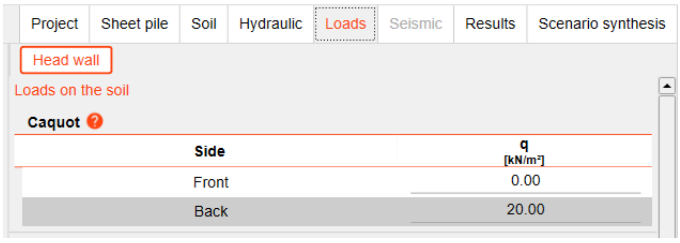


Figure 17. Loads tab

Results tab provides all results we need, in particular:

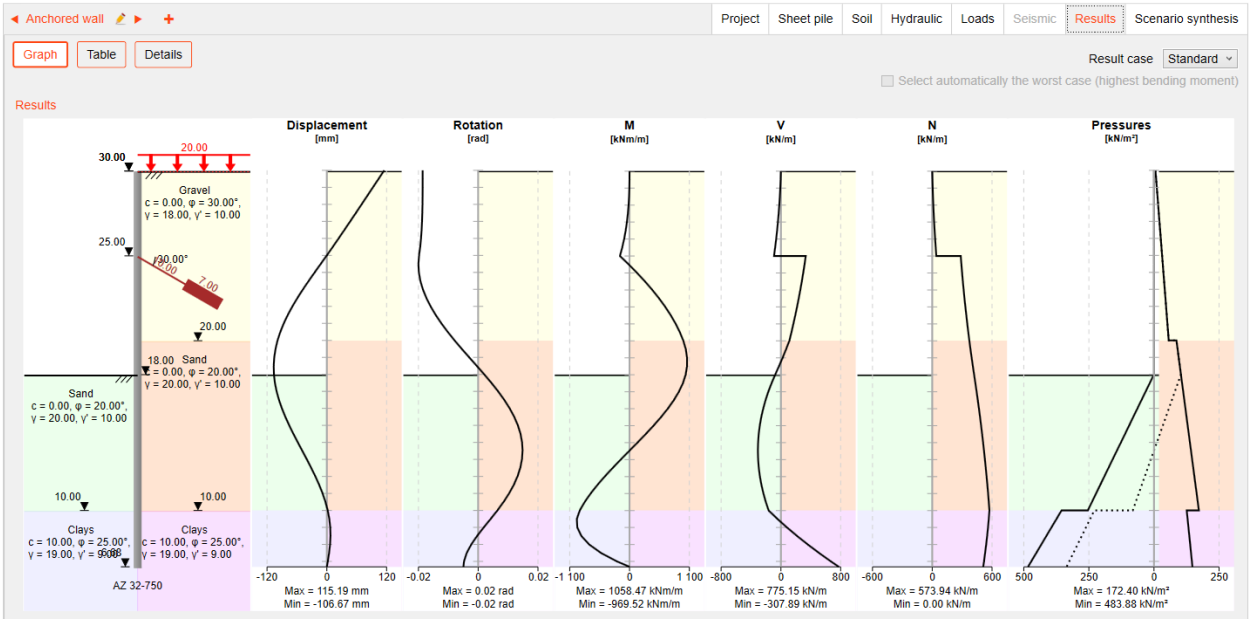
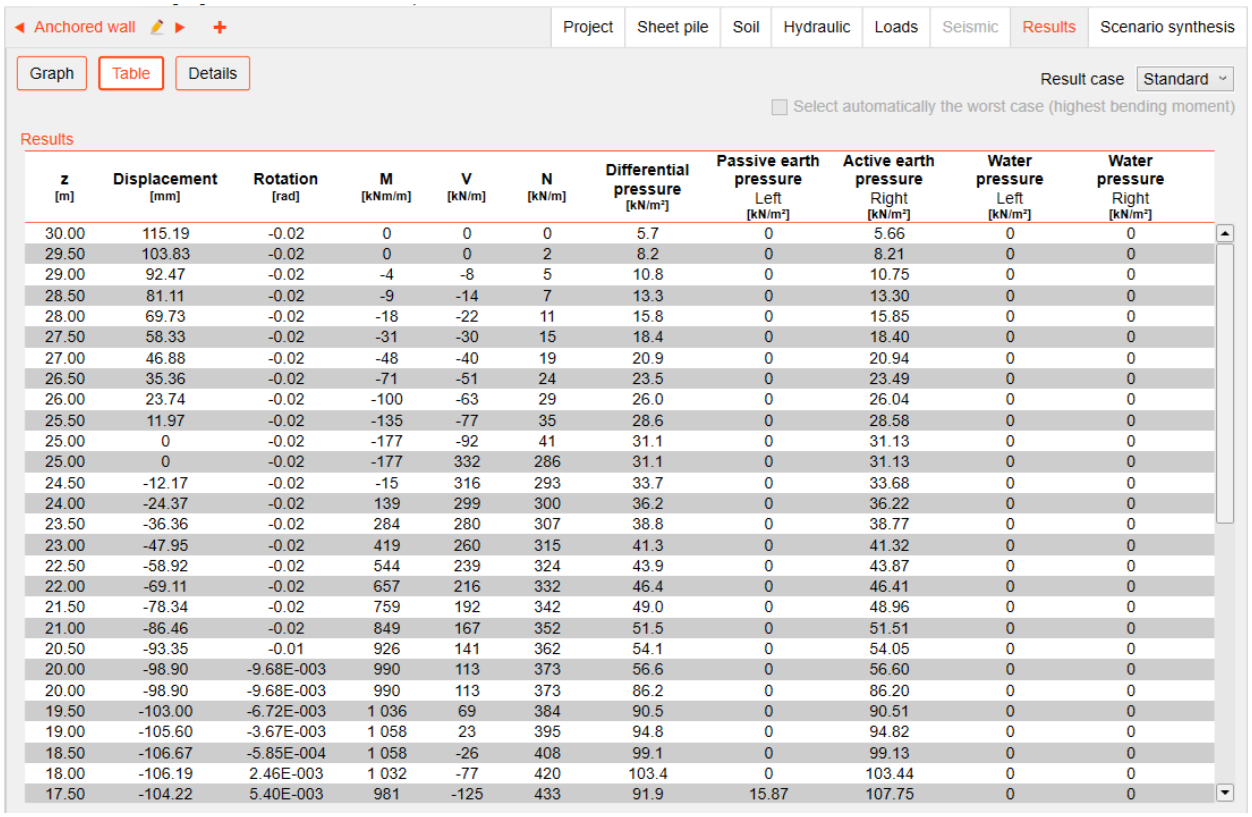


Figure 18. Results tab (graph)



z [m]	Displacement [mm]	Rotation [rad]	M [kNm/m]	V [kN/m]	N [kN/m]	Differential pressure [kN/m²]	Passive earth pressure Left [kN/m²]	Active earth pressure Right [kN/m²]	Water pressure Left [kN/m²]	Water pressure Right [kN/m²]
30.00	115.19	-0.02	0	0	0	5.7	0	5.66	0	0
29.50	103.83	-0.02	0	0	2	8.2	0	8.21	0	0
29.00	92.47	-0.02	-4	-8	5	10.8	0	10.75	0	0
28.50	81.11	-0.02	-9	-14	7	13.3	0	13.30	0	0
28.00	69.73	-0.02	-18	-22	11	15.8	0	15.85	0	0
27.50	58.33	-0.02	-31	-30	15	18.4	0	18.40	0	0
27.00	46.88	-0.02	-48	-40	19	20.9	0	20.94	0	0
26.50	35.36	-0.02	-71	-51	24	23.5	0	23.49	0	0
26.00	23.74	-0.02	-100	-63	29	26.0	0	26.04	0	0
25.50	11.97	-0.02	-135	-77	35	28.6	0	28.58	0	0
25.00	0	-0.02	-177	-92	41	31.1	0	31.13	0	0
25.00	0	-0.02	-177	332	286	31.1	0	31.13	0	0
24.50	-12.17	-0.02	-15	316	293	33.7	0	33.68	0	0
24.00	-24.37	-0.02	139	299	300	36.2	0	36.22	0	0
23.50	-36.36	-0.02	284	280	307	38.8	0	38.77	0	0
23.00	-47.95	-0.02	419	260	315	41.3	0	41.32	0	0
22.50	-58.92	-0.02	544	239	324	43.9	0	43.87	0	0
22.00	-69.11	-0.02	657	216	332	46.4	0	46.41	0	0
21.50	-78.34	-0.02	759	192	342	49.0	0	48.96	0	0
21.00	-86.46	-0.02	849	167	352	51.5	0	51.51	0	0
20.50	-93.35	-0.01	926	141	362	54.1	0	54.05	0	0
20.00	-98.90	-9.68E-003	990	113	373	56.6	0	56.60	0	0
20.00	-98.90	-9.68E-003	990	113	373	86.2	0	86.20	0	0
19.50	-103.00	-6.72E-003	1 036	69	384	90.5	0	90.51	0	0
19.00	-105.60	-3.67E-003	1 058	23	395	94.8	0	94.82	0	0
18.50	-106.67	-5.85E-004	1 058	-26	408	99.1	0	99.13	0	0
18.00	-106.19	2.46E-003	1 032	-77	420	103.4	0	103.44	0	0
17.50	-104.22	5.40E-003	981	-125	433	91.9	15.87	107.75	0	0

Figure 19. Results tab (table)

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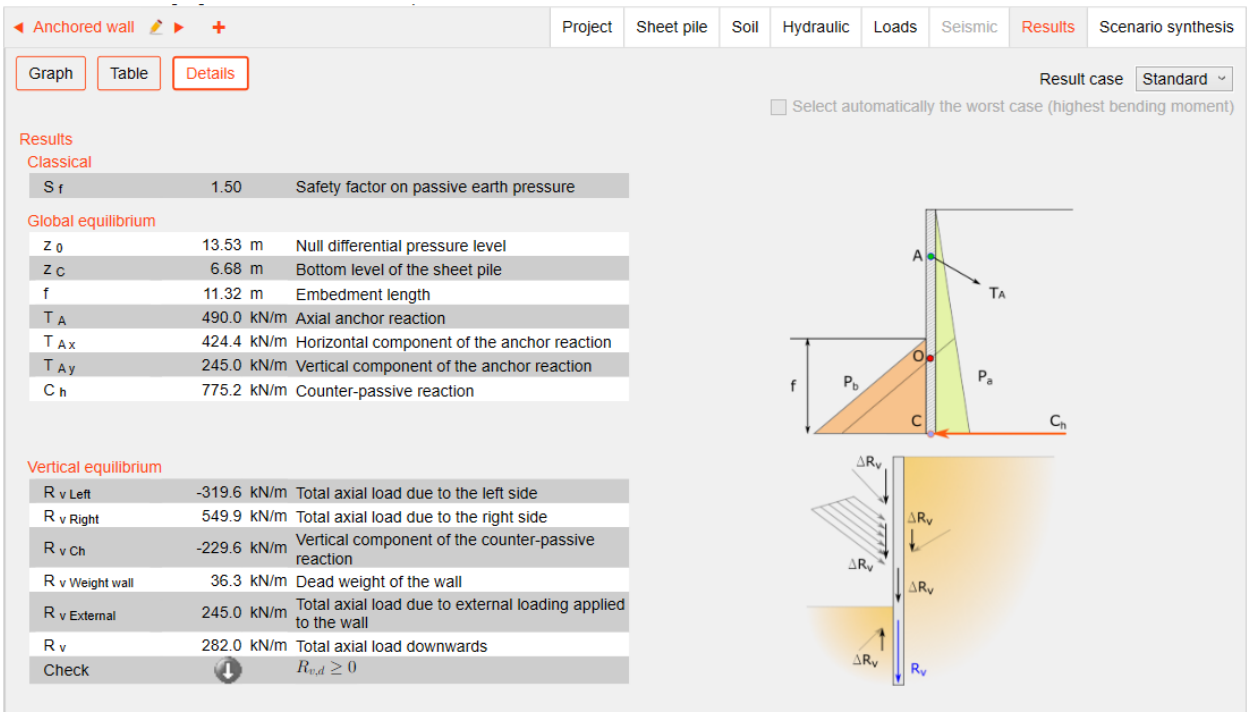

Figure 20. Results tab (details)

Null differential pressure level and null bending level is z=13.53m (Blum's assumption).

Required embedment to ensure global wall equilibrium with global safety on passive earth pressure equal to 1.50 is 11.32 m, that is bottom level at z = 6.68 m. Required counter-passive earth reaction is 775.2 kN/m to ensure global equilibrium. An overlength should be considered to ensure that counter-passive reaction is mobilized.

Finally, vertical resultant force is downwards (positive value) so vertical equilibrium is coherent. Bearing capacity has to be checked with 282.0 kN/m at the bottom level of the sheet pile wall.

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3. Head wall and anchor wall system

3.1. Description

This example shows a head wall and anchor wall system in a multilayer soil. An excavation is planned on the front side of the wall over a height of 16.0 m. Top level of the sheet pile is considered at 30.0 m, so excavation level is at 14.0 m. The water table is assumed to be very deep in relation to the project. Uniform permanent load (20 kPa) must be taken into account only at the top level of the head wall back side. AZ 52-700 section has been chosen in the design for the head wall and AZ 32-750 for the anchor wall, separated by 21 m. The tie rods are inclined between levels 26.0 m (at the head wall) and 25.0 m (at the anchor wall).

Calculation will be done according to Eurocode method (approach 2*) considering a free earth support for the head wall as well as anchor wall.

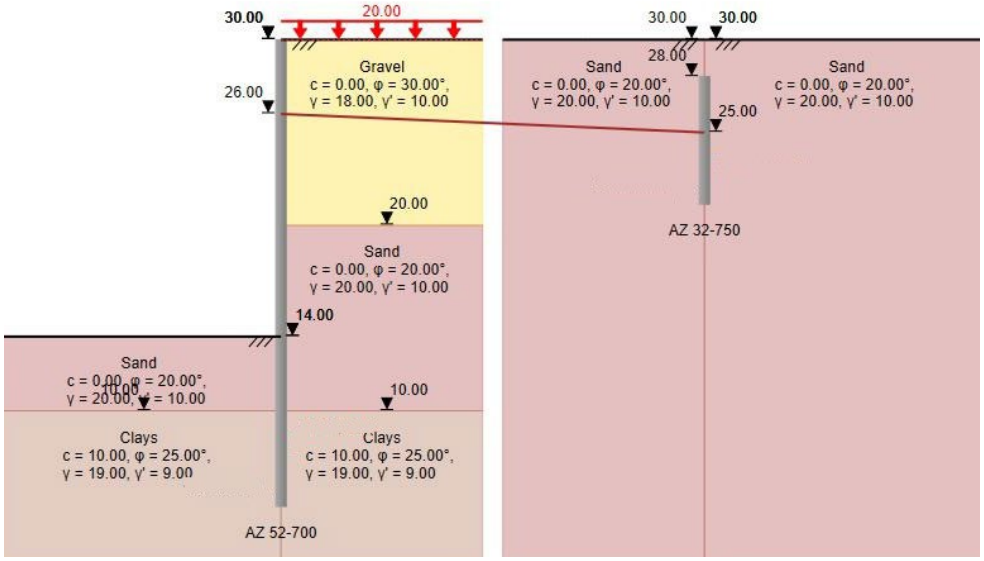

Figure 21. Cross section

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3.2. Eurocode method

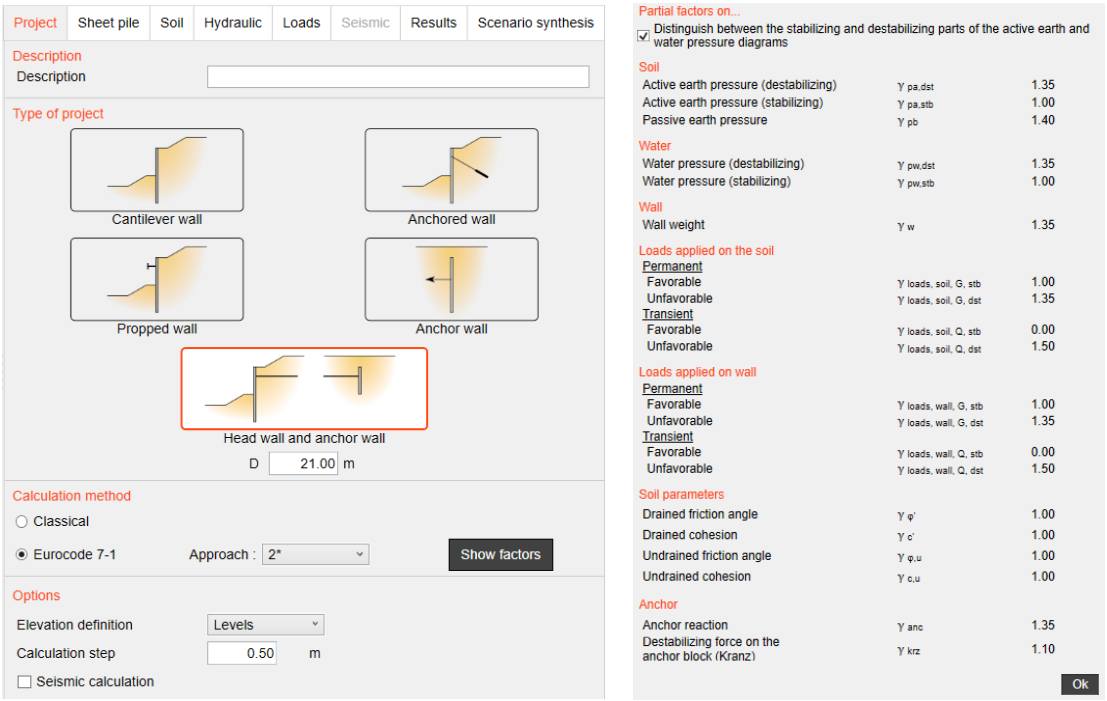

Figure 22. Project tab and partial safety factors

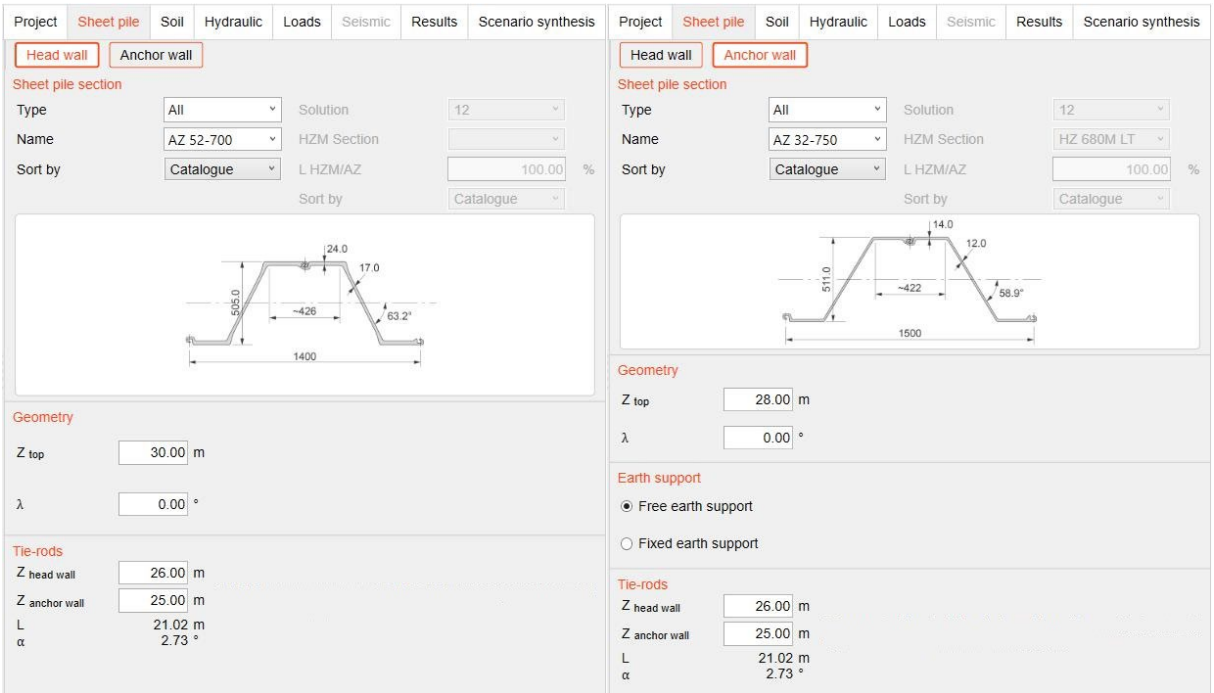

Figure 23. Sheet pile tab (head wall on the left and anchor wall on the right)

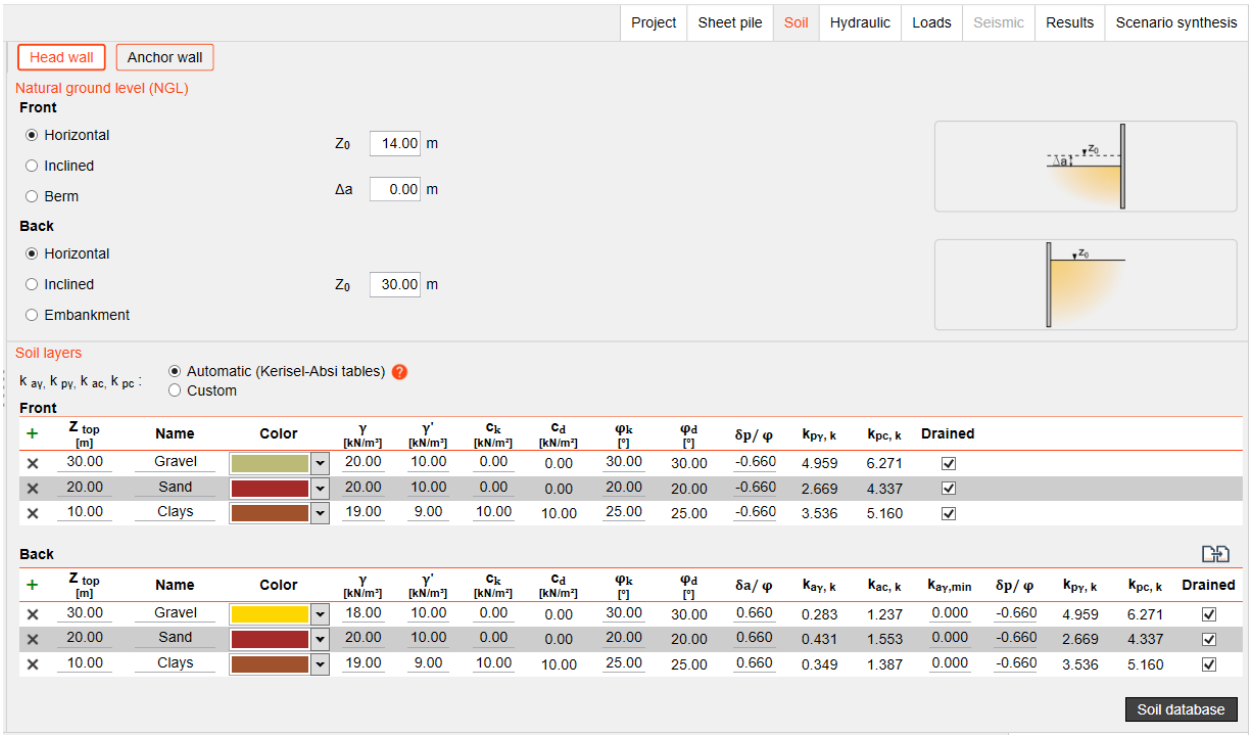

Figure 24. Soil tab (head wall)

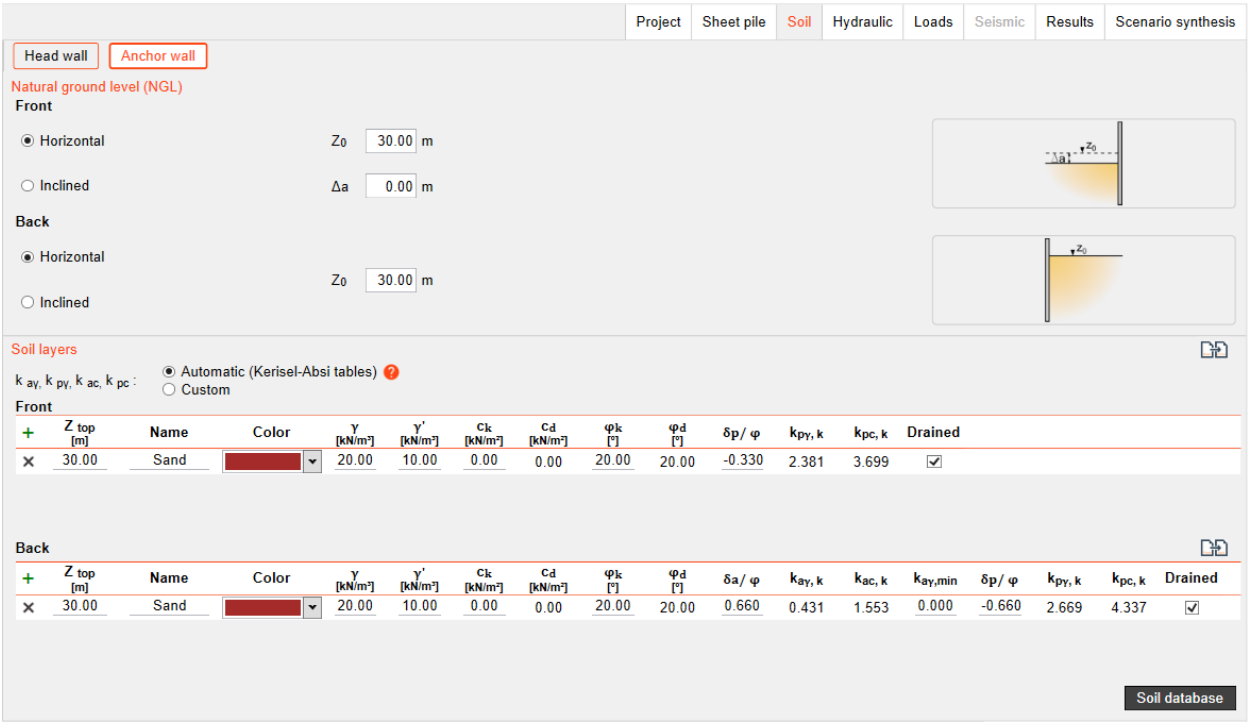

Figure 25. Soil tab (anchor wall)

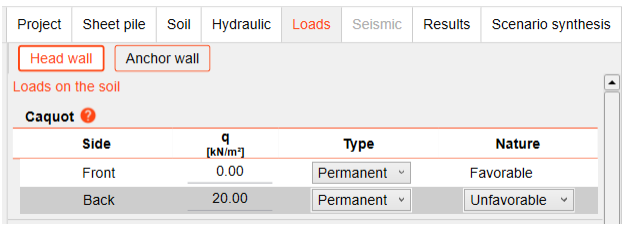

Figure 26. Loads tab

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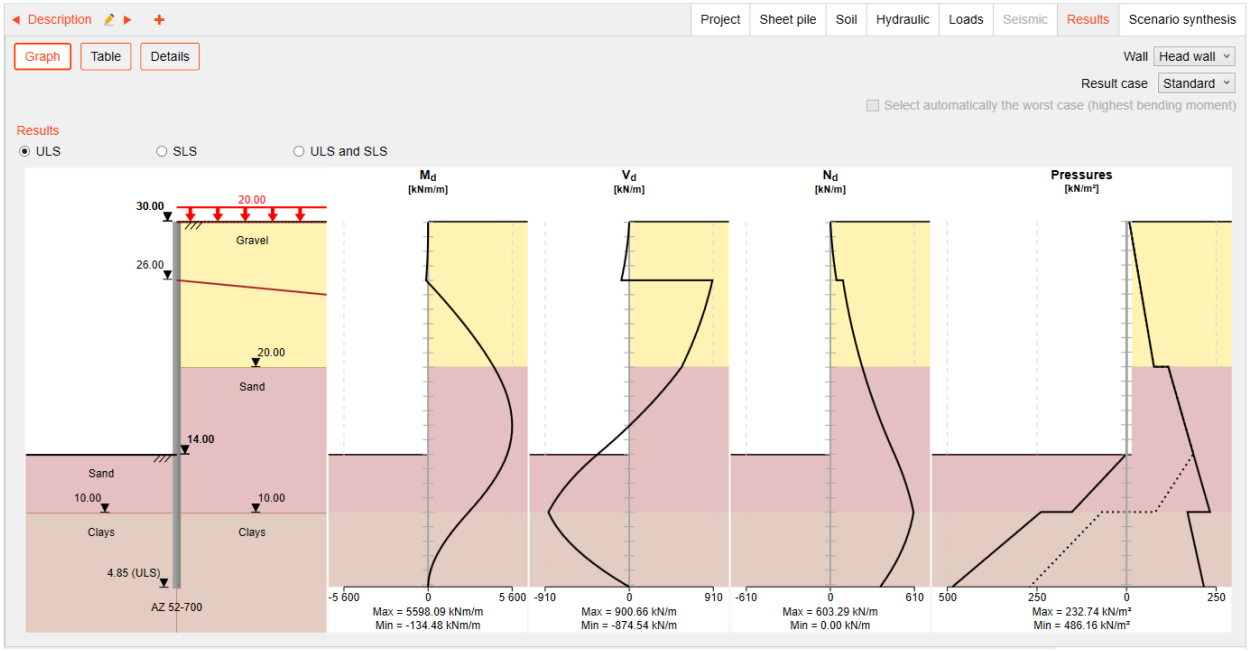

Figure 27. ULS results (graphs for head wall)

Figure 28. ULS results (graphs for anchor wall)

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◄ Description ► + | Project | Sheet pile | Soil | Hydraulic | Loads | Seismic | Results | Scenario synthesis

Graph | Table | Details

Wall: Head wall

Result case: Standard

Select automatically the worst case (highest bending moment)

Results

ULS | SLS

Global equilibrium

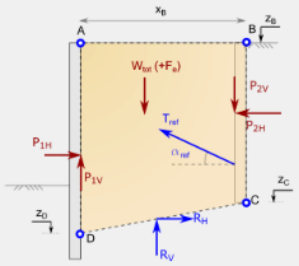
z_P	4.85	m	Bottom level of the sheet pile
f	9.15	m	Embedment length
T_A	987.4	kN/m	Axial anchor reaction
T_{Ax}	986.2	kN/m	Horizontal component of the anchor reaction
T_{Ay}	47.0	kN/m	Vertical component of the anchor reaction

Kranz

z_D	4.85	m	Null shear level
x_C	21.00	m	Abscissa of the anchor point
z_C	21.14	m	Anchor point level
α	0.00	°	Inclination of the anchoring force
W_{tot}	7 126.6	kN/m	Total weight of the massif taking into account external loads
$P_{1,H}$	3 120.6	kN/m	Horizontal component of front reaction
$P_{1,V}$	625.3	kN/m	Vertical component of front reaction
$P_{2,H}$	248.5	kN/m	Horizontal component of back reaction
$P_{2,V}$	0.0	kN/m	Vertical component of back reaction
R_H	-1 737.8	kN/m	Total horizontal resultant force applied to the block
R_V	6 501.4	kN/m	Total vertical resultant force applied to the block
$T_{dsb;k}$	1 134.3	kN/m	Destabilizing anchoring force (characteristic value)
$T_{dsb;d}$	1 031.2	kN/m	Destabilizing anchoring force (design value)
$T_{ref;d}$	987.4	kN/m	Axial anchor reaction = T_A (design value)
$T_{ref;k}$	731.4	kN/m	Axial anchor reaction (characteristic value)
Check	✓		$T_{ref,d} \leq T_{dsb,d}$

Vertical equilibrium

$R_{vd\ Left}$	-624.8	kN/m	Total axial load due to the left side
$R_{vd\ Right}$	855.0	kN/m	Total axial load due to the right side
$R_{vd\ Weight\ wall}$	84.4	kN/m	Dead weight of the wall
$R_{vd\ External}$	47.0	kN/m	Total axial load due to external loading applied to the wall
R_{vd}	361.5	kN/m	Total axial load downwards
Check	↓		$R_{v,d} \geq 0$



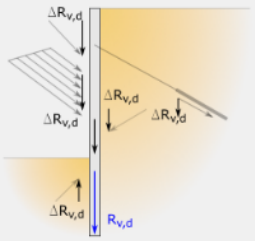


Figure 29. ULS results (details for head wall)

Head wall

Required embedment to ensure global wall equilibrium is 9.15 m, that is bottom level at z = 4.85 m. Anchor reaction is 987.4 kN/m (ULS design value).

According to Eurocode (NF P94-282), Prosheet has performed Kranz check automatically considered C level at the bottom level of the anchor wall. Reference effort (design value) is 987.4 kN/m (anchor reaction), which is less than 1031.2 kN/m (destabilizing effort, design value).

Finally, vertical resultant force is downwards (positive value) so vertical equilibrium is coherent. Bearing capacity must be checked with 361.5 kN/m at the bottom level of the sheet pile wall.

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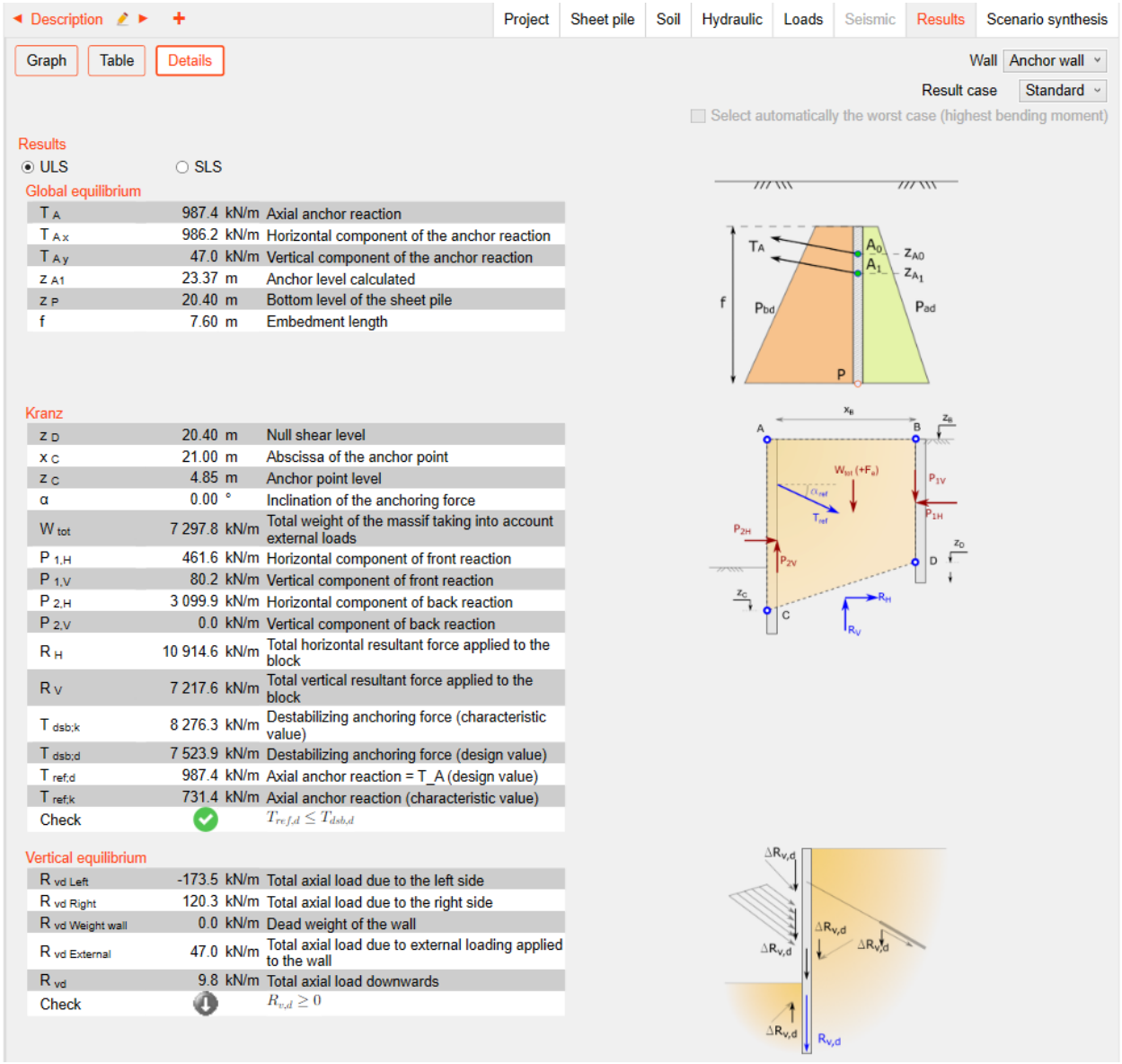

Figure 30. ULS results (details for anchor wall)

Anchor wall

Input anchor reaction is 987.4 kN/m (ULS design value). Initially, anchor level was defined at 25.00 m. After calculation, anchor level has been recalculated to ensure momentum equilibrium, that is z_{A1} = 23.37 m .

Required embedment to ensure global wall equilibrium is 7.60 m that is bottom level at z = 20.40 m.

Finally, vertical resultant force is downwards (positive value) so vertical equilibrium is coherent. Bearing capacity must be checked with 9.8 kN/m at the bottom level of the sheet pile wall.