

User manual



GeoWall 2.0

Calculation of sheet pile walls

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INTRODUCTION

GeoWall program is designed for a complex calculation of sheet pile walls on strength and stability.

The program allows to carry out calculations for almost all types of retaining walls: diaphragm wall, ones from bored piles, pipes, double T-iron and sheet piles.

Moreover, for the first time in our country there has appeared a possibility of calculating sheet pile wall from Jet piles (jet-grouting piles), constructed by using jet-grouting technology.

The program allows to calculate sheet pile walls, consisting of detached, tangent and intercrossing boring or jet-grouting piles.

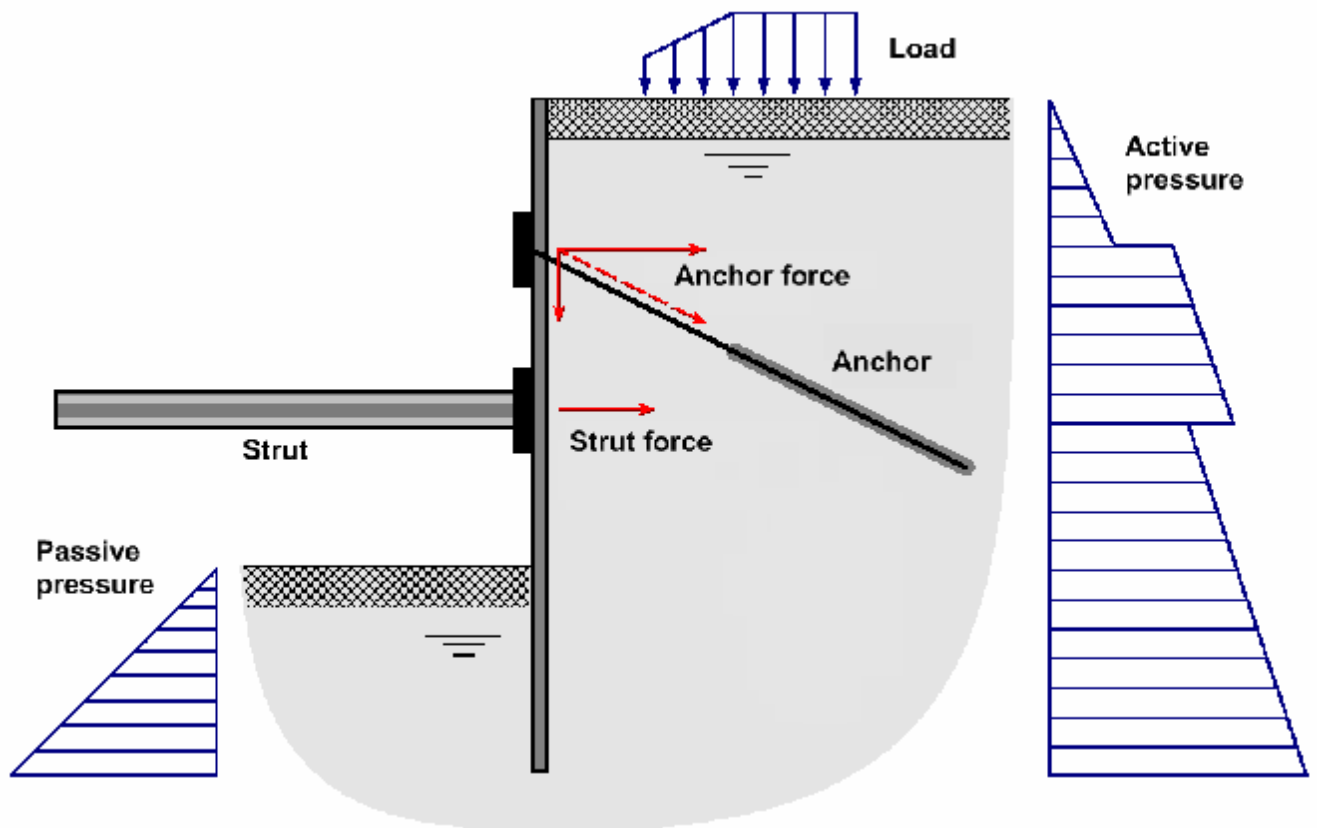
GeoWall interface is simple and easy-to-use.

The program options are the following:

- Calculation of any type of retaining wall.
- Record of soil mass geological structure and groundwater level.
- Calculation of active and passive pressure on sheet pile wall.
- Calculation of sheet pile wall bending moment, longitudinal and lateral forces.
- Calculation of retaining wall horizontal displacement.
- Calculation of forces in anchors and struts.
- Sheet pile wall strength calculation.
- Step-by-step pit calculation.
- Calculation of effective section characteristics (inertia moment, elasticity modulus, area) for «diaphragm wall» and boring piles.
- Database of physical and mechanical soil properties.
- Database of reinforcing elements – pipes, double T-iron and reinforcing cages.
- Saving and printing of report with calculation results, design scheme and diagrams.

METHODS OF CALCULATION

GeoWall program is designed for strength calculation of flexible retaining walls and for estimation of soil stability around a deepened wall part.



Pic. 1. Design scheme

Sheet pile wall stability calculation is carried out by Blume-Lomeyer method («elastic curve» method).

Sheet pile wall strength calculation is based on numerical task solution of beam bending, fixed by one end in elastic-plastic soil and restrained by ties (anchors, struts).

Finite element method is used for elastic wall bending modeling.

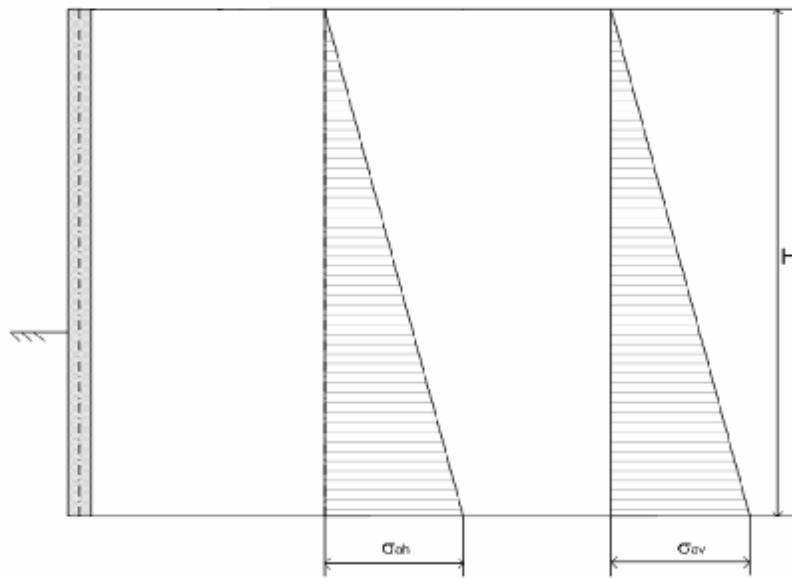
The following calculations are carried out for task solution:

1. Calculation of active and passive soil pressure on sheet pile wall.
2. Calculation of elastic-plastic reaction and soil stability around a deepened wall part (sheet pile wall).
3. Calculation of longitudinal forces in anchors and struts.

4. Task solution of elastic wall bending under the action of soil pressure from the pit side direction by finite element method.
5. Sheet pile wall strength calculation.

Calculation of soil pressure

Calculation of soil pressure on sheet pile wall is carried out on Coulomb theory.



Pic. 2.1. Horizontal and vertical components of noncohesive soil active pressure

In case of load-free surface, horizontal S_{ah} and vertical S_{av} components of active pressure for noncohesive soil at depth z (pic. 2.1) are defined by formulas:

$$S_{ah} = gzI_a,$$

$$S_{av} = S_{ah}tg d$$

where g – calculated value of specific soil weight (defined as a weighted average value of overlying soils);

d – “wall-soil” friction angle;

I_a – coefficient of active soil pressure;

$$I_a = \left[\frac{\cos j}{1 + \sqrt{\frac{\sin(j+d)\sin(j)}{\cos d}}} \right]^2,$$

Horizontal S'_{ah} and vertical S'_{av} components of active pressure for cohesive soil at depth z (pic. 2.2) are defined by formulas:

$$S'_{ah} = S_{ah} - S_{ch},$$

$$S'_{av} = S'_{ah} \operatorname{tg} d,$$

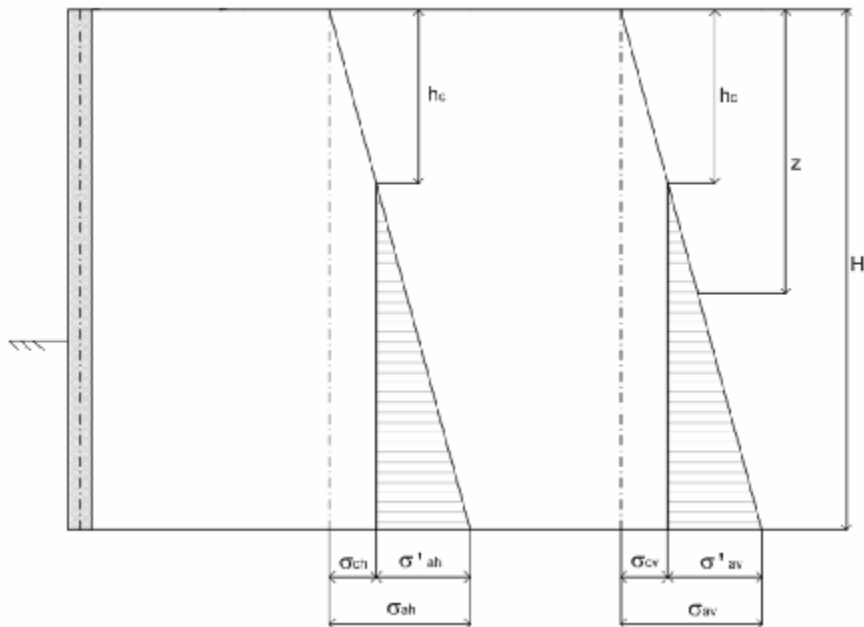
where S_{ch} – cohesiveness pressure;

$$S_{ch} = cK$$

where c – specific soil cohesion;

$$K = \frac{1 - I_a}{\operatorname{tg} j}$$

If K value, calculated by this formula, is less than 0, then the equality $K = 0$ is taken in calculations.



Pic. 2.2. Components of cohesive soil active pressure

At uniformly distributed load on the surface q , horizontal s_{ph} and vertical s_{pv} components of passive pressure at depth z from the surface are defined by formulas:

$$s_{ph} = (q + gz)I_{ph} + \frac{c}{tgj}(I_{ph} - 1)$$

$$I_{ph} = \left[\frac{\cos j}{1 - \sqrt{\frac{\sin(j+d)\sin j}{\cos d}}} \right]^2$$

Calculation of soil stability around a deepened wall part

The following assumptions are taken at calculation of soil pressure on flexible sheet pile wall.

1) *Sheet pile wall along the full pit side height has only active soil pressure.*

Sheet pile wall displacement can be presented as a sum of its rigid displacement to the pit direction and displacements from bending.

Calculations show that even at complex reversed bending of anchored walls the value of rigid translational displacement exceeds displacements from bending.

In the accepted model of wall deformation only displacements from bending are calculated.

2) *It is supposed that only forces, caused by unstable prism displacement, act on sheet pile wall.*

3) *Soil pressure, equal to lateral pressure in virgin mass, acts on absolutely rigid fixed retaining walls.*

4) *It is admitted that soil, lying around a deepened wall part, can be considered static when defining its horizontal reaction on wall displacements.*

Limiting total local soil pressure (from both sides) at some point of a deepened wall part will be equal to the difference of passive soil pressure from the wall displacement direction and active soil pressure from the opposite direction:

$$s_l = |s'_{ah} - s'_{ph}|.$$

Pressure will act to the direction opposite to wall displacement.

The value of elastic horizontal soil reaction at some point of a deepened wall part, equal to a sum of forces acting from left and right, can be found by Winkler model:

$$s_{eh} = ku_h,$$

where s_{eh} - total soil reaction on horizontal wall displacement u_h , k – soil reaction coefficient, containing wall deepening.

Winkler horizontal soil reaction should satisfy the condition

$$|s_{eh}| \leq s_l.$$

Where the condition is not satisfied, soil is in limiting state and reacts to wall displacement, equal to s_l .

Vertical soil reaction to a deepened wall part is also defined by Winkler model:

$$s_{ev} = k'u_v,$$

where s_{ev} – vertical soil reaction, k' – soil reaction coefficient, u_v – vertical wall displacement.

Soil stability around wall deepening is estimated by the following criterion:

5) *Soil condition around wall deepening is stable, if passive soil reaction from each deepening direction doesn't reach its limiting value.*

When passive soil reaction reaches its limiting value (that is passive pressure in Coulomb theory) from at least one wall deepening direction, it will lead to plastic hinge appearance and sheet pile wall stability loss.

Soil stability criterion, containing wall deepening, is the following:

6) *Soil around wall deepening is stable, if $K > 1$,*

$$K = \min(K^+, K^-),$$

$$K^- = \frac{\int s_l dx^-}{\int s_h dx^-}, \quad K^+ = \frac{\int s_l dx^+}{\int s_h dx^+},$$

S_h - soil reaction value at some point of a deepened wall part, equal to a sum of forces acting from left and right.

A "minus" index stands for a deepening part, which displaces to the pit direction, and a "plus" index stands for that deepening part, which displaces to the pit side direction.

Calculation of longitudinal forces in anchors

Method of force calculation in anchors takes into account pre-tension and step-by-step retaining wall displacements at pit excavation assuming stages of anchor layer arrangement.

Anchor is considered as an elastic tie, reaction of which is proportional to anchor displacement. It is considered that anchors are tied with sheet pile wall by strapping.

Anchor stiffness c , which connects longitudinal force in anchor P with anchor displacement U , to which this force is applied, is taken as an anchor deformation characteristic:

$$c = \frac{P}{u} .$$

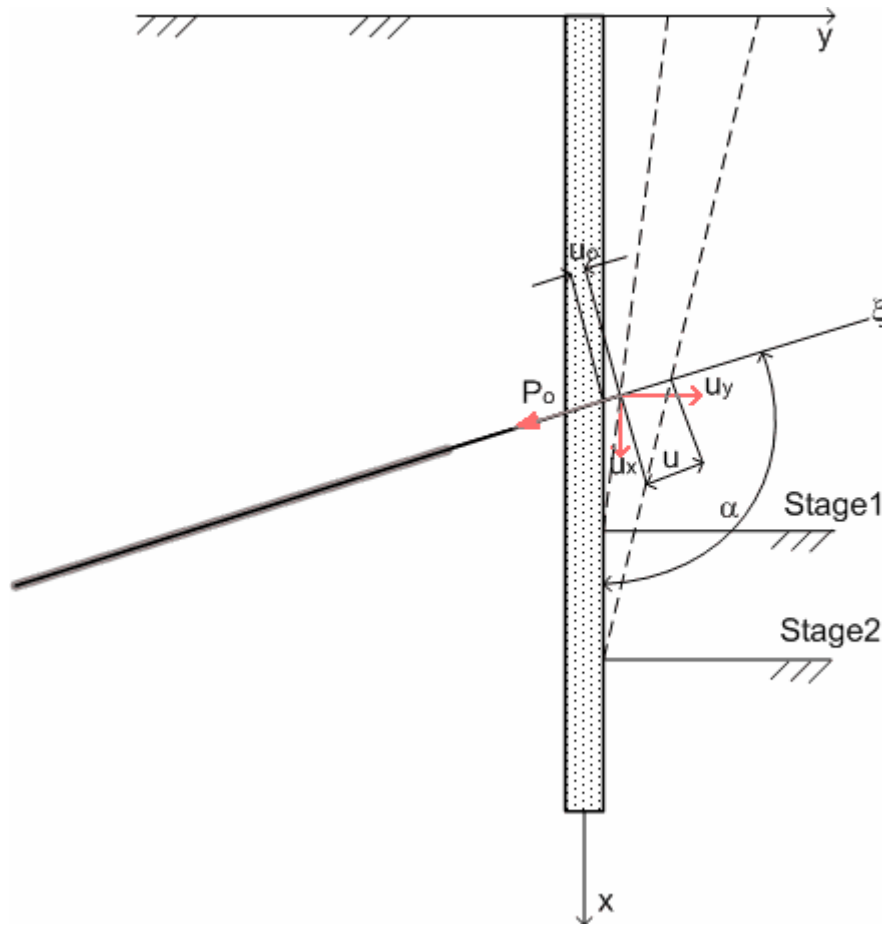
Continuous pit excavation in the model is replaced by discontinuous one, at the same time pit excavation discretization is connected with time points (and corresponding depths) of anchor layer arrangement.

In the excavation process a flexible wall is deformed, and wall displacements depend on pit depth.

Anchor longitudinal force is caused by anchor displacement, which occurs after excavation works of the next stage or by anchor pre-tension.

Therefore, it is necessary to take into account only anchor displacements at strapping fixing point for calculating pit excavation stages on stress and strain states of the anchored flexible wall.

Let us model reaction of anchor, arranged after the first stage of pit excavation.



Pic. 4. Design scheme of defining anchor longitudinal force

Fixing point of expected anchor (anchor is not arranged yet) after the first stage of pit excavation has got displacement u_0 (pic. 4). Then, anchor is arranged, and wall deformation after excavation of the second stage leads to anchor displacement u .

Then, taking into account anchor pre-tension P_0 , longitudinal force in anchor P will be equal

$$P_x = -P_0 - c(U_x - u_{ox}),$$

where U_x - x component of final displacement;

u_{ox} - projection of anchor fixing point displacement before its arrangement.

Let us express projection of displacement U_x through projections U_x, U_y :

$$U_x = U_x \cos a + U_y \sin a ,$$

Let us record initial displacement ratio in a similar way

$$u_{ox} = u_{ox} \cos a + u_{oy} \sin a .$$

Let us find x and y components of force P :

$$P_x = P_x \cos a = -P_o \cos a - c(U_x \cos^2 a + U_y \sin a \cos a - u_{ox} \cos^2 a - u_{oy} \sin a \cos a) ,$$

$$P_y = P_x \sin a = -P_o \cos a - c(U_x \cos a \sin a + U_y \sin^2 a - u_{ox} \cos a \sin a - u_{oy} \sin^2 a) .$$

Task solution of elastic wall bending

Task of wall bending is solved numerically by finite element method using Lagrange's variational statement with flat cross-section hypothesis. Only longitudinal stress-strain component is taken into account.

Variational task statement is formulated in the following way: to find displacements v , returning minimum to a functional

$$J(v) = \frac{1}{2} \int_{\Omega} S(v) \cdot e(v) dx + \frac{1}{2} \int_{S_c} C_n w^2 dS_c + \frac{1}{2} \int_{S_c} C_t u_t^2 dS_c - \int_{S_p} P \cdot v dx$$

C_n - Winkler's base soil reaction coefficient,

C_t - soil shear stiffness.

Let us superpose Ox axis with the beam one, and Oy axis – with deflection direction.

Beam strain with accepted assumptions is equal to

$$e = e_x ii ,$$

where i – Ox unit vector.

Beam deflection equals to $w = v \cdot j$ (j – Oy unit vector), Ox displacement equals to $u = v \cdot i$.

Longitudinal strain will be summed up of compressive (tensile) strain

$$e_x(u) = \frac{du}{dx}$$

and bending strain

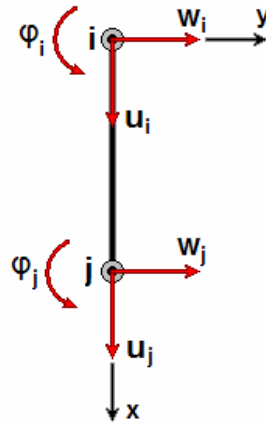
$$e_x(w) = -y \frac{d^2w}{dx^2}$$

Strains and stresses are connected by Hooke's law

$$S_x = Ee_x.$$

Sheet pile wall bending is modeled as elastic beam bending by section, falling on one sheet pile wall spacing.

Finite element with 6 degrees of freedom is realized in the program.



Pic. 5. Beam finite element with 6 degrees of freedom

Finite element approximates:

Beam deflection by cubic function

$$w(x) = a_1 + a_2x + a_3x^2 + a_4x^3$$

Rotation angles by function

$$j(x) = \frac{dw}{dx} = a_2 + 2a_3x + 3a_4x^2$$

Beam curvature by linear function

$$K = \frac{d^2w}{dx^2} = 2a_3 + 6a_4x$$

Longitudinal displacements by linear function

$$u(x) = ax + b = u_i \left(1 - \frac{x}{L}\right) + u_j \frac{x}{L}.$$

Element longitudinal strain is

$$e_x = \frac{du}{dx} = \left[1 - \frac{x}{L}, \frac{x}{L}\right] \begin{Bmatrix} u_i \\ u_j \end{Bmatrix} = [N] \begin{Bmatrix} u_i \\ u_j \end{Bmatrix},$$

$$[N] = \frac{1}{L}[-1 \quad 1].$$

Sheet pile wall strength calculation

Calculation of effective characteristics and strength calculation of sheet pile walls like “diaphragm wall”, boring and Jet piles are realized in GeoWall program.

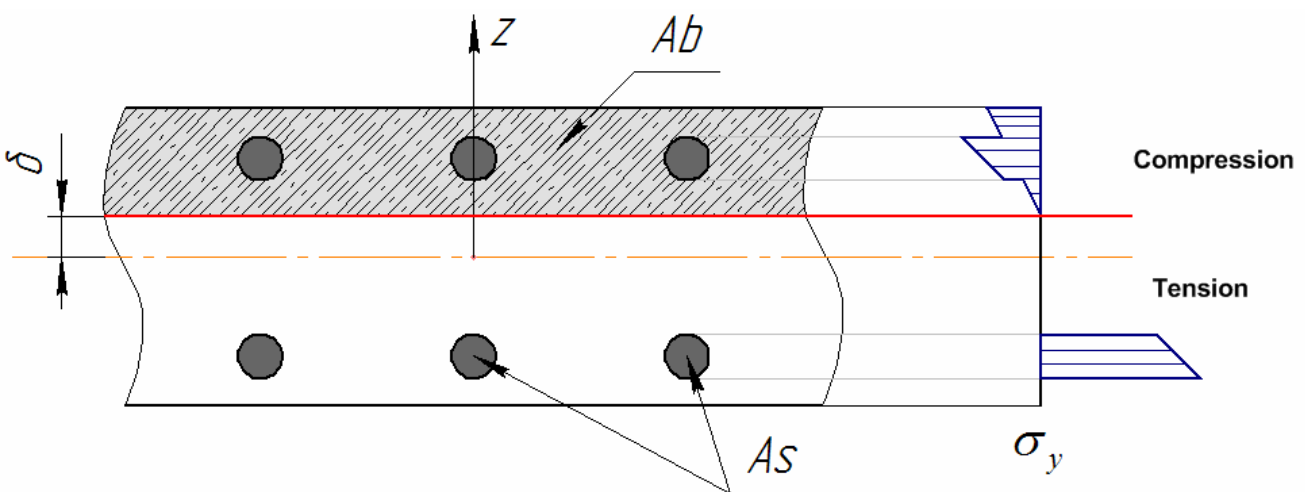
The following assumptions are accepted:

- Only longitudinal component of stress-strain tensor is taken into account;
- Concrete (soil-concrete) can fail only by tensile stresses;
- Carrying out flat cross-section hypothesis along the full sheet pile wall height is supposed.

Taking into account accepted assumptions, stresses in arbitrary wall section can be found with the help of static equilibrium equations for external forces, applied to the wall part, the width of which is equal to one pile spacing and located above the design section.

In general, soil pressure, wall weight, anchor and strut reactions influence the upper wall part. The action of all these forces can be reduced to a principal moment M_o^e and resultant vector R^e relative to the arbitrary reduction centre O. Design section point on the pile axis can be accepted as this reduction centre.

Longitudinal forces in reinforcing element and concrete, which we reduce to a resultant vector R^{bs} , applied in the reduction centre O, and principal moment M_o^{bs} , will act from the neglected wall part direction to the upper part.



Pic. 6. Sheet pile wall cross section
(As – reinforcing element, Ab – concrete).

Let us direct Oy axis along the pile one. Equilibrium equations can be written in the following form:

$$R_y^{bs} + R_y^e = 0,$$

$$M_o^{bs} + M_o^e = 0.$$

For getting a closed system of equations let us use:

- Cauchy relations according to which $p_{by} = -s_y$, $p_{sy} = -s_y$, p_{by} , p_{sy} - Oy components of forces, acting in design section,
 s_y - longitudinal stress tensor component;
- flat cross-section hypothesis:

$$e_y(z) = \frac{d+z}{r}$$

where δ – neutral line position coordinate, ρ – neutral line curvature radius (pic. 6).

- and Hooke's law, connecting longitudinal bending strain with longitudinal stresses.

$$s_y = E e_y.$$

Substitution of relations taking into account Cauchy relations gives the following equation:

$$\int_A E \left(\frac{d+z}{r} \right) dA = R_y^e$$

Let us re-arrange moment equation in a similar way

$$\int_A E \left(\frac{d+z}{r} \right) z dA = M_o^e$$

We can find neutral line position and curvature, solving the system of two equations. Thereafter, returning to previous equations, let us find stress distribution in calculated sheet pile wall section.

This design model can be realized for any type of retaining wall with any reinforcement parameters.

Effective wall section characteristics

Effective characteristics for each wall section are calculated with the help of calculations, described in the previous part, as loads (bending moment and longitudinal force) are variable by sheet pile wall height. Hence, neutral line position and, correspondingly, concrete compression zone for each section are different.

These characteristics are used at solving task of elastic beam bending with variable characteristics.

At calculating the integral

$$\int_A E y^2 dA = E_0 \int_A y^2 dA = E_0 J_0$$

effective static inertia moment

$$J_0 = \int_A y^2 dA$$

and effective value of longitudinal elasticity modulus are considered.

$$E_0 = \frac{\int_A E y^2 dA}{J_0} = \frac{E_b J_b + E_s J_s}{J_0}$$

Effective inertia moment is more than the actual one, when the section part makes no resistance to bending as a result of destruction.

Effective section area is introduced from the condition of equality of longitudinal force for actual and effective characteristics at the same longitudinal strain ϵ :

$$\int_A E \epsilon dA = E_0 \epsilon A_0 .$$

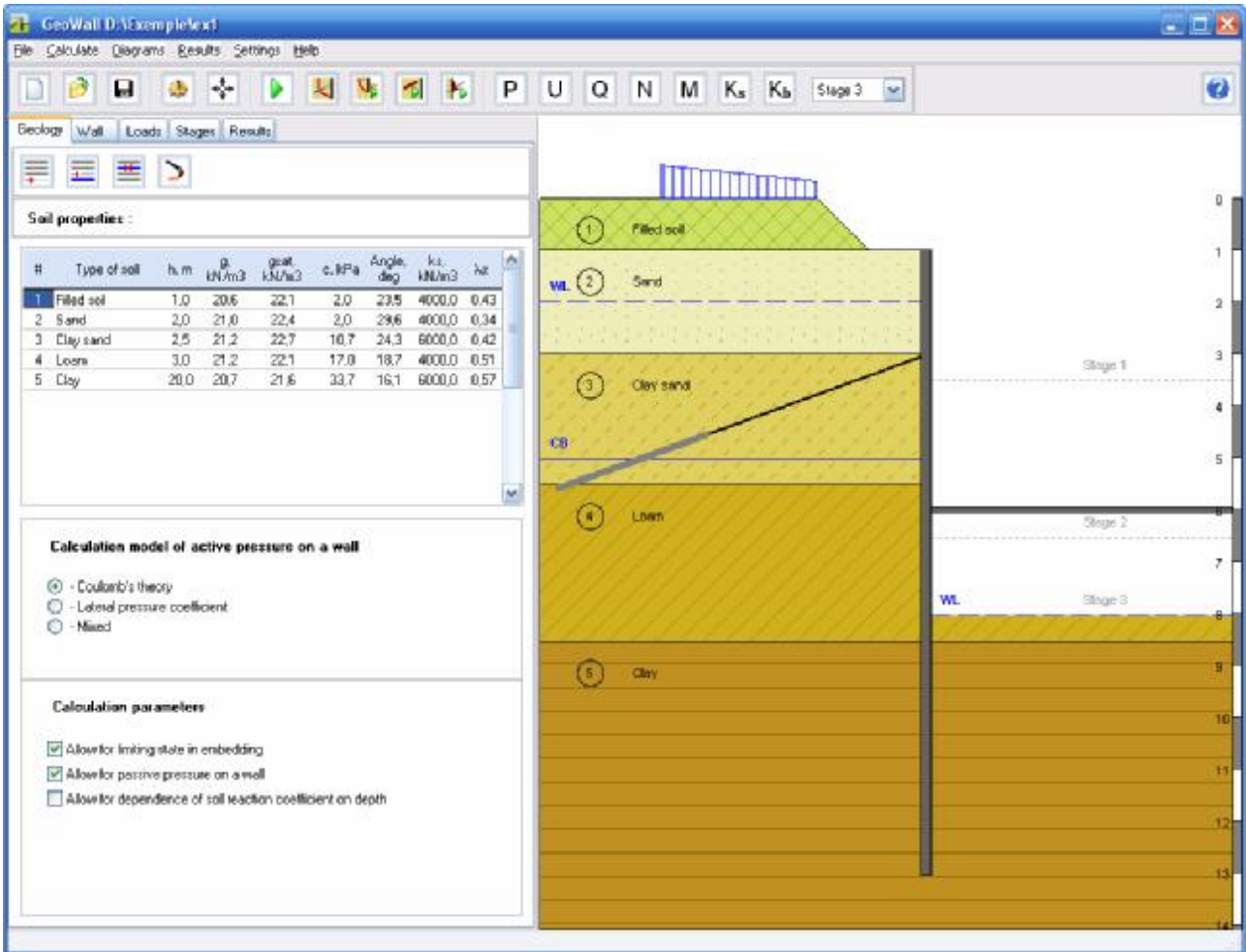
From the last equality

$$A_0 = \frac{\int E dA}{E_0} .$$

Effective section characteristics are used at calculating retaining walls from boring and Jet piles as well as «diaphragm walls» in GeoWall program.

PROGRAM OVERVIEW

GeoWall window looks like the following:

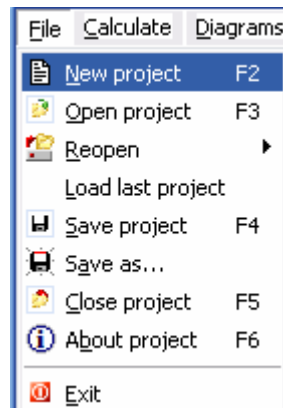










The program window consists of the following elements:

- Menu
- Toolbar
- Data input panel
- Graphic field (data input panel)

Menu

«File» menu



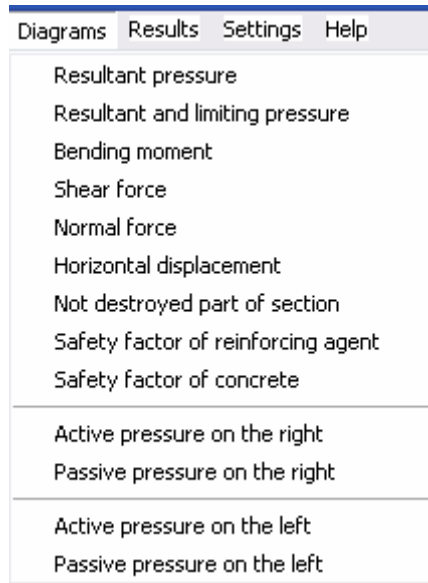
-  [New project](#) – creates a new working project (key F2).
-  [Open a project](#) – opens a previously created project (key F3).
-  [Reopen](#) - opens one of the three most recent projects
- [Load last project](#)
-  [Save a project](#) – saves a current project (key F4).
-  [Save as...](#) – saves a current project under a new name.
-  [Close a project](#) – closes a current project (key F5).
-  [About project](#) – (key F6).
-  [Exit](#) – exits GeoWall program.

«Calculate» menu

Calculate	Diagrams	Results	Settings
Wall calculation			F7
Stability analysis (Kranz method)			F8
Stability analysis			F9
Anchor calculation			F10
Framing beam calculation			F11

- [Wall calculation](#) – (key F7).
- [Stability analysis \(Kranz method\)](#) – (key F8).
- [Stability analysis](#) – (key F9).
- [Anchor calculation](#) – (key F10).
- [Framing beam calculation](#) – (key F11).

«Diagrams» menu



Resultant pressure – plots a diagram of calculated pressure on sheet pile wall in a graphic field.

Resultant and limiting pressure – plots a diagram of calculated and limiting pressure on sheet pile wall.

Bending moment – plots a diagram of bending moment, acting on sheet pile wall.

Shear force – plots a diagram of sheet pile wall crosscutting force.

Normal force – plots a diagram of longitudinal force, acting on sheet pile wall.

Horizontal displacement – plots a diagram of sheet pile wall horizontal displacement.

Not destroyed part of section – displays graphically compression zone part in sheet pile wall.

Safety factor of reinforcing agent – plots a diagram of safety coefficient in reinforcing element in each retaining wall section.

Safety factor of concrete – plots a diagram of safety coefficient in concrete in each retaining wall section.

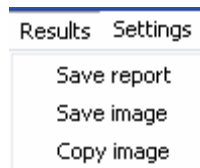
Active pressure on the right – plots a diagram of active horizontal pressure from the pit direction.

[Passive pressure on the right](#) – plots a diagram of passive horizontal pressure from the pit direction.

[Active pressure on the left](#) – plots a diagram of active horizontal pressure on sheet pile wall.

[Passive pressure on the left](#) – plots a diagram of passive horizontal pressure on sheet pile wall.

«Results» menu

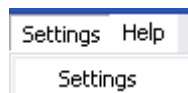


[Save report](#) – save the report to file.

[Save image](#) – save picture to file.

[Copy image](#).

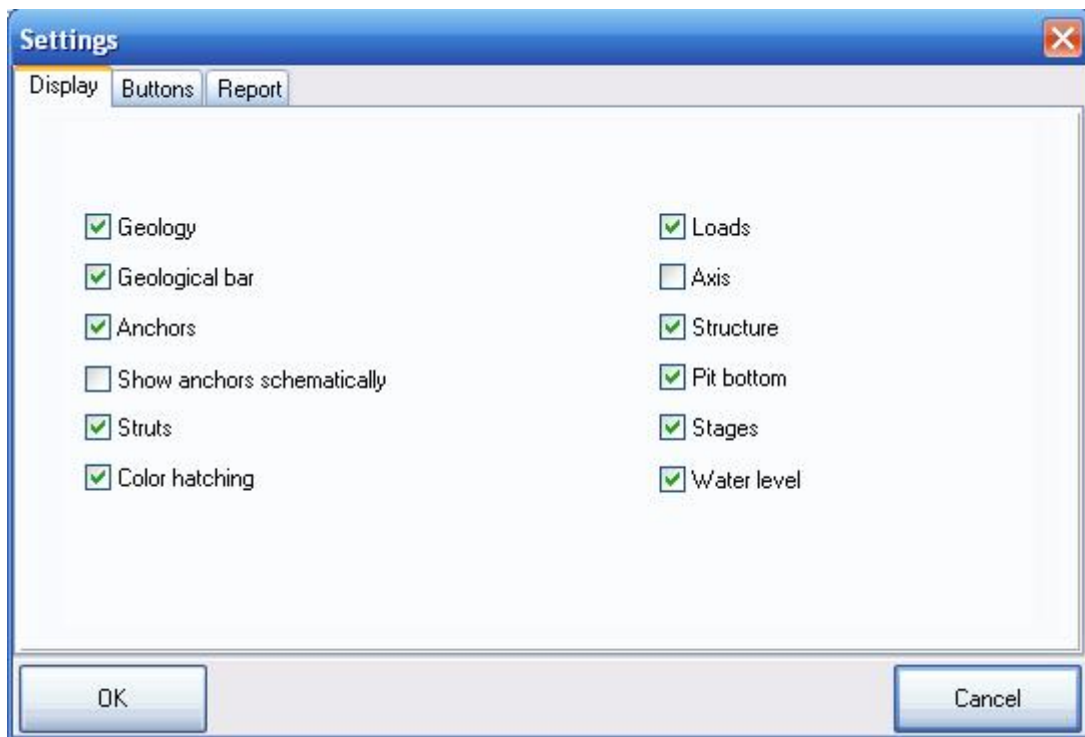
«Settings» menu



[Settings](#) – contains a window of program display settings.

Settings:

- Display
- Buttons
- Report



Geology – to hide/display EGE.

Geological bar – to hide/display a geological ruler.

Anchors – to hide/display anchors.

Show anchors schematically

Struts – to hide/display struts.

Colour hatching – displays EGE colour hatching (EGE - engineering-geological element).

Loads – to hide/display loads.

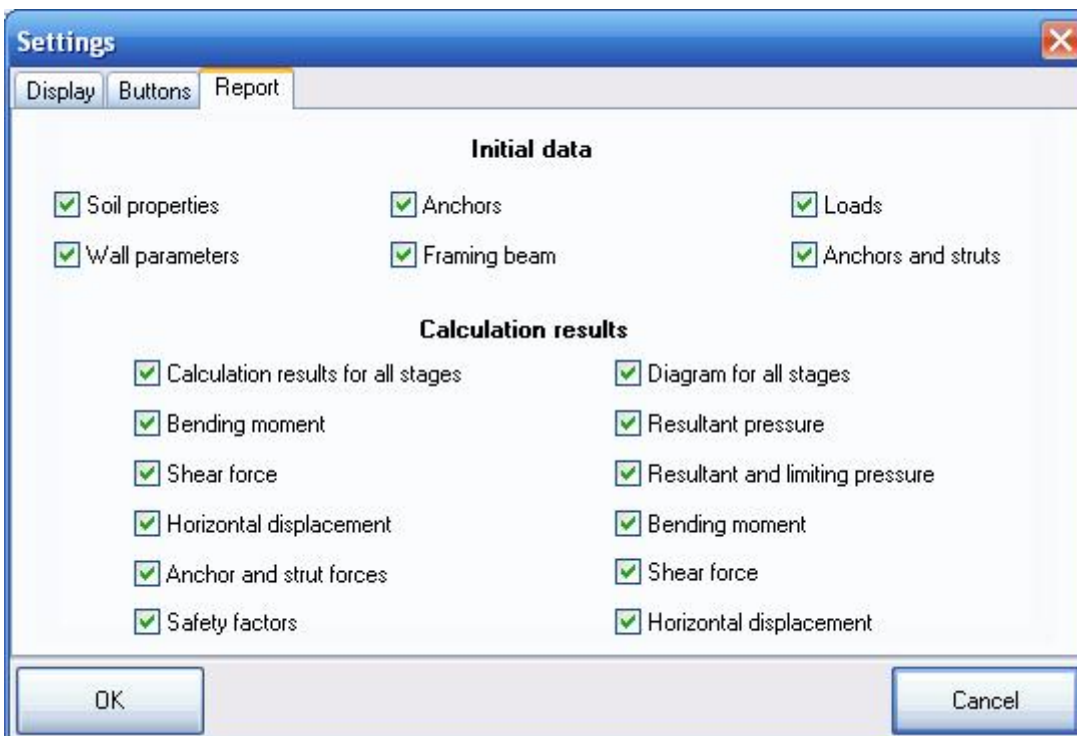
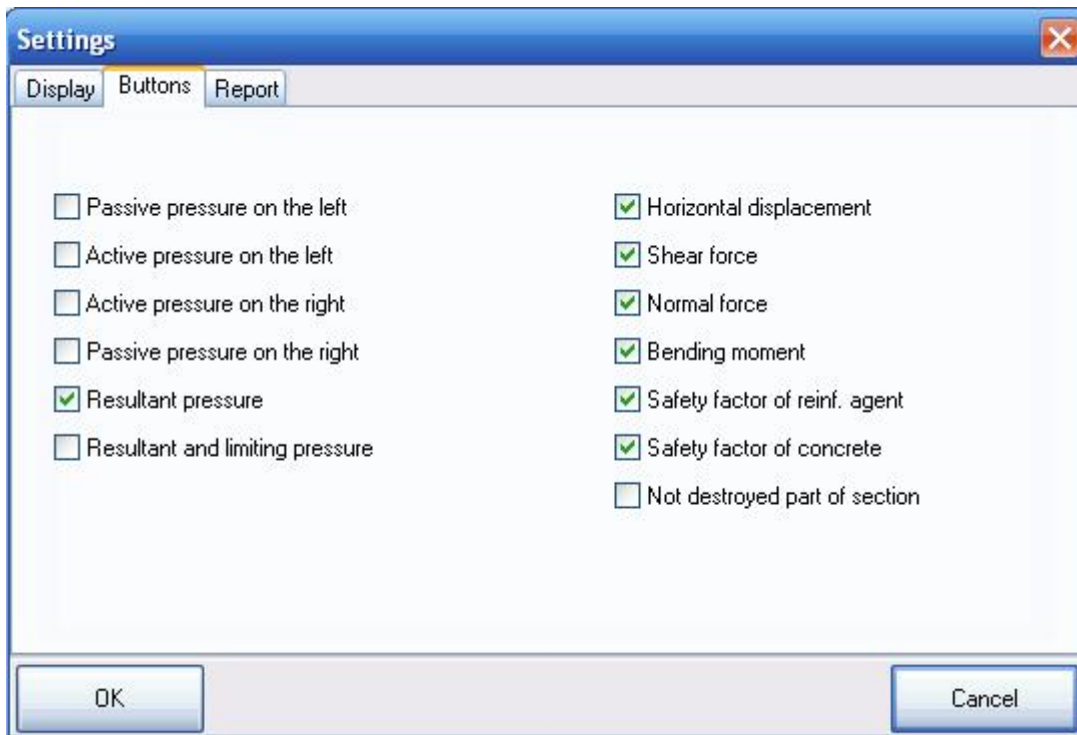
Axis – to hide/display sheet pile wall axis.

Structure – to hide/display retaining structure.

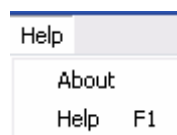
Pit bottom – to hide/display pit bottom.

Stages – to hide/display pit construction stages.

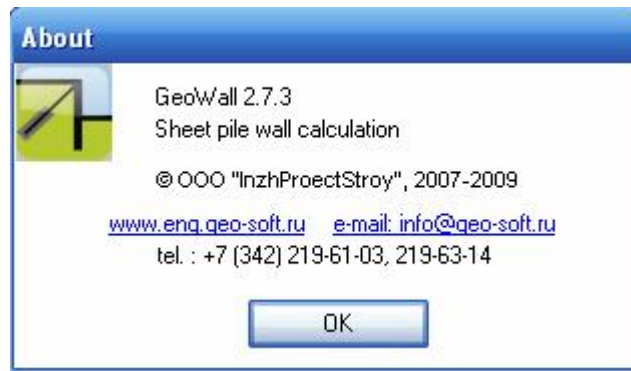
Water level – to hide/display groundwater level.



«Help» menu



About – outputs information about the program version and developer’s contact data.




















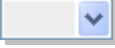

Help – (key F1).

Toolbar



Buttons, integrated by functions, are placed in Toolbar.

-  **Create a project** – creates a new working project.
-  **Open a project** – opens a previously created project.
-  **Save a project** – saves a current project.
-  **Display settings** – opens a window of display settings.
-  **Full-screen mode** – outputs a graphic field in full-screen mode, hides a data input panel.
-  **Carry out calculation** – starts up the main program calculation, outputs results on the screen.
-  **Stability analysis (Kranz method)**
-  **Stability analysis**
-  **Anchor calculation**
-  **Framing beam calculation**
-  **Calculated pressure** – plots a diagram of calculated pressure on sheet pile wall.

-  **Horizontal displacements** – plots a diagram of sheet pile wall horizontal displacement.
-  **Crosscutting force** – plots a diagram of sheet pile wall crosscutting force.
-  **Longitudinal force** – plots a diagram of sheet pile wall longitudinal force.
-  **Bending moment** – plots a diagram of sheet pile wall bending moment.
-  **Safety coefficient in reinforcing element** – plots a diagram of safety coefficient in reinforcing element.
-  **Safety coefficient in concrete** – plots a diagram of safety coefficient in concrete.
-  – stage selection window, where it is necessary to plot a diagram according to calculation results.
-  **Help** – outputs program help.

Data input panel

«Geology» insert

Physical and mechanical soil properties are inputted in *Geology* insert.

Geology Wall Loads Stages Results

Soil properties :

#	Type of soil	h, m	g, kN/m ³	gsat, kN/m ³	c, kPa	Angle, deg	ks, kN/m ³	λ α
1	Filled soil	1,0	20,6	22,1	2,0	23,5	4000,0	0,43
2	Sand	2,0	21,0	22,4	2,0	29,6	4000,0	0,34
3	Clay sand	2,5	21,2	22,7	10,7	24,3	6000,0	0,42
4	Loam	3,0	21,2	22,1	17,0	18,7	4000,0	0,51
5	Clay	20,0	20,7	21,6	33,7	16,1	6000,0	0,57

Calculation model of active pressure on a wall

- Coulomb's theory
- Lateral pressure coefficient
- Mixed

Calculation parameters

- Allow for limiting state in embedding
- Allow for passive pressure on a wall
- Allow for dependence of soil reaction coefficient on depth

EGE – engineering-geological element number according to geological survey. EGE number can be repeated, for example, two layers №3 can be specified in the program.

h, m – layer thickness,

g, kN/m³ – soil volume weight in natural state,

gsat, kN/m³ – soil volume weight at full water saturation,

c, kPa – specific cohesion,

Angle, degree – internal friction angle,

ks, kN/m³ – soil reaction coefficient,

λ α – accept by $(\text{tg}(45-\gamma/2))^2$.

Groundwater data is inputted in *Water level* and *Confining bed* fields. Values are inputted without «minus» mark.

The following buttons are placed in *Geology* insert:



Add a row at the table end.



Insert a row above the active one.



Delete a row.



Hatching selection – hatching selection by search for the marked soil layer.

In *Geology* insert it is also possible to specify method of calculation of active sheet pile wall pressure:

- Coulomb's theory
- Lateral pressure coefficient
- Mixed

Calculation model of active pressure on a wall

- Coulomb's theory
- Lateral pressure coefficient
- Mixed

Calculation parametrts:

- Allow for limiting state in embedding
- Allow for passive pressure on a wall
- Allow for dependence of soil reaction coefficient on depth

Calculation parameters

- Allow for limiting state in embedding
- Allow for passive pressure on a wall
- Allow for dependence of soil reaction coefficient on depth

«Wall» insert

Data about pit depth, sheet pile wall length and its section parameters are inputted in *Wall* insert.

Excavating depth – pit depth is specified from the ground surface.

Wall height – length of piles or «diaphragm wall».

Embedding – this parameter is calculated automatically and shows the value of sheet pile wall embedment length.

Friction coefficient – parameter, responsible for transferring longitudinal force on sheet pile wall, varies from 0,0 to 1,0 (in percentage of soil internal friction angle).

For retaining walls from Jet piles it is recommended to take *Soil contact* value equal to 1,0.

Wall type– allows to select the type of used retaining wall: *Slurry wall, Bored pipe wall, Jet-grouting, Another...*



Cross-section properties – opens a window for inputting geometry and strength characteristics of the selected retaining wall as well as for calculating effective section characteristics.

Strength analysis – sheet pile wall strength calculation is also carried out.

If it is necessary to calculate only moments and internal forces in retaining walls, it is recommended to switch off this option for accelerating calculation.

In case of retaining wall calculation, missing in *Wall type* list, e.g. retaining wall from sheet piles of another profile, it is possible to select *Another...* point and specify user geometry and strength section characteristics:

b – sheet pile wall spacing (pile spacing or sheet pile length), m

A – section area, m²

W – resisting moment, m³

J – inertia moment, m⁴

E – elasticity modulus, MPa

Rs – ultimate strength, Mpa

Space	<input type="text" value="1"/>	m
Depth	<input type="text" value="1"/>	m
Angle of slope	<input type="text" value="45"/>	deg

Sheet pile wall section characteristics

«Slurry wall» window

The window allows to input geometry and strength characteristics of «Slurry wall» for carrying out further calculation.

The screenshot shows the 'Slurry wall' dialog box with the following data:

Slurry wall characteristics			Reinforcing parameters		
Wall thickness	400	mm	Rebar diameter	20	mm
Cover	50	mm	Cross-section area of reinf.	3,14	cm ²
Elasticity modulus of concrete	30000	MPa	Rebar spacing	100	mm
Compressive strength of concrete	14,5	MPa	Elasticity modulus of reinf.	200000	MPa
Tensile strength of concrete	1,05	MPa	Tensile strength of reinf.	270	MPa

The diagram below the table illustrates a rectangular cross-section of a slurry wall. The total height is 400 mm. The top and bottom reinforcement layers are positioned 50 mm from the top and bottom edges, respectively. The spacing between the top reinforcement bars is 100 mm. A single bar is shown with a diameter of 20 mm. The wall is shaded gray, and the reinforcement bars are represented by blue circles.

Characteristics – opens a panel for calculation of effective section characteristics (inertia moment, section area, elasticity modulus), stresses and safety coefficients, allows to analyze sensitivity of sheet pile wall parameters from moment and load.

For precheck of sheet pile wall section strength it is possible to specify moment and normal force in *Loads* part and press *Calculate* button. After calculation

effective section characteristics, concrete and reinforcement stresses and safety coefficients will be calculated as well as stress diagram will be shown.

Slurry wall
✕

Slurry wall characteristics			Reinforcing parameters		
Wall thickness	400	mm	Rebar diameter	20	mm
Cover	50	mm	Cross-section area of reinf.	3,14	cm ²
Elasticity modulus of concrete	30000	MPa	Rebar spacing	100	mm
Compressive strength of concrete	14,5	MPa	Elasticity modulus of reinf.	200000	MPa
Tensile strength of concrete	1,05	MPa	Tensile strength of reinf.	270	MPa

Loads		Maximum active stress		Characteristics for 1 m.	
M	74	kNm/m	In reinforcing agent	24,4	MPa
N	342	kN/m	In concrete	4,11	MPa
<input type="button" value="Calculate"/>		Safety factor		Destruction boundary	-32
		In reinforcing agent	11,1	Neutral axis coordinate	15
		In concrete	3,53	Moment of inertia, J	0,00296071
				Cross-section area, A	0,17591
				Elasticity modulus, E	46234,8

«Bored pile wall» window

The window allows to specify geometry and strength parameters of retaining wall from boring piles (bored piles, CFA piles, bored injection piles and so on).

There is also a possibility to carry out calculation of double-row retaining walls from piles.

Bored pile wall
✕

Characteristics of piles			Reinforcing agent characteristics		
Rows quantity	<input checked="" type="radio"/> 1 row <input type="radio"/> 2 rows		Reinforcing agent type	Rebar cage ▾	
Pile diameter	500	mm	Pipe diameter	440	mm
Pile spacing	400	mm	Pipe wall thickness	8	mm
Row spacing		mm	Cross-section area	20,358	cm ²
Elasticity modulus of concrete	30000	MPa	Moment of inertia	258,591	cm ⁴
Compressive strength of concret	20	MPa	Elasticity modulus of reinf.	210000	MPa
Tensile strength of concrete	2	MPa	Tensile strength of reinf.	365	MPa
			Reinforcement (row #1)	50	%
			Reinforcement (row #2)		%

✎ Rebar cage

EJA Characteristics

✔ OK

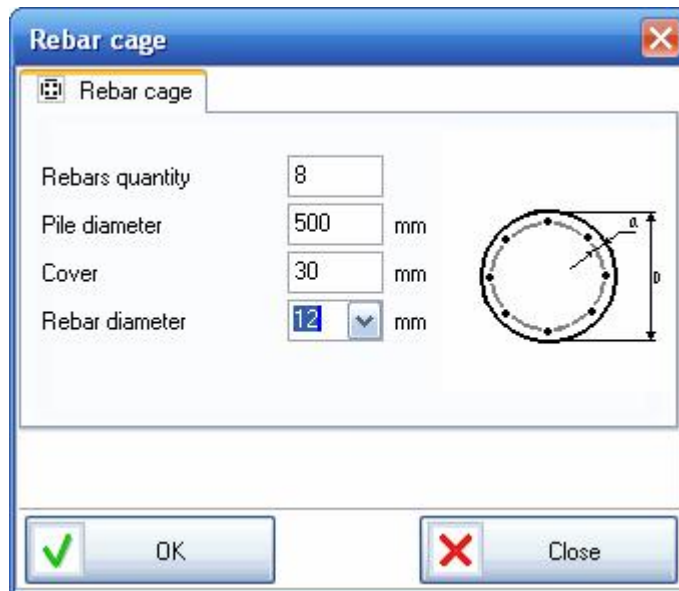
✖ Close

Compression

Tension

Loads			Section effective characteristics		
Bending moment, M	92	kNm/m	Destruction boundary	-134	mm
Force, N	41	kNm/m	Neutral axis coordinate	-148	mm
			Moment of inertia, J	0,0012	m ⁴
			Cross-section area, A	0,041	m ²
			Elasticity modulus, E	30166	MPa
<div style="border: 1px solid #ccc; padding: 5px; display: inline-block; background-color: #e6e6fa;">▶ Calculation</div>			Maximum active stress		
			In reinforcing agent	374,8	MPa
			In concrete	14,9	MPa
			Safety factor		
			for reinforcing agent	0,9739	
			for concrete	1,343	

Rebar cage, which contains data of pipes, double-T-iron and reinforcement, can be used to simplify specifying reinforcing element parameters.



In this module it is also possible to carry out calculation of effective section characteristics, analyze sensitivity of sheet pile wall parameters from moment and longitudinal force as well as calculate section stresses and safety coefficients.

«Jet-grouting» window

The window allows to specify geometry and strength parameters of retaining wall from Jet piles (jet-grouting piles).

Jet-grouting
✕

Piles characteristics					Reinforcing agent characteristics			
Rows quantity	<input type="radio"/> 1 row <input checked="" type="radio"/> 2 rows				Reinforcing agent type	Pipe		<div style="border: 1px solid gray; padding: 2px; margin-bottom: 2px;"> Rebar cage </div> <div style="border: 1px solid gray; padding: 2px; margin-bottom: 2px;"> Characteristics </div> <div style="border: 1px solid gray; padding: 2px; margin-bottom: 2px;"> OK </div> <div style="border: 1px solid gray; padding: 2px;"> Close </div>
Pile spacing	500	mm		Outer diameter	89	mm		
Row spacing	300	mm		Pipe wall thickness	6,5	mm		
#	D, mm	E, MPa	R, MPa	Rt, MPa	Cross-section area	16,847	cm ²	
▶ 1	500	3000	2	0,2	Moment of inertia	144,219	cm ⁴	
2	500	3000	2	0,2	Elasticity modulus of reinf.	210000	MPa	
3	500	3000	2	0,2	Tensile strength of reinf.	379	MPa	
4	500	3000	2	0,2	Reinforcement (row #1)	100	%	
					Reinforcement (row #2)	100	%	

Loads			Section effective characteristics					
Bending moment, M	78	kNm/m	#	A, m ²	E, MPa	J, m ⁴	Zs, mm	Zo, mm
Force, N	207	kN/m	▶ 1	0,074	16762	0,002324	156,2	106,6
			2	0,074	16762	0,002324	156,2	106,6
			3	0,074	16762	0,002324	156,2	106,6
			4	0,074	16762	0,002324	156,2	106,6
			5	0,074	16762	0,002324	156,2	106,6

Calculation

The difference of *Jet-grouting* module from *Bored pile wall* one is that the first module allows to specify the diameter, deformation modulus and pile material strength for each soil layer.

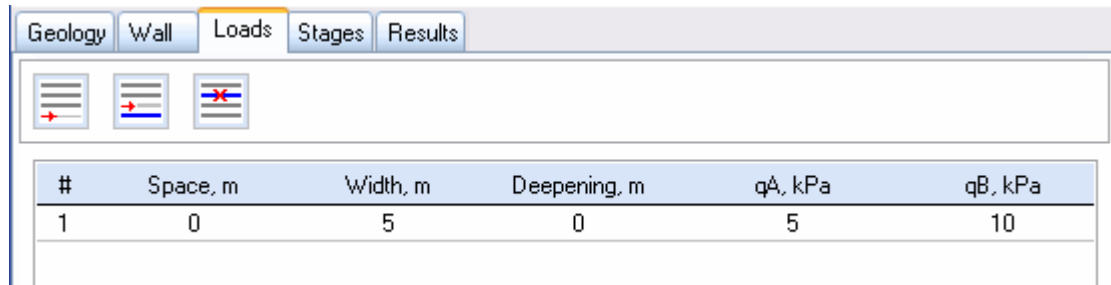
This option is necessary as the diameter and jet-grouting pile strength depend on the type of soil.

Rebar cage, similar to one for *Bored pile wall*, can be used to simplify specifying reinforcing element parameters.

There is also a possibility to carry out checking calculation for different combinations of moment and longitudinal force.

«Loads» insert

Information about distributed loads for specifying loads from nearby buildings and equipment is inputted.



#	Space, m	Width, m	Deepening, m	qA, kPa	qB, kPa
1	0	5	0	5	10

– sequence number,

Space, m – load edge-to-pit side spacing,

Width, m – load width,

Deepening, m – load application depth,

Pressure qA, kPa – load value at the left point,

Pressure qB, kPa – load value at the right point.

«Stages» insert

Quantity of pit excavation stages as well as anchor and strut parameters is specified in *Stages* insert.

Ground anchor and strut parameters are specified in *Anchors and thrust system* part.

Stage – stage, from which anchor or strut is taken into account in calculation,

Type – type of tie: Anchor or Strut,

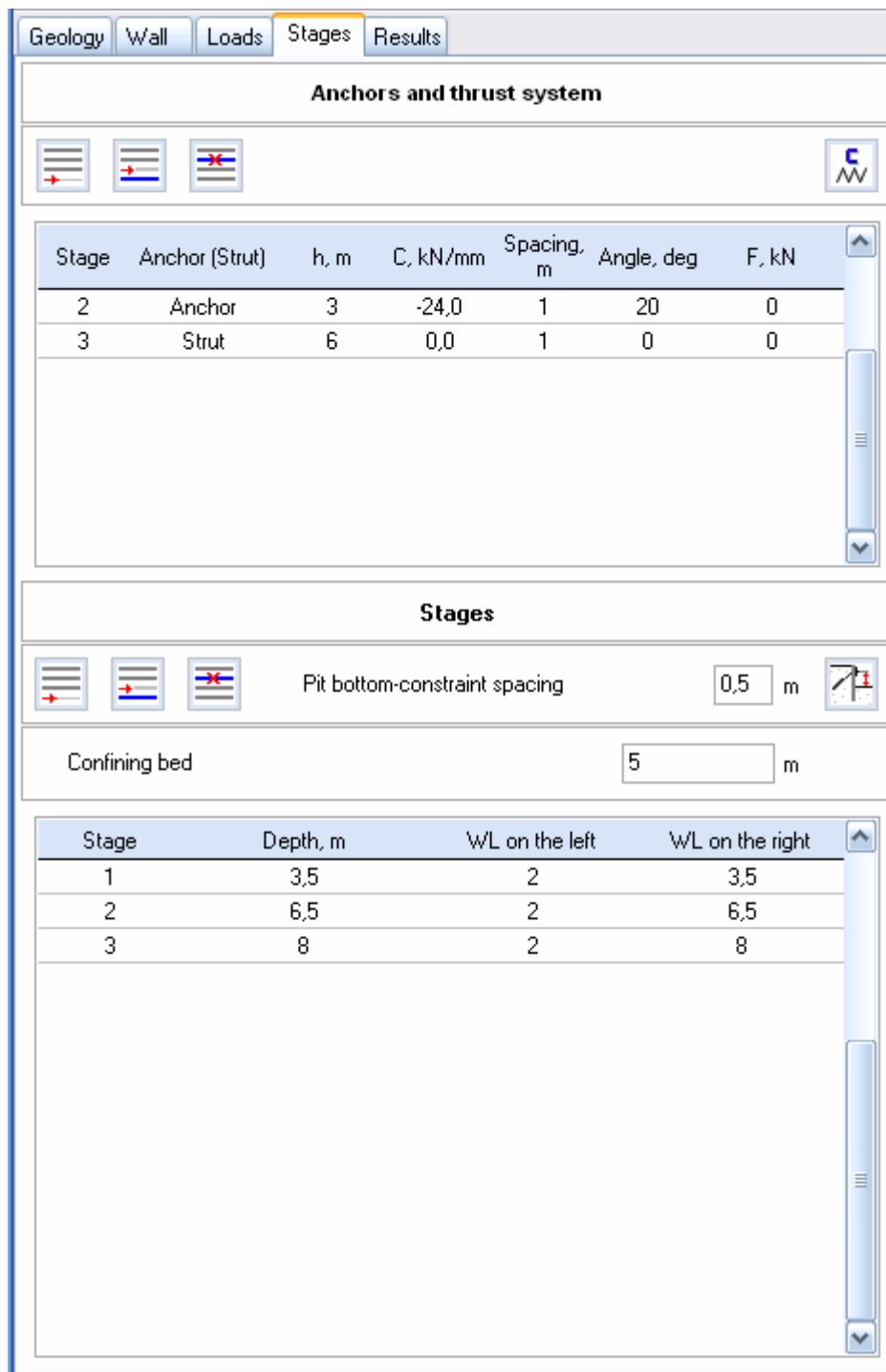
h, m – setting depth,

C, kN/mm – anchor or strut stiffness,

Spacing, m – anchor or strut spacing,

Angle, degree – horizontal tilting angle,

Force F, kN – anchor tension force.




For example, if anchor is arranged at a depth of 1,5 m, for its arrangement at Stage 1 it is necessary to excavate a pit approx. 2,0 m deep and arrange anchor, so anchor is taken into account in calculation from Stage 2.

For specifying the type of tie it is necessary to click the mouse on *Type* field and select *Anchor* or *Strut* from the list.

According to experimental data anchor stiffness varies from 10 to 50 kN/mm. Anchor stiffness can be also calculated in GeoAnchor program.

Depth of pit excavation stages is specified in *Stages* part.

The program can automatically fill depths of stages according to arranged anchors or struts. In order to do this, it is necessary to specify the depth from the anchor mouth till the bottom, minimum required for anchor arrangement by a drill rig (0,1-0,5 m), in *Pit bottom-constraint spacing* part and press  button.

«Results» insert

Results for each stage of sheet pile wall construction are outputted in *Results* insert.

The following buttons are placed in this insert:



[Add initial data](#) – adds calculation source data into the window with results.



[Save report](#) – saves calculation results in a RTF file, which can be opened in Word text editor.



[Copy image](#) – places a graphic field image in the clipboard.



[Export report to MS Word](#).



[Export results to MS Excel](#).

It is sufficient to press one of the following buttons on Toolbar for diagram plotting:



[Resultant pressure.](#)



[Horizontal displacements.](#)



[Shear force.](#)



[Normal force.](#)



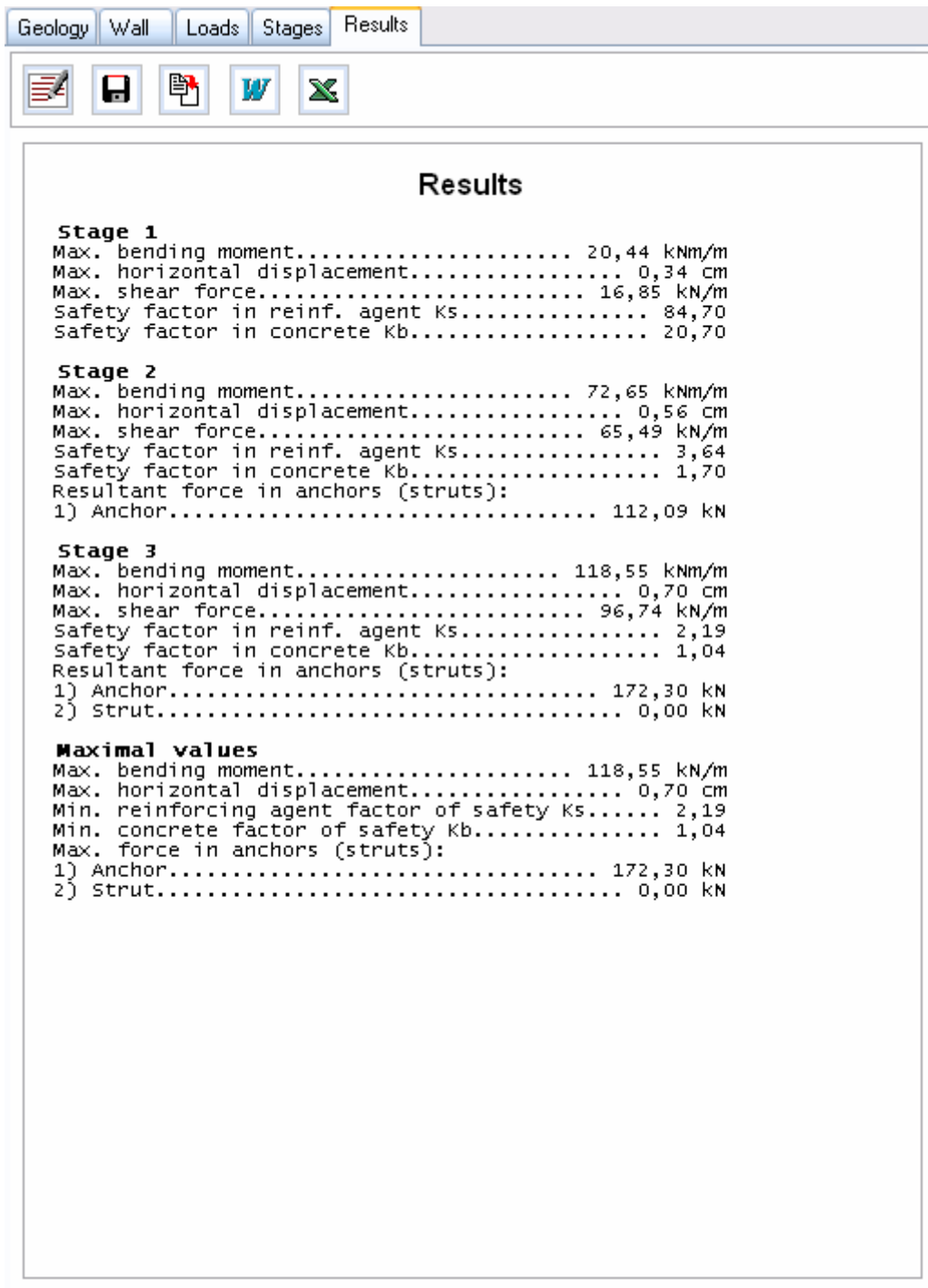
[Bending moment.](#)



[Reinforcing agent factor of safety.](#)



[Concrete factor of safety.](#)




There is a full list of diagrams in *Results* menu, which the program can display.

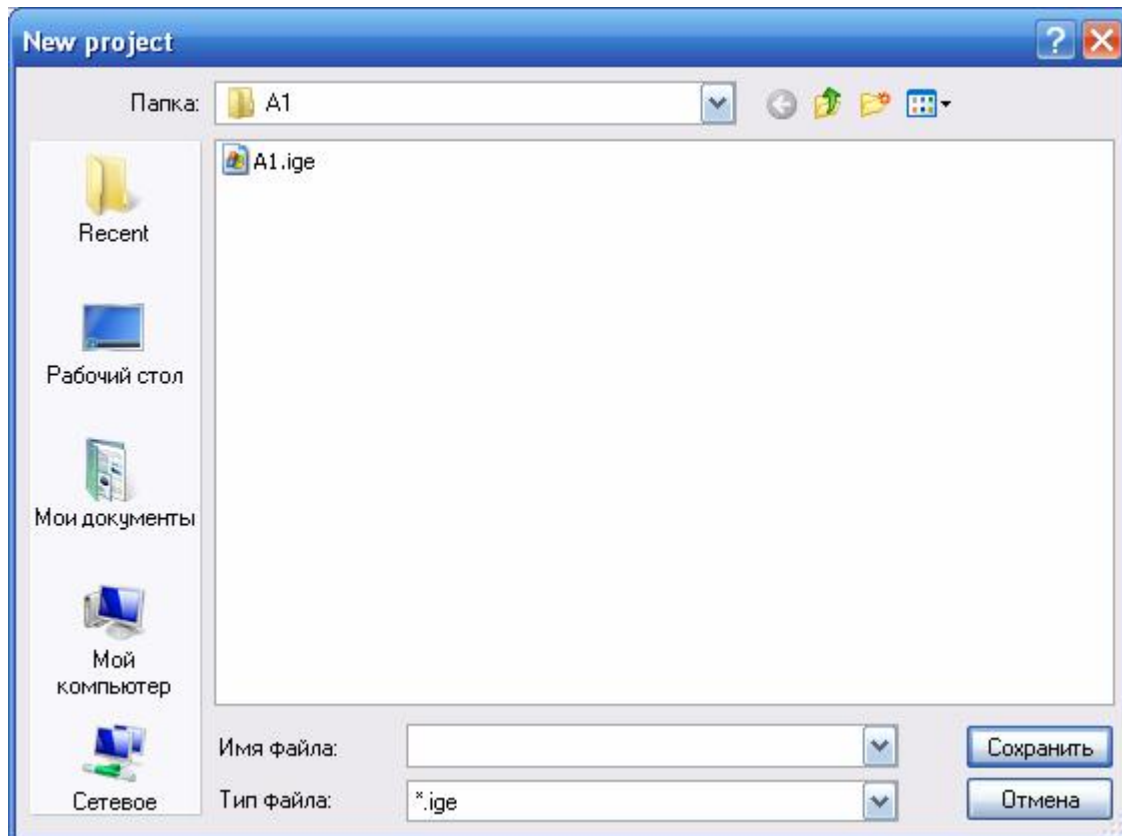
In order to select the stage, where a diagram should be plotted, it is necessary to use the stage selection window

When displaying diagrams of safety coefficients, if coefficient value exceeds the minimum one by 4 times, the diagram is displayed as a straight line on this section. Actually, the diagram should be outside the picture on these sections.


Example of calculation and program work.

For starting work it is necessary to create a project by pressing *New project*

 button and indicating a file for project data storage. Each project should be kept in a separate folder.



Actually, work can be started even without pressing *New project* button. In this case the program saves all the information in a temporary file, placed in the directory, where the program is installed. It is: C:\Program files\GeoSoft\GeoWall\Temp\no name.* on default.

It is recommended to save the project from time to time by pressing *Save project*  button.

Because of the fact that the program uses databases when working with tables in *Geology, Loads, Stages, Anchors* inserts, data is saved automatically immediately after changing values in the table.

All the values, such as pit depth, inputted in entry fields, are saved by pressing *Save project* button.

Then it is necessary to specify soil properties and groundwater level data in *Geology* insert.

Soil properties :

#	Type of soil	h, m	g, kN/m ³	gsat, kN/m ³	c, kPa	Angle, deg	ks, kN/m ³	λ _α
1	Filled soil	1,0	20,6	22,1	2,0	23,5	4000,0	0,43
2	Sand	2,0	21,0	22,4	2,0	29,6	4000,0	0,34
3	Clay sand	2,5	21,2	22,7	10,7	24,3	6000,0	0,42
4	Loam	3,0	21,2	22,1	17,0	18,7	4000,0	0,51
5	Clay	20,0	20,7	21,6	33,7	16,1	6000,0	0,57

Then sheet pile wall parameters, such as pit depth and pile length, are filled in *Wall* insert.

Excavating depth: 8 m

Wall height: 12 m

Embedding: 5 m

Friction coefficient: 0,67

After that, *Wall type* is selected and section parameters are specified by pressing *Cross-section properties* **E, J, A** button.

Wall type: Bored pile wall

Cross-section properties: **E, J, A**

Strength analysis:

It is necessary to input geometry and strength parameters of sheet pile walls, such as pile spacing for retaining wall from boring piles, pile diameter, type of reinforcing element, strength and elasticity modulus of concrete and metal.

Rebar cage can be used to fill geometry and strength parameters of reinforcing element.

Bored pile wall
✖

Characteristics of piles			Reinforcing agent characteristics		
Rows quantity	<input checked="" type="radio"/> 1 row <input type="radio"/> 2 rows		Reinforcing agent type	Rebar cage ▾	
Pile diameter	500	mm	Pipe diameter	440	mm
Pile spacing	400	mm	Pipe wall thickness	8	mm
Row spacing		mm	Cross-section area	20,358	cm ²
Elasticity modulus of concrete	30000	MPa	Moment of inertia	258,591	cm ⁴
Compressive strength of concret	20	MPa	Elasticity modulus of reinf.	210000	MPa
Tensile strength of concrete	2	MPa	Tensile strength of reinf.	365	MPa
			Reinforcement (row #1)	50	%
			Reinforcement (row #2)		%

Rebar cage

Characteristics

OK

Close

Loads			Section effective characteristics		
Bending moment, M	92	kNm/m	Destruction boundary	-134	mm
Force, N	41	kNm/m	Neutral axis coordinate	-148	mm
<div style="border: 1px solid gray; padding: 5px; display: inline-block;"> Calculation </div>			Moment of inertia, J	0,0012	m ⁴
			Cross-section area, A	0,041	m ²
			Elasticity modulus, E	30166	MPa
			Maximum active stress		
			In reinforcing agent	374,8	MPa
			In concrete	14,9	MPa
			Safety factor		
			for reinforcing agent	0,9739	
			for concrete	1,343	

If loads from nearby building or storage materials need to be specified in the project, it is necessary to pass to *Loads* insert, where corresponding fields should be filled.

Geology
Wall
Loads
Stages
Results

#	Space, m	Width, m	Deepening, m	qA, kPa	qB, kPa
1	0	5	0	5	10

Anchor or strut systems are specified in *Stages* insert.

Anchors and thrust system

Stage	Anchor (Strut)	h, m	C, kN/mm	Spacing, m	Angle, deg	F, kN
2	Anchor	3	-24,0	1	20	0
3	Strut	6	0,0	1	0	0

Stages

Pit bottom-constraint spacing: 0,5 m

Confining bed: 5 m






Stage	Depth, m	WL on the left	WL on the right
1	3,5	2	3,5
2	6,5	2	6,5
3	8	2	8

When all data is inputted, it is necessary to press *Wall calculation*  button.

For carrying out sheet pile wall strength calculation it is necessary to activate *Strength analysis* option in *Wall* insert.

Calculation results for each pit excavation stage are displayed in *Results* insert as well as in the form of diagrams in a graphic field.

Geology Wall Loads Stages Results

Results

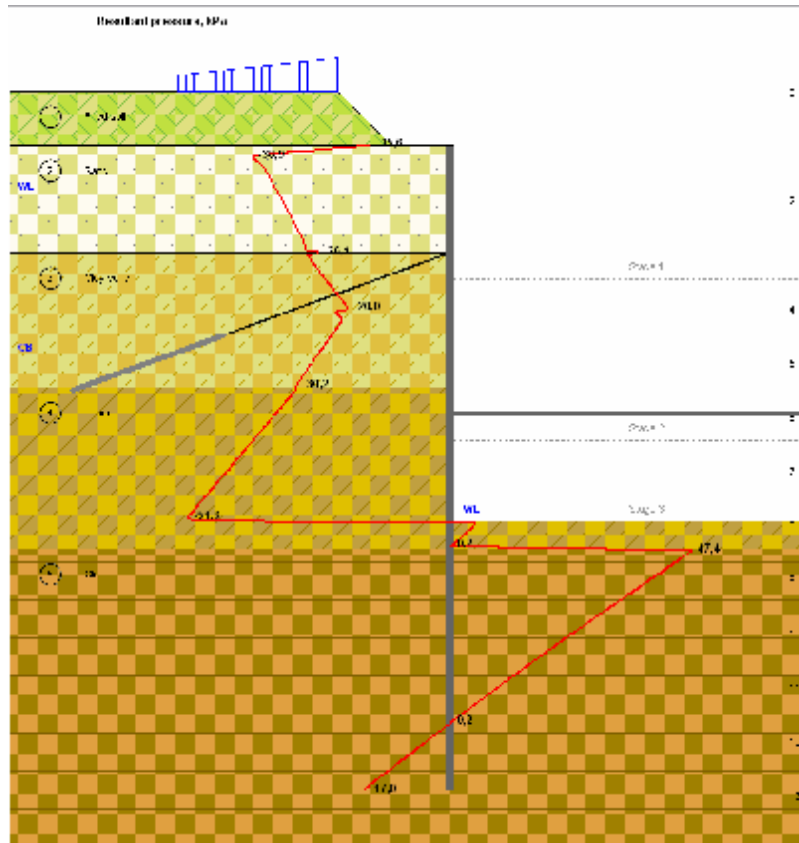
Stage 1
 Max. bending moment..... 20,44 kNm/m
 Max. horizontal displacement..... 0,34 cm
 Max. shear force..... 16,85 kN/m
 Safety factor in reinf. agent Ks..... 84,70
 Safety factor in concrete Kb..... 20,70

Stage 2
 Max. bending moment..... 72,65 kNm/m
 Max. horizontal displacement..... 0,56 cm
 Max. shear force..... 65,49 kN/m
 Safety factor in reinf. agent Ks..... 3,64
 Safety factor in concrete Kb..... 1,70
 Resultant force in anchors (struts):
 1) Anchor..... 112,09 kN

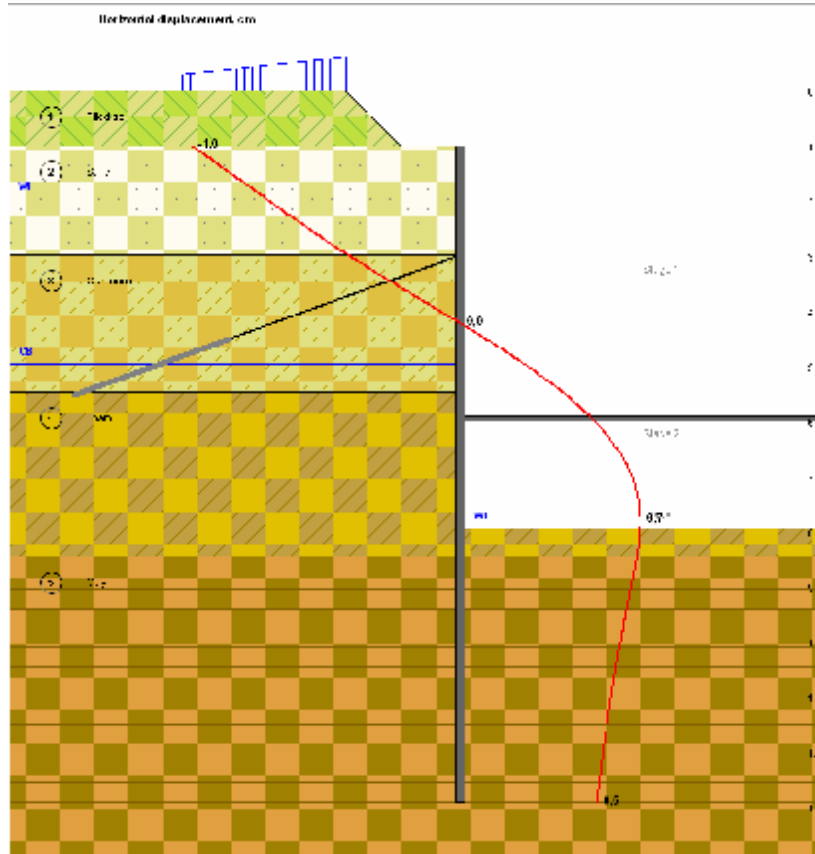
Stage 3
 Max. bending moment..... 118,55 kNm/m
 Max. horizontal displacement..... 0,70 cm
 Max. shear force..... 96,74 kN/m
 Safety factor in reinf. agent Ks..... 2,19
 Safety factor in concrete Kb..... 1,04
 Resultant force in anchors (struts):
 1) Anchor..... 172,30 kN
 2) Strut..... 0,00 kN

Maximal values
 Max. bending moment..... 118,55 kNm/m
 Max. horizontal displacement..... 0,70 cm
 Min. reinforcing agent factor of safety Ks..... 2,19
 Min. concrete factor of safety Kb..... 1,04
 Max. force in anchors (struts):
 1) Anchor..... 172,30 kN
 2) Strut..... 0,00 kN

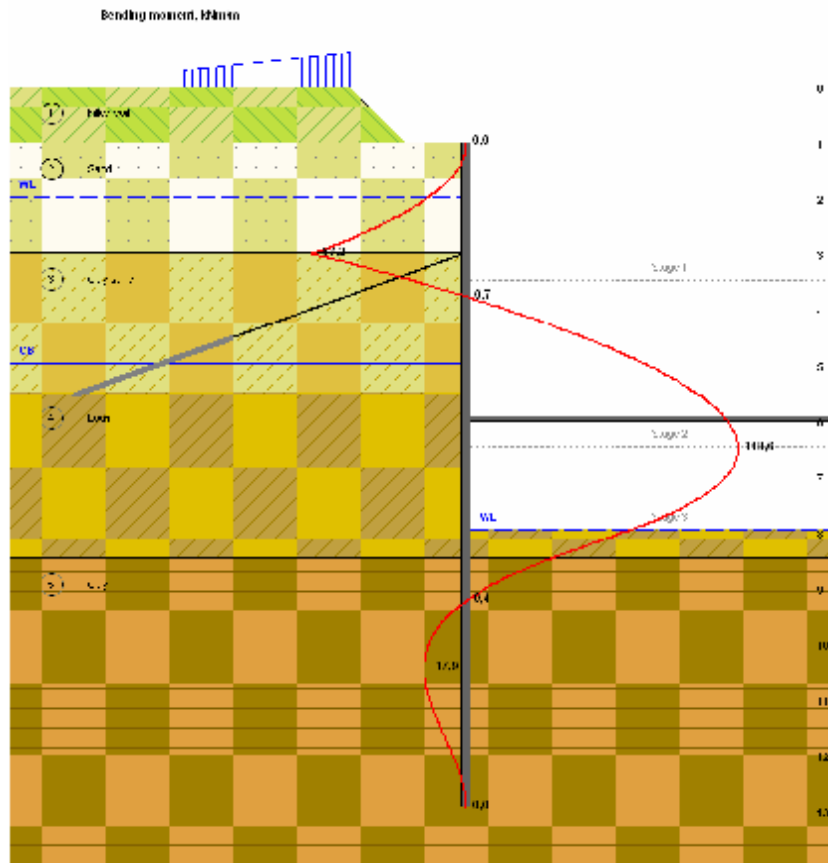
Calculation results in text format



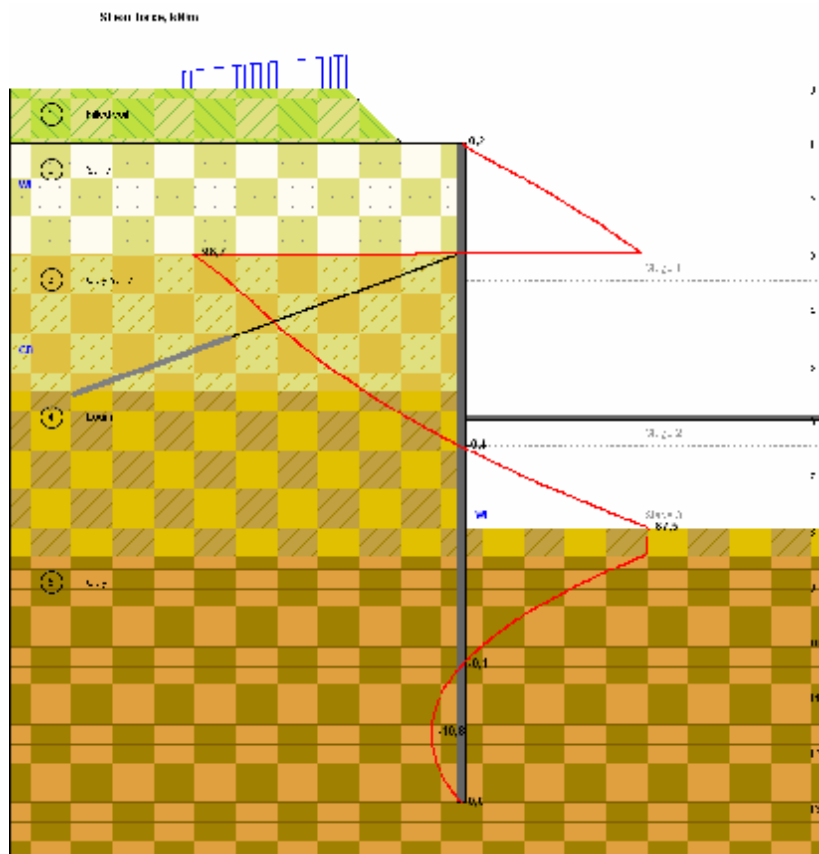
Calculated pressure, kPa



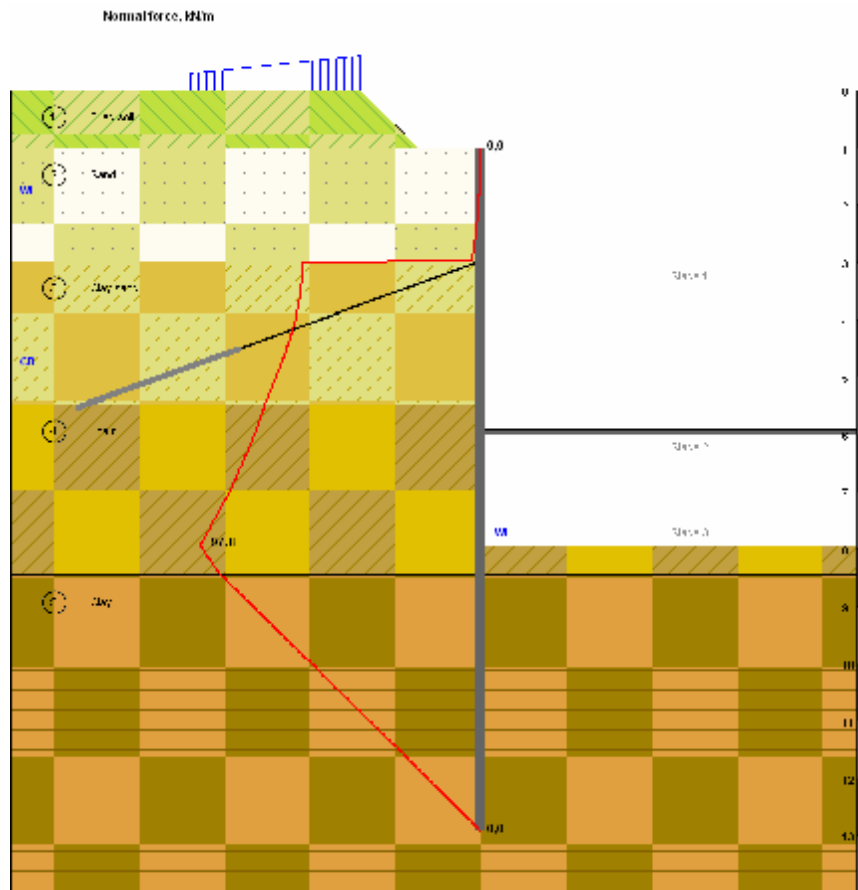
Horizontal displacement, cm



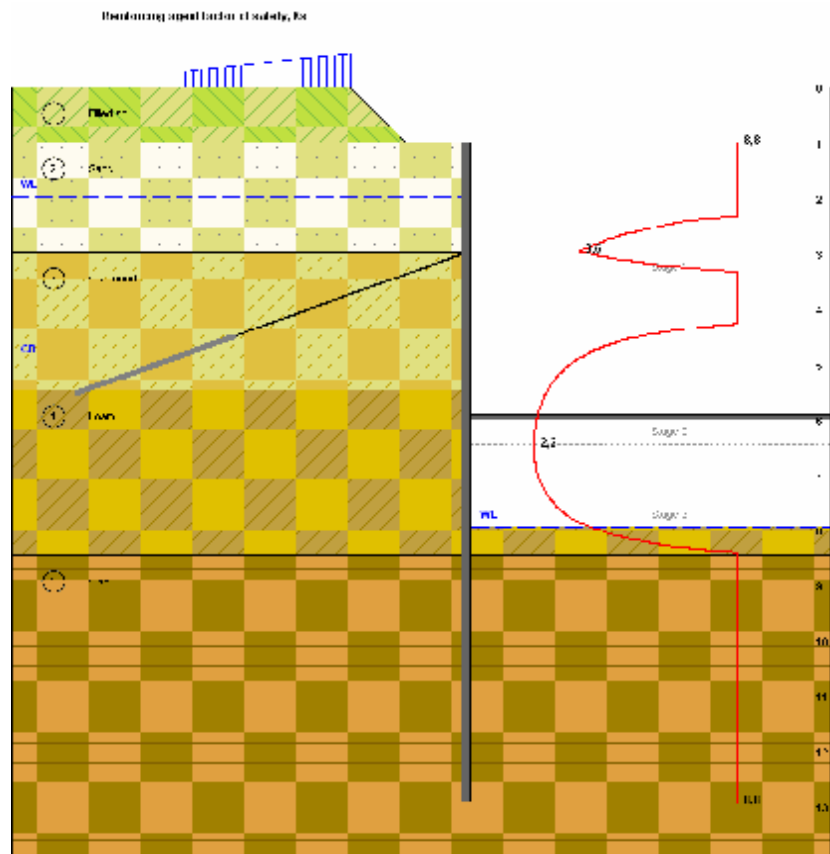
Bending moment, kNm/m



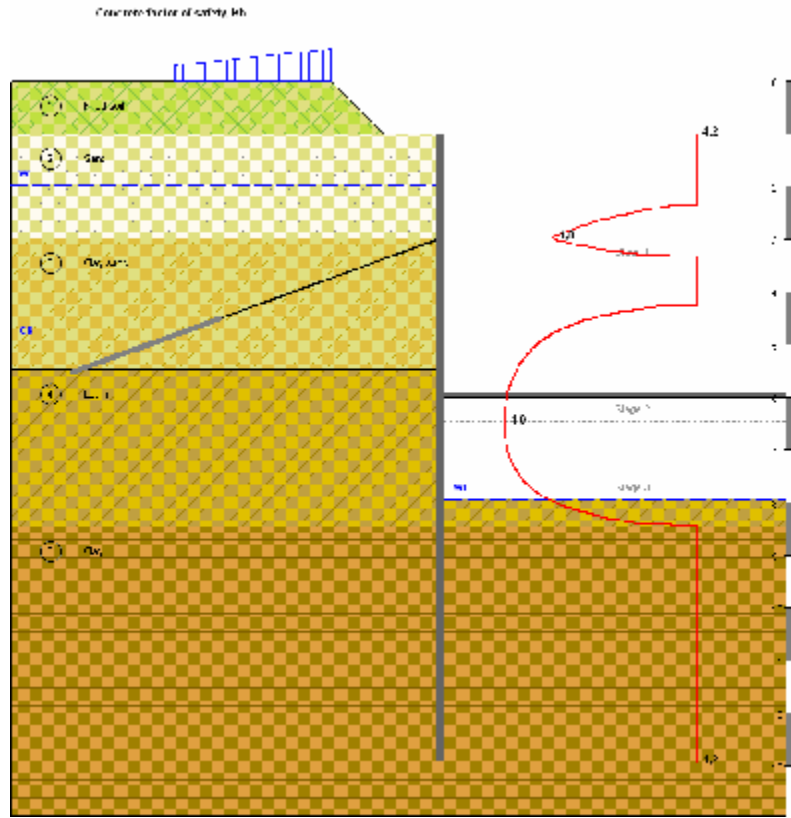
Crosscutting force, kN/m



Longitudinal force, kN/m



Safety coefficient in reinforcing element



Safety coefficient in concrete

REFERENCES

1. Bases, foundations and underground structures (Designer handbook). – Moscow: Stroyizdat, 1985.
2. Code of Practice 2.06.07-87 «Retaining walls, ship locks, fishways and fish protection structures».
3. Code of Rules 50-101-2004 «Design and construction of bases and foundations of buildings and structures», 2005.
4. Code of Practice 2.01.07-85* «Loads and stresses», 2003.
5. Malinin A., Malinin P., Chernopazov S. Method of calculation of retaining walls, constructed using jet-grouting // Permskie stroitelnye vedomosti.
6. Malinin A. Jet-grouting, 2007.