Practice course – braced excavation modeling with

DeepXcav 2010

Deep Excavation LLC
INTRODUCTION

DeepXcav 2010 is a software program for braced excavations in soils with 2D limit-equilibrium and non-linear analysis methods, and structural verification of all elements (with AISC, ASD, Eurocodes).

It offers the ability to analyze walls with multiple braces (tiebacks) in multilayered soils.

The non-linear analysis considers elastoplastic behavior for the whole soil-wall-support system.

The program also offers the ability to perform traditional limit-equilibrium analyses.

The graphical interface is completely interactive and the input is simplified to a great extend.

The program utilizes archives of wall types, structural and soil materials, ground anchors etc.

The analysis can be performed in either an ultimate state or at a service state (allowable design or LRFD).

The program offers the ability to automatically set all critical settings according to the desired design methodology.
INTRODUCTION

It is strongly recommended to model all the necessary construction stages as the real construction sequence affects the obtained results. It is therefore advised to subdivide the construction of the model in more than one stages as required.

Stage 0

- Define basic project information (name, coordinates etc).
- Reset global elevations to match the general site elevations.
- Material selection
  - Definition of soil types and soil stratigraphy (borings).
  - Definition of structural material archives for concrete, steel, and rebar steel used in walls and supports (tiebacks, struts, slabs, etc.).
INTRODUCTION

- Define the initial surface elevations and coordinates (horizontal, inclined, berms etc).
- Apply surface loads: strip loads (uniform or trapezoid), linear loads, 3D.
- Apply loads directly on the wall: Distributed loads, linear loads, moments, imposed displacements or rotations.
- Define basic wall type: Soldier pile walls, sheet pile, secant pile, diaphragm walls etc.
INTRODUCTION

➢ STAGE 1

- Excavation
  - Lowering the excavation to the first level (left or right, typically up to 10ft or 3.5m)

➢ STAGE 2

- Insert ground anchor, strut, or slab support above the excavation level. It is recommended to create a separate stage where the support is activated and the excavation levels are kept the same as in the previous stage.

- Define the newly inserted support type, basic dimensions, and prestress for ground anchors.
INTRODUCTION

➢ STAGE 3

- Final retained ground level;
- Final excavation to subgrade level.

➢ STAGE 4

- Application of seismic loads if required. The seismic load can be applied at anytime during the construction of the model, not only at the end. Like for the insertion of the supports, it is better to create an appropriate phase in which only the seismic load is applied.
- Select the applicable structural design code (USA, Europe, etc).
- Automatic generation of the Design Approached (Europe).
- Calculate and verify the design.
INTRODUCTION

- 4 levels of results
  - Summary tables showing principal results.
  - On screen diagrams.
  - Detailed diagrams.
  - Detailed tables showing wall results for every node and every stage along the wall.

- Report

  It is possible to construct a report with simple drag & drop of prototype report sections. The reports can include any stage and any design section of the calculation. Reports can be exported in PDF and Word formats.

  Do not forget to Press “Select all” to include all the stages and design sections for the report.
Soil properties

\( \phi' \) = friction angle used in calculations for non-clay soils and limit-equilibrium analysis.

Serves for the calculation of the lateral earth pressure coefficients \( K_0, K_a \) and \( K_p \).

\( E' \) = elasticity of the soil (in non-linear analysis).

\( \phi_{cv} \) = Constant volume shearing angle (used for clays in NL analysis).

\( \phi_{cv} \) is NOT used for sand, silt and rock soil types.

The program offers a number of correlations to help the user estimate \( \phi_{cv} \) and the calculation friction angle \( \phi' \).

\( \phi_{cv} \) is required for clay soil types when a non-linear analysis is performed.
SOIL PROPERTIES

\( \phi_{\text{PEAK}} = \) Peak angle of shearing (used for clays in NL analysis).

NOT required for sands, silts and rocks.

Correlations are available to relate \( \phi_{\text{cv}} \) with \( \phi_{\text{PEAK}} \) and \( \phi' \).

\( \phi_{\text{PEAK}} \) is required for clays in non-linear analysis and is used in determining the soil elasticity domain.

\( S_u \) (undrained shear strength) is not enabled with sands, silts and rocks. \( E' \) and \( S_u \) are required with clays as it defines the elastic domain frontier. When the simplified clay modeling is used, \( S_u \) is the only parameter used together with the undrained elastic modulus \( E_u \).

\( c' \) (effective cohesion) is an optional parameter for sands, silts, and rocks. For clays it is only used in limit equilibrium analysis during drained conditions.
SOIL PROPERTIES - ELASTICITY SOIL DOMAIN

- \( \sigma'_v \)
- \( \sigma'_h \)
- \( K_{A,peak} \)
- \( K_{P,peak} \)
- \( K_{A,cv} \)
- \( K_{P,cv} \)

INTERCEPTS ON AXES PROPORTIONAL TO APPARENT COHESION

ELASTIC DOMAIN EVOLUTION

ELASTIC DOMAIN
SOIL PROPERTIES

\[ \sigma'_V, \sigma_V, \Delta \sigma_V = 0 \]

\[ \text{T3 BOUNDARY} \]

\[ \text{TSP} \]

\[ \text{ES BOUNDARY} \]

\[ \sigma'_h, \sigma_h \]
SOIL PROPERTIES

Analysis warning: For clays when $\phi_{\text{PEAK}} = \phi_{\text{CV}}$

Analysis NL: it gives a warning since the apparent cohesion $c'$ cannot be determined
**SOIL PROPERTIES**

\[ k_x = \text{horizontal permeability coefficient.} \]

\[ k_z = \text{vertical permeability coefficient.} \]

\[ k_x \, \& \, k_z \text{ used to determine water pressures in ground water flow analysis (1D-2D) and hydrodynamic effects during earthquakes.} \]

\[ K_a = \text{active earth pressure coeffient. Calculated with Rankine method (default).} \]

\[ K_p = \text{passive earth pressure coeffient. Calculated with Rankine method (default).} \]

**Note:** \( K_a \) and \( K_p \) within the soil type dialog are calculated with the corresponding friction angle. It is strongly recommended to only use the default rankine values within this dialog.
SOIL PROPERTIES

- It is recommended to maintain the option Autoestimate Ka and Kp for friction angle checked. This allows the automatic calculation of Ka and Kp when the friction angle is changed.

- The option Use default engine Rankine Ka - Kp is used in the NL analysis.

- Option include soil in parameter variation: Includes the soil type in soil strength reduction design approaches (similar to Eurocode 7, etc)

A tool is available that allows the manual calculation of Ka and Kp based on various theories.
SOIL PROPERTIES

Friction Angle, Wall friction, and Slope Angle B:

<table>
<thead>
<tr>
<th></th>
<th>ax</th>
<th>g</th>
<th>ax</th>
<th>g</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ</td>
<td>30.000°</td>
<td></td>
<td>δ = 0.000°</td>
<td></td>
</tr>
<tr>
<td>β</td>
<td>0.000°</td>
<td></td>
<td>δwall</td>
<td></td>
</tr>
</tbody>
</table>

Active Coefficient Values

<table>
<thead>
<tr>
<th>φ</th>
<th>30°</th>
<th>δ/φ</th>
<th>0</th>
<th>δ/ψ</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ka</td>
<td>0.333</td>
<td></td>
<td></td>
<td>Kah</td>
<td>0.333</td>
</tr>
<tr>
<td>Coulomb</td>
<td>0.333</td>
<td></td>
<td></td>
<td>Richards-Shi</td>
<td>0.333</td>
</tr>
<tr>
<td>Richards-Shi</td>
<td>0.333</td>
<td>σ</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ka estimation dialog and data:

- ϕ': soil friction angle
- β = surface slope angle
- δ = wall-soil interface friction angle.

Note: For clays the angle d must necessarily be inserted in this window and it cannot change during all the course of the analysis. For sands d can be changed from the main menu and can have various values in any stage.

Note: When the window is closed the values of b and d are reset, however the Ka values are preserved.
### SOIL PROPERTIES

<table>
<thead>
<tr>
<th>Method</th>
<th>Active Coefficient</th>
<th>Passive Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Available</td>
<td>Surface angle</td>
</tr>
<tr>
<td>Rankine</td>
<td>Yes</td>
<td>No¹</td>
</tr>
<tr>
<td>Coulomb</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Caquot-Kerisel Tabulated</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Lancellota</td>
<td>No</td>
<td>-</td>
</tr>
</tbody>
</table>

¹ The Rankine values are converted automatically to Coulomb if the program detects soil-wall friction or an inclined surface with a single slope angle.

² Seismic effects are considered separately.
SOIL PROPERTIES

The Elasto-Plastic tab is used to define the elastoplastic behavior of the soil (and therefore the soil reactions) in each calculation stage, depending on the drainage conditions and the stress history.

For clays an option to use a Simplified clay model is also available (Total Stress Analysis).

For all soil types:

- Evc = Elastic compression modulus during primary loading. The oedometer modulus can be used as a rough approximation.

- Eur = Elastic modulus during reloading (on excavation side)

For the clays and the Simplified Clay Model:

- Eu = Elastic modulus during undrained conditions.
In the Tab D. Bond it is possible to select the ultimate adhesion value between the soil type and the fixed length of ground anchors.

Note: The software considers initially an arbitrary default value. This value is used for all anchors whose grouted length is within this type of soil layer. The possibility exists to define a custom value of skin friction for each tieback type irrespective of the soil type. In order to activate this option go to the Load/Support tab in the main program and uncheck the “Use soil bond values to calculate geotechnical capacity for tiebacks). In this way the software uses the defined value of \( q \) in the window of the pulling properties of each tieback section (archive).

A tool is available to correlate \( q \) with pressiometer test data according to correlations by Bustamante and FHWA. Note that \( q \) is dependent both on the soil type and on the drilling technique.
Surface profile definition

Conventional analysis: no warning.

NL Analysis: no warning.

Note: Remember to extend the model coordinates so that the surface profile fits.
Surface profile definition (inclined surface)

Conventional analysis: no warning

NL Analysis: Warning for approximations during analysis with inclined surface.
Surface profile definition

Conventional analysis: Warning that wedge analysis optimization might not be resulting in a proper solution. Recommendation -> deactivate wedge analysis optimization from ka button.

NL Analysis: no warning (left side modelled with a series of strip loads).
Surface profile definition
(Wedge analysis with Culmann's method)
Surface profile definition

Conventional analysis: Wedge analysis optimization routine warning.

NL Analysis: Warning that certain approximations are made.
## Available load types

<table>
<thead>
<tr>
<th>Surcharge Type</th>
<th>Permanent/Temporary (P/T)</th>
<th>Exists in Paratie Engine</th>
<th>Exists in Conventional Analysis</th>
<th>Conventional Analysis Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Line load</td>
<td>P &amp; T</td>
<td>No</td>
<td>Yes</td>
<td>Theory of elasticity. Can include both Horizontal and Vertical components.</td>
</tr>
<tr>
<td>Line load</td>
<td>P &amp; T</td>
<td>No</td>
<td>Yes</td>
<td>Same as above</td>
</tr>
<tr>
<td>Wall Line Load</td>
<td>P &amp; T</td>
<td>No</td>
<td>Yes</td>
<td>Same as above</td>
</tr>
<tr>
<td>Surface Strip Surcharge</td>
<td>P &amp; T</td>
<td>Yes</td>
<td>Yes</td>
<td>Same as above</td>
</tr>
<tr>
<td>Wall strip Surcharge</td>
<td>P &amp; T</td>
<td>Yes</td>
<td>Yes</td>
<td>Same as above</td>
</tr>
<tr>
<td>Arbitrary Strip Surcharge</td>
<td>P &amp; T</td>
<td>No</td>
<td>Yes</td>
<td>Same as above</td>
</tr>
<tr>
<td>Footing (3D)</td>
<td>P</td>
<td>No</td>
<td>Yes</td>
<td>Theory of elasticity. Vertical Direction only.</td>
</tr>
<tr>
<td>Building (3D)</td>
<td>P</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>3D Point Load</td>
<td>P &amp; T</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Vehicle (3D)</td>
<td>T</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Area Load (3D)</td>
<td>P &amp; T</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Moment/Rotation</td>
<td>-</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
Surface loads or strip loads (infinite length) are available with different options:
- Uniform field surcharge applied on the whole side (directly on the vertical stress)
- Strip load with theory of elasticity or distribution angle.
- Strip load not applied on the surface or with trapezoidal distribution.

Note: a load of equal length to the halfspace, is automatically used as a field surcharge surcharge even if the option is explicitly selected.
Surface loads
Field surcharge applied on model half space
(vertical stress increase on left)
Strip load with distribution angle (NL Analysis)

Uniform load of finite length

Distribuzione di sforzi verticali dovuti ad un carico nastroforme
B=2m; Dy=2m \( \beta = 45^\circ \)
Surface loads
Surface loads

Strip modificato per mezzo del fattore m

Diagram showing surface loads and forces with labels DY, B, QF, ZF, and ZETA. Graphs illustrate the distribution of vertical forces due to a nastro-formed load with parameters B=2m, Dy=2m, β=45°.
Surface loads from elasticity applied on the wall

Input file NL analysis.

step 0 : Stage 0
setwall Leftwall
geom 0 0
water -20 0 -15 0 0

dload step Leftwall -0.2 10.7774 0 0
dload step Leftwall -0.4 17.7593 -0.2 10.7774
dload step Leftwall -0.6 21.069 -0.4 17.7593
dload step Leftwall -0.8 22.3904 -0.6 21.069
dload step Leftwall -1 22.8495 -0.8 22.3904
dload step Leftwall -1.2 22.9459 -1 22.8495
dload step Leftwall -1.4 22.8805 -1.2 22.9459
dload step Leftwall -1.6 22.7365 -1.4 22.8805
dload step Leftwall -1.8 22.5512 -1.6 22.7365
dload step Leftwall -2 22.343 -1.8 22.5512
dload step Leftwall -2.2 22.1213 -2 22.343
dload step Leftwall -2.4 21.8914 -2.2 22.1213
dload step Leftwall -2.6 21.6565 -2.4 21.8914
dload step Leftwall -2.8 21.4186 -2.6 21.6565
Surface loads

When the theory of elasticity is used.
Surface loads

c' = 0 kPa

Wall displacement (cm)

Surcharge  Strip m = 1  Strip  Strip su semispazio  Strip m = 1.5

Load type
Surface loads

c' = 0 kPa

Wall moment (kN-m/m)

Load type

Surcharge  Strip m = 1  Strip  Strip su semispazio  Strip m = 1.5
Surface loads

\( c' = 10 \text{ kPa} \)

Wall displacement (cm)

<table>
<thead>
<tr>
<th>Load type</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surcharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strip m = 1</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strip m = 1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Strip su semispazio</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DeepXcav 2010 – Advanced course
WALL PARAMETERS

Diaphragm wall reinforcement options (left side and right side)
WALL PARAMETERS

Diaphragm walls shear reinforcement.

Note: In the default option there is no shear reinforcement.

- $s_V$ = Vertical spacing.
- $s_H$ = Horizontal spacing.

![Diagram of wall parameters with annotations](image)
WALL PARAMETERS

Warning: The reinforcement on the 2nd wall has the same layout (left & right) as the 1st wall.
WALL PARAMETERS

For pile walls and sheet pile walls: The parameter unsupported length factor below the excavation is important.
**WALL PARAMETERS**

Unbraced length for structural design of soldier piles and sheet piles

With factor $= 0$

With unbraced length increased by $\Delta H$

$\Delta H = \frac{x}{100}$ spessore paratia or

$\Delta H = LF \times$ Wall width
WALL PARAMETERS

Soldier piles and sheet piles: equivalent thickness calculation

Sheet piles:

\[ T_{eq} = 3 \sqrt{\frac{12J_{xx}}{S}} \]

- \( S = 1 \) for sheet pile walls

Piles:

\[ J_{eq} = \left( \frac{E_s J_{tubo} + E_{cls} J_{cls}}{E_{om} N} \right) \]

- \( N = 1/S, \ S = \) pile spacing
- \( E_{om} = E \) mat. Selected normalization material
WALL PARAMETERS

Soldier piles: equivalent thickness in DeepXcav

\[
J_{eq} = \left( \frac{E_s J_{tubo} + E_{cls} J_{riempimento+crosta}}{E_s N} \right)
\]

\[
J_{tubo} = \frac{\pi (R_e - R_i)^4}{4}
\]

\[
J_{riempimento+crosta} = \frac{\pi R_i^4}{4} \frac{x}{100} + \frac{\pi (R_c - R_e)^4}{4}
\]

\[
T_{eq} = \frac{3}{\sqrt{12J_{xx}}} \frac{S}{S}
\]
## WALL PARAMETERS

### TABella DI CONFRONTO SPESSORI EQUIVALENTI

<table>
<thead>
<tr>
<th></th>
<th>PARATIE 7.0</th>
<th>PARATIE PLUS (senza camicia)</th>
<th>PARATIE PLUS (camicia esterna)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$l_{tubo} \ (cm)$</td>
<td>1,2</td>
<td>1,2</td>
<td>1,2</td>
</tr>
<tr>
<td>$r_{est,tubo}\ (cm)$</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>$l_{tubo} \ (cm4)$</td>
<td>2246</td>
<td>2246</td>
<td>2246</td>
</tr>
<tr>
<td>$r_{est} \ (cm)$</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>$r_{int} \ (cm)$</td>
<td>7,8</td>
<td>7,8</td>
<td>7,8</td>
</tr>
<tr>
<td>$l_{cls - interno}\ (cm4)$</td>
<td>2907</td>
<td>2907</td>
<td>2907</td>
</tr>
<tr>
<td>$l_{cls - cover}\ (cm4)$</td>
<td>0</td>
<td>6346</td>
<td></td>
</tr>
<tr>
<td>% area cls</td>
<td>/</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>$l_{cls - tot} \ (cm4)$</td>
<td>11499</td>
<td>2907</td>
<td>9253</td>
</tr>
<tr>
<td>$E_{cls} \ (Mpa)$</td>
<td>31000</td>
<td>31000</td>
<td>31000</td>
</tr>
<tr>
<td>$E_{steel} \ (Mpa)$</td>
<td>210000</td>
<td>210000</td>
<td>210000</td>
</tr>
<tr>
<td>$s \ (passo in \ cm)$</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>$N \ (=1/s)$</td>
<td>0,025</td>
<td>0,025</td>
<td>0,025</td>
</tr>
<tr>
<td>$J_{eq} \ (cm4)$</td>
<td>98,58</td>
<td>66,87</td>
<td>90,29</td>
</tr>
<tr>
<td>$t \ (cm)$</td>
<td>10,6</td>
<td>9,3</td>
<td>10,27</td>
</tr>
</tbody>
</table>
WALL PARAMETERS

Soldier piles with offset

6. Pile offset options (double row of piles for soldier piles and tangent pile walls only)

- Use pile offset
- Use stiffness increase

\[
\frac{\Delta J}{palo} = \frac{x}{100} A \left( \frac{\text{offset}}{2} \right)^2
\]

A = Steel or concrete element area.

x = Factor for increase in stiffness by user.

Note: the increased moment of inertia DJ is only used in the equivalent thickness of the wall during analysis and not for the structural capacity calculations.
WALL PARAMETERS

Custom wall

Release bottom and top.

User mat.

Top elevation

Inertia

Equiv. thickness

$T_{eq} = \sqrt[3]{\frac{12J_{eq}}{S}}$

Warning:

For conventional analysis only first user beam is used. For Spring Analysis, ALL beams are used.
WALL PARAMETERS

Custom wall

Correct modelling

<table>
<thead>
<tr>
<th>Top (m)</th>
<th>Mat.</th>
<th>box (cm²)</th>
<th>Svincolo base paratia</th>
<th>Svincolo sommità paratia</th>
<th>t (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0: Use...</td>
<td>8333...</td>
<td>None</td>
<td>All</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>0: Use...</td>
<td>8333...</td>
<td>All</td>
<td>None</td>
<td>1</td>
</tr>
</tbody>
</table>

8 m

7 m
WALL PARAMETERS

Sezioni personalizzate

Assurdo!

8 m

7 m
WALL PARAMETERS

Release options

<table>
<thead>
<tr>
<th>Top (m)</th>
<th>Mat.</th>
<th>box (cm4)</th>
<th>Svincolo base paratia</th>
<th>Svincolo sommità paratia</th>
<th>1 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0: Use...</td>
<td>83333</td>
<td>None</td>
<td>Shear</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>0: Use...</td>
<td>83333</td>
<td>Mom...</td>
<td>None</td>
<td>1</td>
</tr>
</tbody>
</table>
WALL PARAMETERS

Custom walls

Currently a wall of this type can be modeled with the custom wall or with multiple wall elements.

With custom walls it is not possible to perform a structural analysis.

With additional wall elements it is now possible to use different wall sections (Version 8.1)
WALL PARAMETERS

Wall width (conventional analysis)

4m excavation 4 m in sand

4. Dimensions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width d</td>
<td>0.29  m</td>
</tr>
<tr>
<td>Hor. Space S</td>
<td>1.5   m</td>
</tr>
<tr>
<td>Passive width (below exc.)</td>
<td>0.9   m</td>
</tr>
<tr>
<td>Active width (below exc.)</td>
<td>0.3   m</td>
</tr>
</tbody>
</table>

The "passive width and active width below exc." are used to multiply soil pressures on the wall element below the excavation grade (see manual).
WALL PARAMETERS

Safety factors for conventional analysis

\[ F_{S_{\text{pass}} } = \frac{F_H \text{ resisting side}}{F_H \text{ driving side}} \]

\[ F_{S_{\text{rot}}} = \frac{M \text{ resisting}}{M \text{ driving}} \]

\[ F\text{S}_{\text{embed length}} = \frac{\text{Provided wall embedment length (below excavation)}}{\text{Embedment length required for } FS = 1 \text{ from preceding safety factors}} \]
WALL PARAMETERS

Active and passive widths (conventional analysis)

4. Dimensions

<table>
<thead>
<tr>
<th>Width d</th>
<th>0.45 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hor. Space S</td>
<td>1 m</td>
</tr>
<tr>
<td>Passive width (below exc.)</td>
<td>0.45 m</td>
</tr>
<tr>
<td>Active width (below exc.)</td>
<td>0.45 m</td>
</tr>
</tbody>
</table>

The “passive width and active width below exc.” are used to multiply soil pressures on the wall element below the excavation grade (see manual).

- \(FS_H = 1.597\)
- \(FS_{rot} = 1.053\)
- \(FS_{inf} = 2.001\)

4. Dimensions

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<tbody>
<tr>
<td>Hor. Space S</td>
<td>1 m</td>
</tr>
<tr>
<td>Passive width (below exc.)</td>
<td>0.1 m</td>
</tr>
<tr>
<td>Active width (below exc.)</td>
<td>0.45 m</td>
</tr>
</tbody>
</table>

The “passive width and active width below exc.” are used to multiply soil pressures on the wall element below the excavation grade (see manual).

- \(FS_H = 0.356\)
- \(FS_{rot} = 0.234\)
- \(FS_{inf} = 0.234\)

4. Dimensions

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The “passive width and active width below exc.” are used to multiply soil pressures on the wall element below the excavation grade (see manual).

- \(FS_H = 1.459\)
- \(FS_{rot} = 1.284\)
- \(FS_{inf} = 1.333\)
Ground anchors (Tiebacks)

Percentage of the fixed length included in the stiffness calculation.

Modellazione micropali di ancoraggio
Conventional analysis options

Analysis menu:

Stability + Menu:
Example 1: $\phi_{cv} = \phi_{peak}$ with clay model

Excavation 4.5 m in clay. Wall = default diaphragm wall

$\phi_{cv} = 21^\circ$, $\phi_{peak} = 15.1^\circ$ → Max displacement = 2.09 cm

$\phi_{cv} = 21^\circ$, $\phi_{peak} = 21^\circ$ → Max displacement = 2.32 cm
Example 1: $\phi_{cv} = \phi_{peak}$ with clay model
Example 2: Clays with overconsolidation

Excavation 6.5 m in clay. Wall = diaphragm, 40 cm, 6φ16mm reinforcement
Example 2: Overconsolidation and clays
Example 2: Sovraconsolidazione nelle argille
Example 3: Effect of undrained shear strength $Su$

Excavation di 4.5 m in clay. Wall = diaphragm (default)

$Su = 25 \text{ kPa}$: NOT CONVERGED
$Su = 30 \text{ kPa}$: 6.39 cm
$Su = 35 \text{ kPa}$: 4.8 cm
$Su = 40 \text{ kPa}$: 4.8 cm
Example 4: Imposed displacement

Excavation 5.0 m in sand. Wall = diaphragm (default)

Basic analysis (no imposed displacement)
Max displacement: 6.26 cm

Step 1

Step 2
Example 4: Imposed displacement
Example 4: Imposed displacement
Example 5: Conventional analysis

Excavation di 5.0 m in sand con parametri di default. Wall = diaphragm (default)

Eseguite 8 analisi convenzionali con diverse lunghezze d’infissione: da 3 m a 10 m a passo 1 m
Example 5: Conventional analysis

![Graph showing conventional analysis results.](image-url)
Example 5: Conventional analysis

Note: Conventional analysis always converges!!!
ANALISI CONVENZIONALE + NL

Model collapses + results do not include all stages in NL

Review of the classic safety factors:
## Soil properties dialog

### Soil type properties:

<table>
<thead>
<tr>
<th>Section</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.</strong> Default drained-undrained behavior for clays</td>
<td>Undrained behaviour</td>
<td>Drained</td>
</tr>
<tr>
<td><strong>4.</strong> Unit Weights - Density</td>
<td>$\gamma$&lt;sub&gt;true&lt;/sub&gt;</td>
<td>20 kN/m³</td>
</tr>
<tr>
<td><strong>5.</strong> Strength Parameters and Poisson Ratio</td>
<td>$c'$</td>
<td>0 kPa</td>
</tr>
<tr>
<td></td>
<td>$S_u$</td>
<td>150 kPa</td>
</tr>
<tr>
<td></td>
<td>$\nu$</td>
<td>0.45</td>
</tr>
<tr>
<td><strong>6.</strong> Permeability</td>
<td>$K_x$</td>
<td>1E-10 m/sec</td>
</tr>
<tr>
<td><strong>7.</strong> Minimum Pressures for clays (Conventional Calcs)</td>
<td>Min sh'</td>
<td>0 kPa</td>
</tr>
<tr>
<td><strong>8.</strong> Include soil in parameter variation</td>
<td>Include in parameter variation (i.e. Eurocode, Statistical analysis). It is strongly recommended to keep this option checked.</td>
<td></td>
</tr>
</tbody>
</table>

**Clay-model Spring Parameters**

- $K_a$ | 0.361 kPa |
- $K_p$ | 0.361 kPa |
- $K_a$ | 2.77 kPa |
- $K_p$ | 2.77 kPa |

- Autoestimate $K_a$-$K_p$ when soil friction values are changed
- Use default engine $K_a$ and $K_p$ (Rankine, soil friction only)

**IMPORTANT:** $K_a$, $K_p$, $K_a$ and $K_p$ are defined in the HORIZONTAL DIRECTION.

RECOMMEND: Define $K_a$ and $K_p$ values without wall friction or slope effects (best to use Rankine $K_a$, $K_p$). Define slope from the Model Tab. Define wall friction from Analysis Tab. Automatic Procedures here use only soil friction and wall friction=0 and slope angle =0 deg.

**9.2 A-skew coefficients**

- $K_{OC}$ | 0.531 kPa |
- $n_{OCR}$ | 0.5 |

$K_0 = K_{OC} \times (OCR)^{n_{OCR}}$
Elastic parameters disabled when only conventional analysis is used.

Soil properties:
CONVENTIONAL ANALYSIS OPTIONS

1. Wall Name
   Wall 1

2. Wall Section Properties
   Section: Wall 1

3. Dimensions
   - Top EL: 0 m
   - Depth L: 15 m
   - Bottom: -15 m
   - Equivalent wall thickness: 0.6 m

4. 3D Wall Coordinates
   - x/Wall: 0 m
   - Out-of-plane y: 0 m

5. Wall Friction - Base Adhesion Options
   - Ignore Wall Friction
   - Use wall friction as a percentage of friction angle: 0 %
   - Use set wall friction: 0.0
   - Vertical undrained adhesion percentage (classical analysis): 0 % of Ss for clays undrained analysis

6. Beam continuity - Release codes (BEF Analysis Only)
   - Top translation
   - Bottom translation
   - Top rotation
   - Bottom rotation

7. Wall Nodes (Analysis Settings)
   Number of Nodes nD: 0-200

Conventional analyses use nD to divide wall into smaller elements. BEF uses Mesh DELTA as defined in the "Analysis Tab" in the main form and recalculates nD.
PILE SPACING EFFECTS

Spacing can account for 3D effects.

In NL analysis the active width is used solely for the water pressures, and the same active and passive widths are used.

For continuous walls it is better to use the same spacing (1m or 1ft).
**Important Command**

**HELLO**

The development team would like to thank you for using our software.
This program has been created with a lot of love and effort :)
Deep Excavation LLC: Dimitrios Konstantakos
CeAS S.R.L.: Bruno Becci, Pierangelo Fellotti
HarpaCeAS: Paolo Sattamino, Carlo Pucci, Ada Zirpoli, Michele Boatti
EFG Group: Marco Pezzela, Ghenadii, Andrea Massioli
Many thanks to everybody that also helped but is not mentioned here.
We wish that this program helps you finish this project soon so you can enjoy your weekend by the sea or mountain more often :)

OK