GeoteknikPro

STUDIO — EXCAVATION SUPPORT STRUCTURES

USER GUIDE

and Calculation Methods Document

Bored pile wall · Diaphragm wall · Steel sheet pile · Berlin-type (soldier pile) wall
Staged construction · Spring solver · Anchors and struts · Global stability · Reinforced concrete and steel design

In accordance with TBDY 2018, KDYY and TS 500

Version 3.0.1

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Symbols and Units

The unit system is fixed at kN–m

The whole module works in kN, metres and kPa, and this cannot be changed in this version. When soil is transferred from the Geotechnical Report module, the unit conversion is made in a single place, and the conversions applied are reported at the end of the transfer.

Table 1. Symbols used in the guide

Symbol	Description	Unit
H	Excavation depth	m
D	Embedment depth (wall length below the excavation base)	m
K_a, K_p, K_0	Active, passive and at-rest earth pressure coefficients	—
K_{ae}, K_{pe}	Seismic active and passive earth pressure coefficients	—
ϕ′, c′	Effective friction angle and cohesion	° · kPa
S_u	Undrained shear strength	kPa
δ	Wall–soil interface friction angle	°
β	Ground surface inclination	°
k_s	Subgrade modulus (soil spring stiffness)	kN/m³
EI, EA	Flexural and axial stiffness of the wall per unit length	kN·m²/m · kN/m
U_x, θ	Horizontal displacement and rotation of a node	m · rad
M, V	Bending moment and shear force in the wall	kNm/m · kN/m
γ_{Rk}	Characteristic factor of safety in global stability	—
k_h, k_v	Horizontal and vertical pseudo-static seismic coefficients	—
r	Reduction factor depending on the permissible displacement	—
S_{DS}	Short-period design spectral acceleration coefficient	—
τ_f	Soil–grout skin resistance in the anchor bond zone	kPa
L_f, L_b	Free length and bond length of the anchor	m
$\delta_{v,max}$	Maximum surface settlement behind the wall	mm
γ_{sd}	Model uncertainty factor	—
M_p	Plastic moment capacity of the wall	kNm/m

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1. Introduction

1.1 What the module does

The Excavation Support Structures module carries out the design of an excavation support structure together with the staged construction sequence. The wall is solved as a beam together with the soil springs on both sides; each excavation stage continues from where the previous one left off. The results are the stage-by-stage and envelope values of moment, shear and displacement in the wall, support forces, adequacy of embedment, global stability safety, hydraulic checks, surface settlement and the design of all structural members.

1.2 The face concept

A project consists of several faces

The four sides of an excavation are not the same: depth, soil, adjacent structures, anchor arrangement and even the wall type change from side to side. The model is therefore built from independent sections called faces. Each face has its own wall, excavation, supports, surcharges and stages; if desired, it can also have its own soil profile. Materials, analysis options, plan and report details, on the other hand, are at project level and are shared by all faces. The face active on screen determines only the view; the calculations are not affected by it, and all faces are calculated.

1.3 Scope

- Structures around the excavation are modelled as loads and as neighbours; superstructure design is not a subject of this module.
- The soil is represented by a finite number of springs and the wall is solved as a beam element; limit equilibrium is used for global stability.
- Shotcrete and soil-nailed walls are not a separate wall type; a soil nail can be modelled approximately as a passive support.
- Surface settlement is the component caused by the excavation; consolidation settlement due to dewatering is not taken into account.

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2. Screen and Workflow

At the top is the main program's common ribbon (the Excavation Support menu appears on this ribbon under the module name), below it the face strip and sixteen tabs. The order of the tabs is the order of the workflow: input tabs, analysis, checks, design, plan, quantity takeoff and outputs. In the upper half of the input tabs the model is drawn continuously — three-dimensional on the left, two-dimensional section on the right — so that when a number changes you can see what has changed.

Table 2. Tabs

Tab	Contents
Materials	Concrete, reinforcing steel and structural steel.
Wall properties	Wall type, excavation base level, wall length, face length and type-specific dimensions; the section and stiffness values per unit length are shown read-only below.
Excavation design	Excavation-side geometry, retained ground surface, groundwater and tension crack.
Soil and spring method	Subgrade modulus method and soil layers; adding from the library and transferring from the Geotechnical Report.
Anchors / Struts	Support rows, their geometry and capacity data; for anchors, free zone and wedge visuals.
Surcharges	Area, strip, line and point loads.
System and stages	Pressure method choices, minimum loading requirement, staged construction settings, earthquake and serviceability limits; generation of the stages.
Analysis	Running the analysis, stage selection, envelope display, result charts and tables, convergence log and surface settlement.
Overall stability	Limit equilibrium solution and Newmark displacement check. This is a read-only section: the model is derived entirely from the excavation support inputs.
Checks	All checks in ten categories carried out at once with the "Check (All)" button, and grouping of the results.
Reinforced Concrete - Steel Design	Pile and diaphragm section, steel wall, capping beam, waler beam and steel waler.
Plan	Location of the faces on the ground; DXF underlay, face creation, shifting of the piles relative to the line and division of the elevation into sheets.
Quantity take-off	Quantities of piles, beams, anchors, sheet piles and steel accessories, with the project total.
Report - Data / Export	Project details, inventory of surrounding structures and official form data; report, drawing and PLAXIS export.

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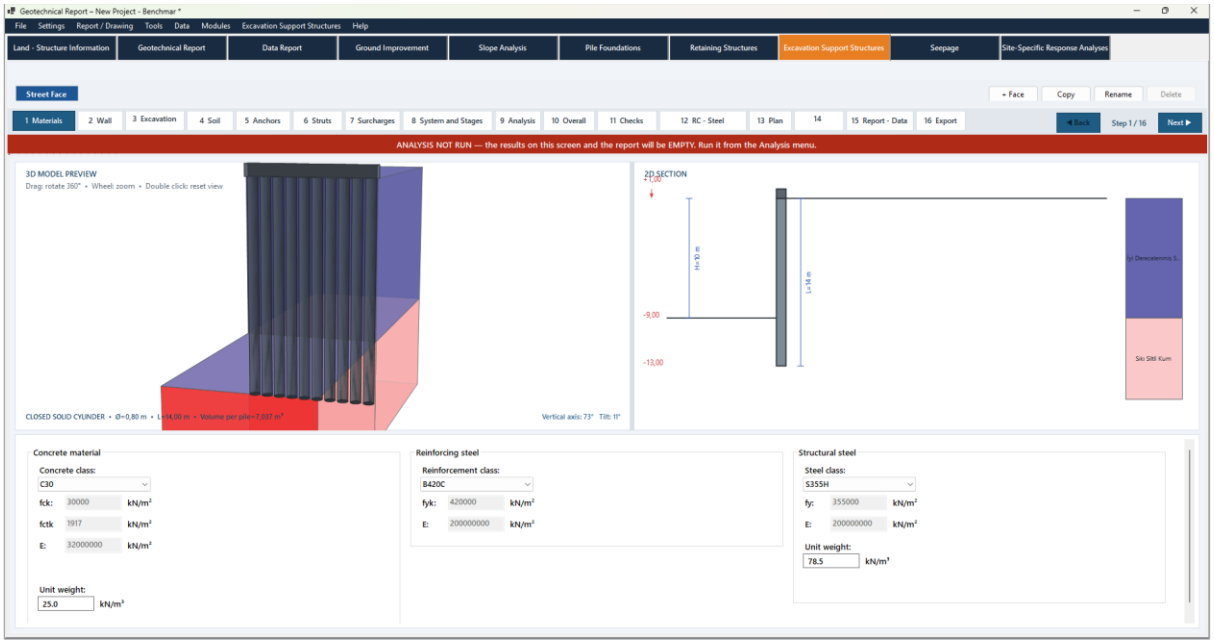


Figure 1. Excavation Support main window, 2 · Wall tab: face strip and sixteen tabs at the top, 3D model preview and 2D section in the middle, wall system and common geometry at the bottom

The “INPUT VALIDATION” button on the Analysis tab checks the inputs without running the analysis. If there are no findings, the message “Input validation: no issues found.” appears. If there are findings, the “Pre-analysis input check” window opens; the findings are listed in the Level, Face, Subject and Finding columns, blocking ones first. The same check is also made when the “ANALYSIS” button is pressed and before the analysis that runs automatically when a project is opened; no message is shown if there are no findings. If there is a BLOCKING finding, the “Continue analysis” button is disabled (“Continue analysis (blocked)”); if there are only warnings, the user may knowingly continue. “Back to inputs” does not start the analysis.

2.1 Currency of results

An out-of-date verdict drops by itself

Every result is stored together with the input that produced it. When the input changes, the results that depend on it drop and the screen returns to the “not run” state; results that are not affected stay in place. The same rule applies to the reinforced concrete verdict: an old “adequate” verdict is never carried over to new input. The up-to-dateness strip at the top of the screen reports when a result is no longer consistent with the input.

The project is saved to and opened from the main program’s single project file (*.geos); there is no separate Save or Open command inside Excavation Support. The only file command in the Excavation Support menu of the common ribbon is “New Project (this module only)”; it resets the Excavation Support data only. The module’s Inputs, Analysis, Design and Settings menus are also in this menu; under Settings are the “Unit system: kN–m”, “Model colors…”, “Design code…” and “Central safety settings…” commands. Report and drawing commands are in the Excavation Support submenu of the common Report / Drawing menu; the settings open as Excavation Support tabs in the main program’s single Settings window.

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3. Ways of Building the Model

3.1 Wall type and support system

There are four wall types: bored pile wall, diaphragm wall, steel sheet pile and Berlin-type wall. Depending on the choice, only the relevant dimensions are asked for; the section area, moment of inertia and stiffnesses are derived from them and shown read-only.

A new Excavation Support project starts with Ø80 cm bored piles, 1.00 m centre-to-centre spacing and a 90×90 cm capping beam; this starting section prevents the shear capacity (V_{max}) from being exceeded in the first analysis. When you change the pile diameter, the capping beam is updated to a D×D square section; you can then change it as you wish.

The support system is not selected, it is derived

The distinction between cantilever, anchored, internally braced or mixed systems is not an option: it is determined by the program according to whether anchors and struts have been defined. This distinction directly affects the seismic reduction factor and the factor of safety required for embedment.

3.2 Excavation, ground surface and water

The excavation side can have one of four geometries: horizontal, benched, sloped or continuously descending slope. The excavation-side slope is applied only in the continuously descending geometry; applying it to a bench as well would be a double penalty, and only this geometry really reduces the passive resistance. The retained ground surface can likewise be horizontal, inclined, or with a single or double bench.

There are three diagrams for groundwater: no water, independent hydrostatic (each side from its own level, linear down to the wall base, no interaction) and hydrodynamic (seepage-balanced; the front side is steeper and the two values become equal at the wall base). Water depths are measured from the top of the wall and the same reference is used for both sides.

The tension crack and the filling of the crack with water are flagged separately; the crack depth is calculated by the program according to the effective stress and the selected active pressure method.

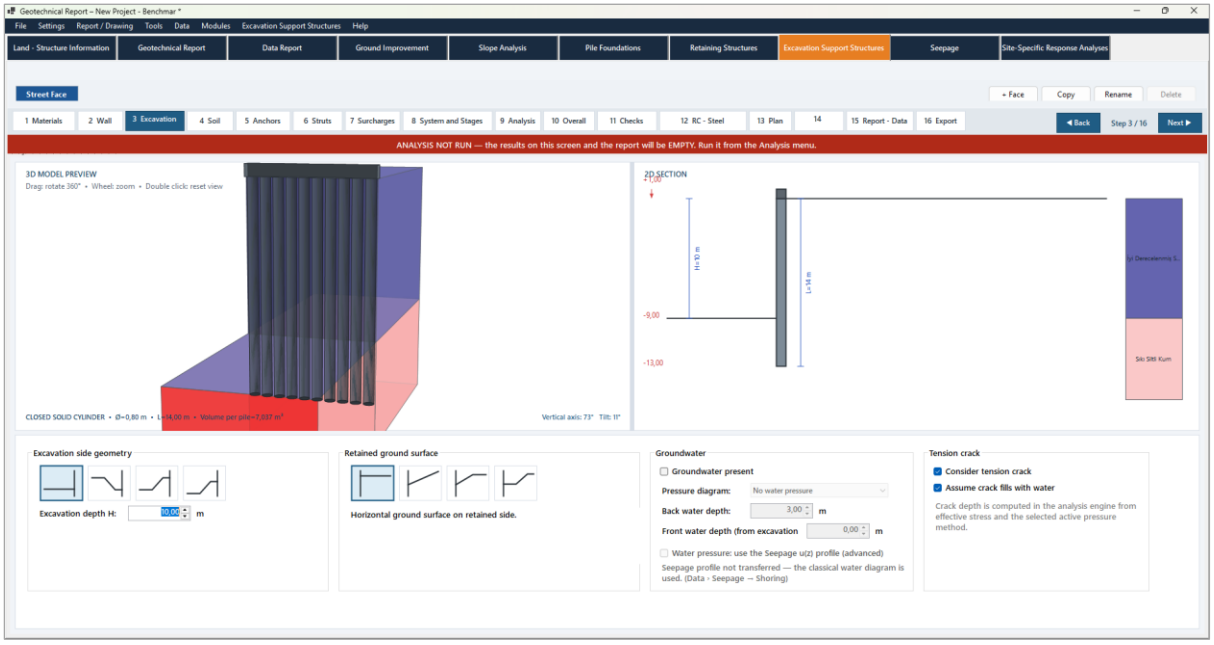


Figure 2. 3 · Excavation and Water tab: excavation-side geometry, retained ground surface, groundwater and tension crack

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3.3 Soil layers and transfer from the Geotechnical Report

Layers can be entered by hand, added from the soil library or transferred from the Geotechnical Report module. The data are checked before the transfer, with two kinds of outcome: BLOCK (no transfer is made, nothing changes) and WARNING (the transfer is made and the assumptions used are written). Since the unit systems of the two modules differ, the units are converted during the transfer; the unit of each field is given in its label.

Each layer also has a “high pore water pressure expected” flag. This is not a display preference: if such a layer lies below the water table, an upper limit on the seismic reduction factor comes into effect (see Section 6).

The wall–soil friction angle δ is entered in the layer table as a ratio to the soil’s ϕ’ (δ/ϕ’); the default ratio is 2/3 and the ratio cannot exceed 1. In this way δ cannot exceed ϕ’, which would make it impossible to produce the active pressure coefficient and leave the pressure empty.

If the borehole depth does not reach the wall toe, the program states this in a note shown in blue.

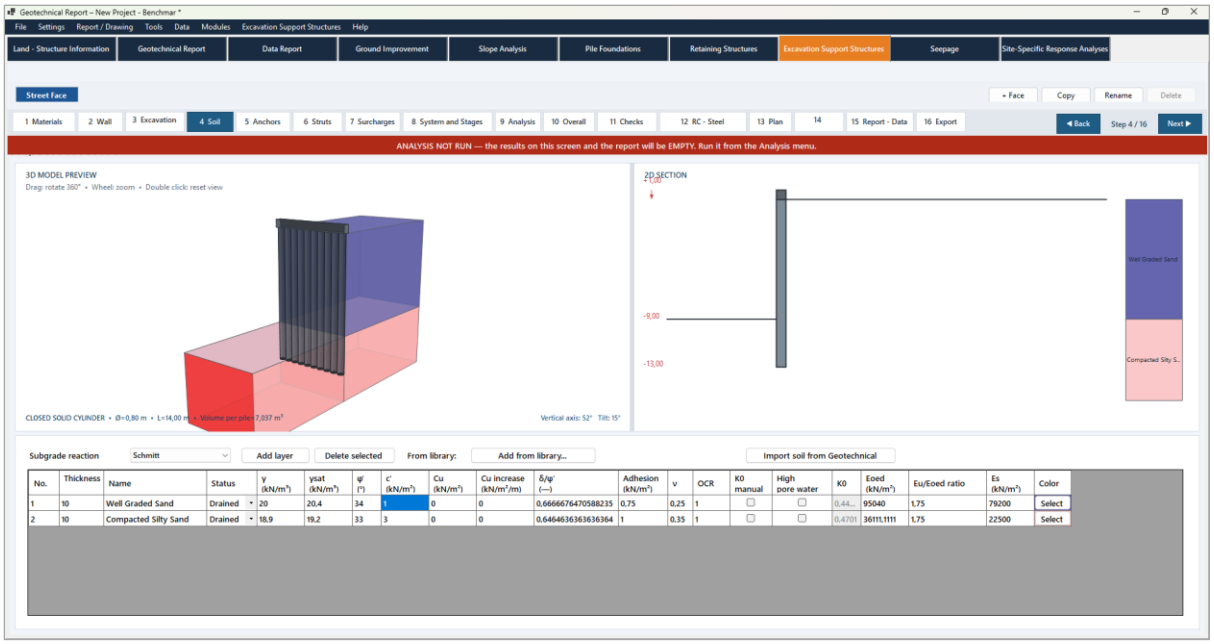


Figure 3. 4 · Soil tab: layer table, library and the “Import soil from Geotechnical Report” button

3.4 Supports

For anchors, the free length, bond length, inclination, horizontal spacing, bond diameter, number and diameter of strands, breaking strength, bond skin resistance and prestress are entered; the waler beam and bearing plate dimensions are also defined. For struts, the length, diameter, wall thickness, spacing, yield strength and preload are entered.

The value in the bond–soil adhesion (τ_f, kN/m^2) cell enters the capacity when the source on the Settings › Anchor τ_f/τ_c tab is “User input”. When derivation based on total or effective stress is selected, τ_f is calculated from the soil at the midpoint of the bond zone; the cell is locked and appears grey.

The free length is derived from a rule

The bond zone of an anchor must start behind the active wedge. The program offsets the active wedge plane backwards by a given distance and takes the free length up to this intersection; it rounds the result up to a whole metre to suit site practice. This calculation uses a single weighted average friction angle for the wedge; in a layered soil with markedly different angles the real plane is kinked, and this assumption makes the wedge look simpler than it is.

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Surcharges are of four kinds: area (infinite in both directions), strip (limited perpendicular to the wall, infinite along the wall), line (a single point perpendicular to the wall, infinite along the wall) and point (limited in both directions). An adjacent building is defined only as a strip load:

- A building is defined only as a strip load; on the Surcharges tab the “Structure (building)” column exists only in the Strip table.
    - Width, distance from wall and foundation level are entered.
    - Surface and point loads cannot be flagged as buildings.
- A building with a foundation depth of 0.30 m or more is modelled as a structure region in global stability.
    - Within its footprint the ground surface is the building base.
    - The load is transferred to the foundation level.
    - Slip surfaces may start at the building base.
    - Surfaces exiting within the footprint or on the side faces of the building are invalid: soil cannot slide into the basement volume.
- The building load is taken as a permanent load; with partial factors, the permanent-load factor applies.
- The top edge of the building follows the retained ground (also for sloping or benched ground).
- The model width is enlarged automatically to contain the building. The report contains a “BUILDING LOAD” note explaining this modelling.
- **Effect on results:** sections with a basement building close to the wall give lower factors of safety than a calculation in which the building is taken as a surface load only; this is the correct result.

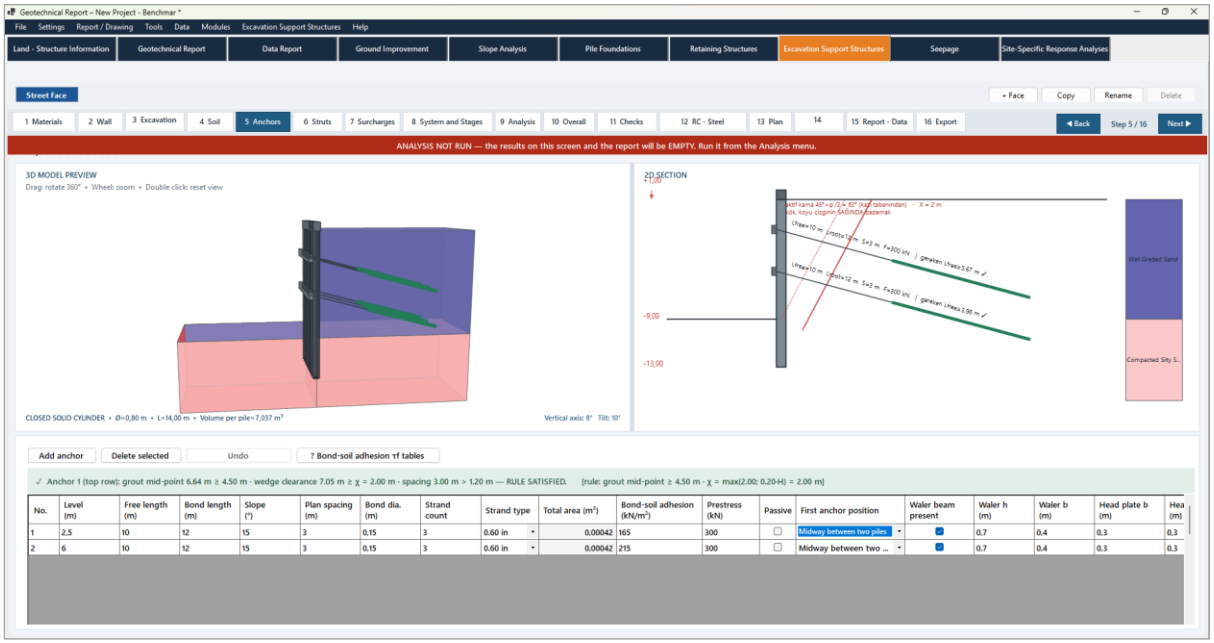


Figure 4. 5 · Anchors tab: anchor table; free length, bond length and active wedge boundary in the 2D section

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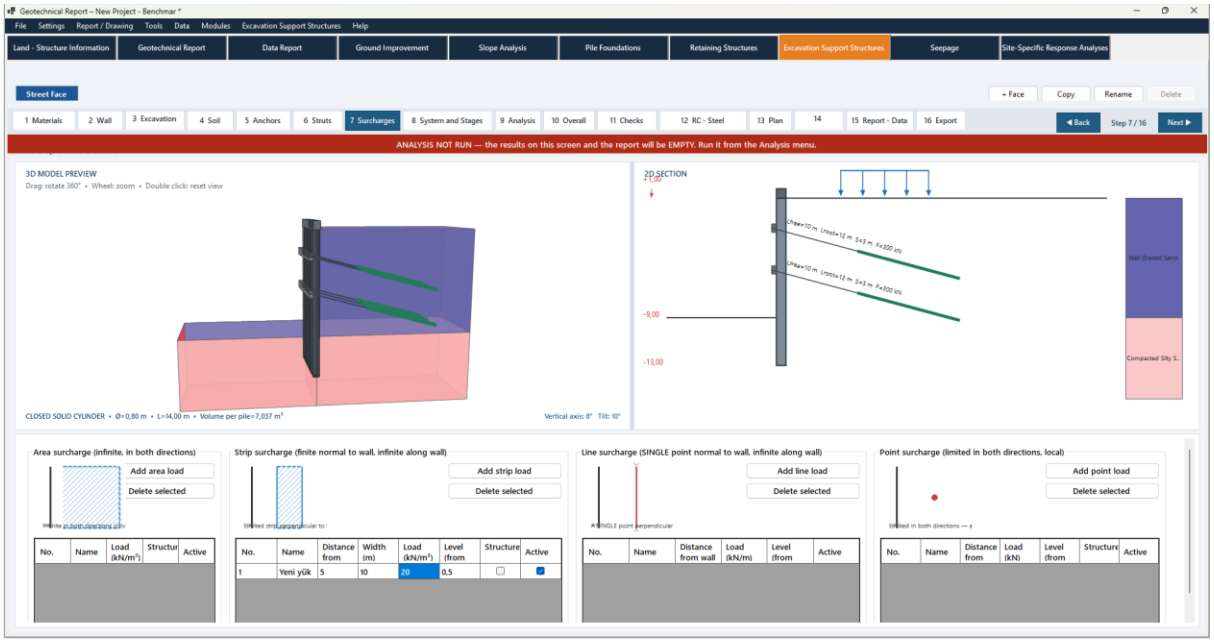


Figure 5. 7 · Surcharges tab: area, strip, line and point load tables

3.5 Plan and DXF

The Plan tab consists of four steps: loading an optional DXF underlay (only line segments are read and the unit is asked for), creating the faces or adding them by coordinates, centring the piles on the face line or offsetting them inwards/outwards, and deciding on how many sheets the face elevation is to be drawn. The last step does not affect the analysis; it is only the drawing layout.

Since the face length is used for the quantity takeoff, the Plan tab comes before the Quantities tab; this order is deliberate.

The face length does not enter the calculation; it is used only in the quantity takeoff, the monitoring layout and the ANNEX-2A table. Therefore, when a face is linked from the DXF on the Plan tab and its length is updated, the analysis and check results do not drop; the quantity takeoff is recalculated from the length on its own screen. The inclination of the excavation support line (free text) and the pile numbers selected for inclinometers are not calculation inputs either; changing them does not drop the results. The inclinometer pile is selected on the Plan tab by face and pile number; the selection affects the monitoring layout and the drawing, not the calculation.

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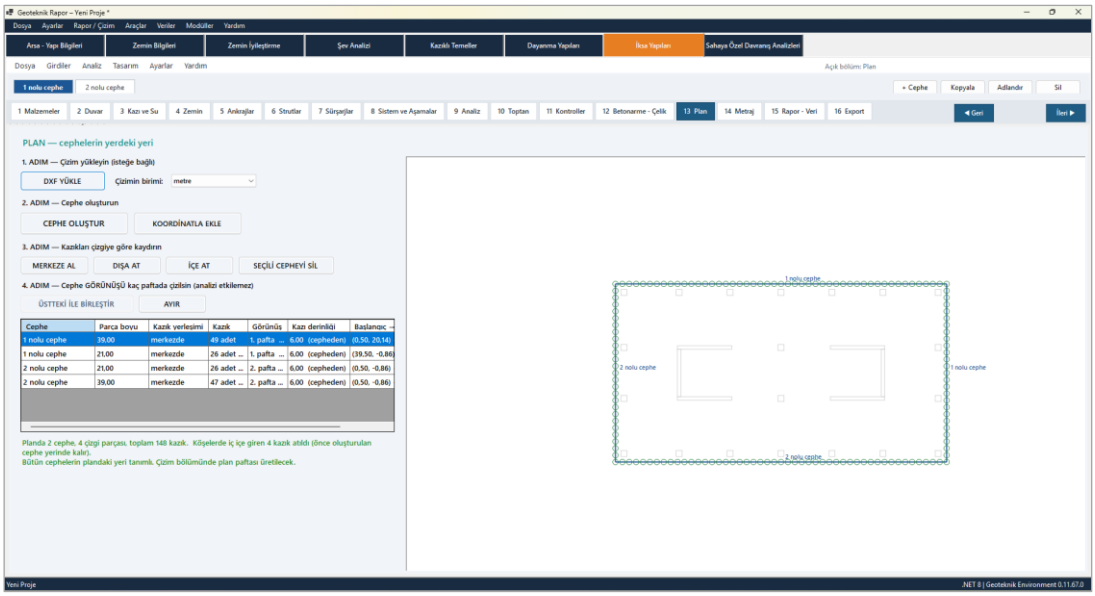


Figure 6. 13 · Plan tab: four-step face set-up, face table and the faces in plan (Turkish interface shown)

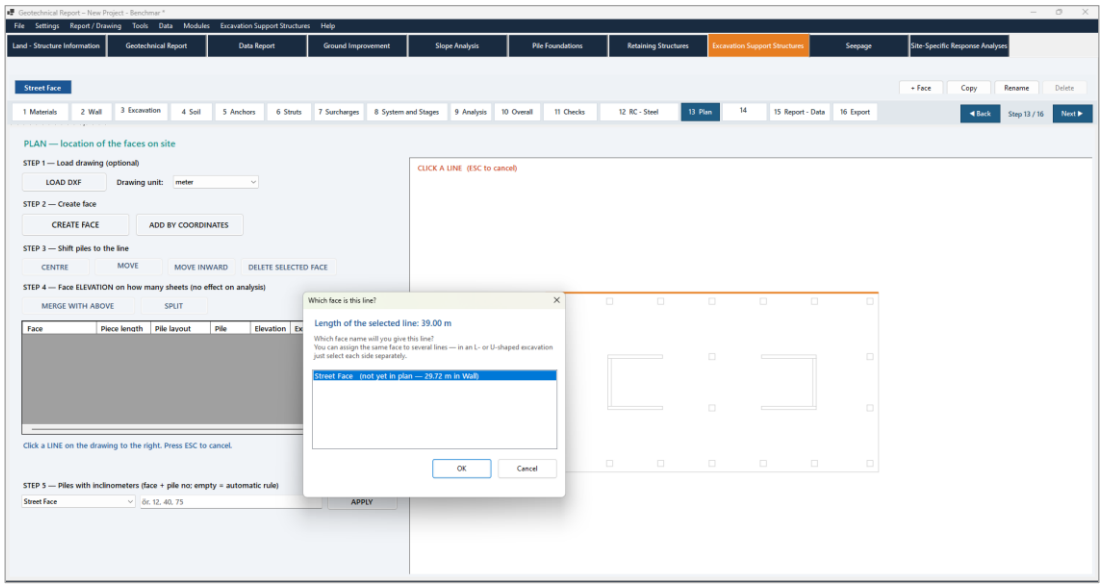


Figure 7. 13 · Plan tab: prompt asking which face the line selected from the DXF underlay is to be assigned to

3.6 Construction stages

Stages are not entered by hand; they are generated with a command. The generated sequence is as follows: the initial state (wall installation and at-rest pressure, no support active); for each support, first the free excavation stage needed before that support can be installed (the support is not yet active), then the stage in which the support is installed and prestress, if any, is applied; final excavation; an optional unplanned excavation stage; and finally, once, the earthquake check.

Free excavation and support installation are separate stages

Before a support can be installed, the excavation must first be taken down below it, and that excavation is made while the support does not yet exist. Merging these two events into a single stage makes the support appear to hold a displacement that has not yet occurred. The program therefore splits them into separate stages.

The unplanned excavation stage represents unforeseen over-excavation, and its depth is clipped so that at least one metre of embedment remains; if it has been clipped, the stage name says so. The earthquake check stage

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is added if the seismic calculation is active or if the system is flagged as permanent support — for a permanent support, the earthquake check is not optional.

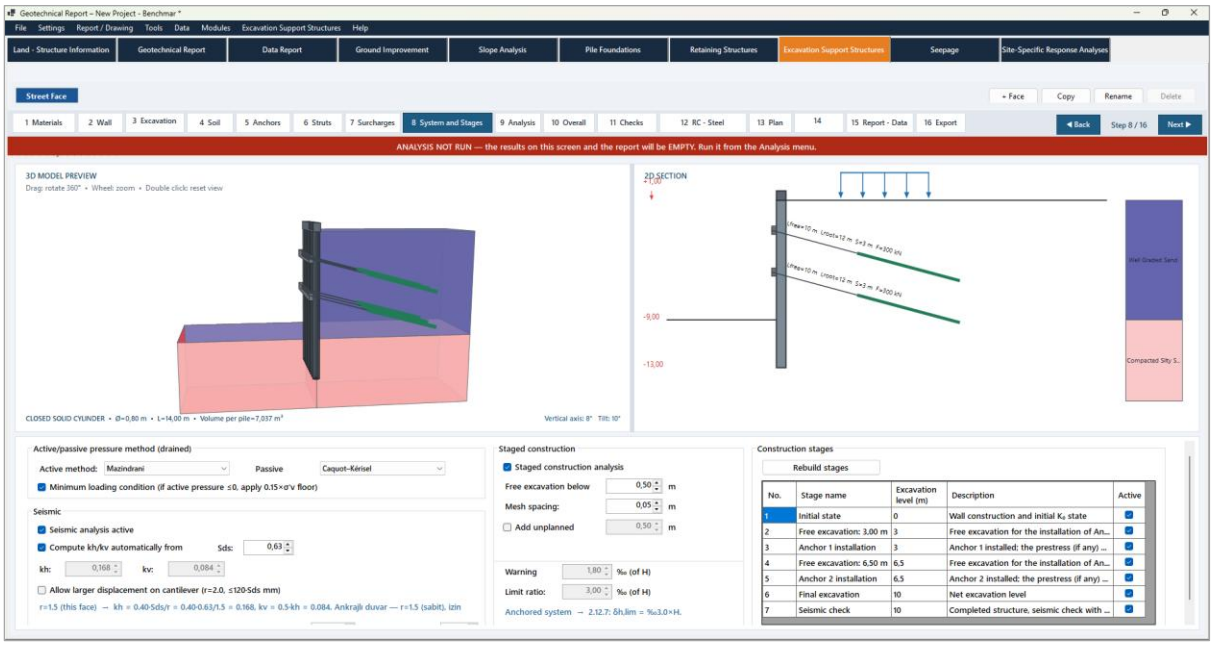


Figure 8. 8 · System and Stages tab: active/passive pressure method, earthquake settings, staged construction and list of construction stages

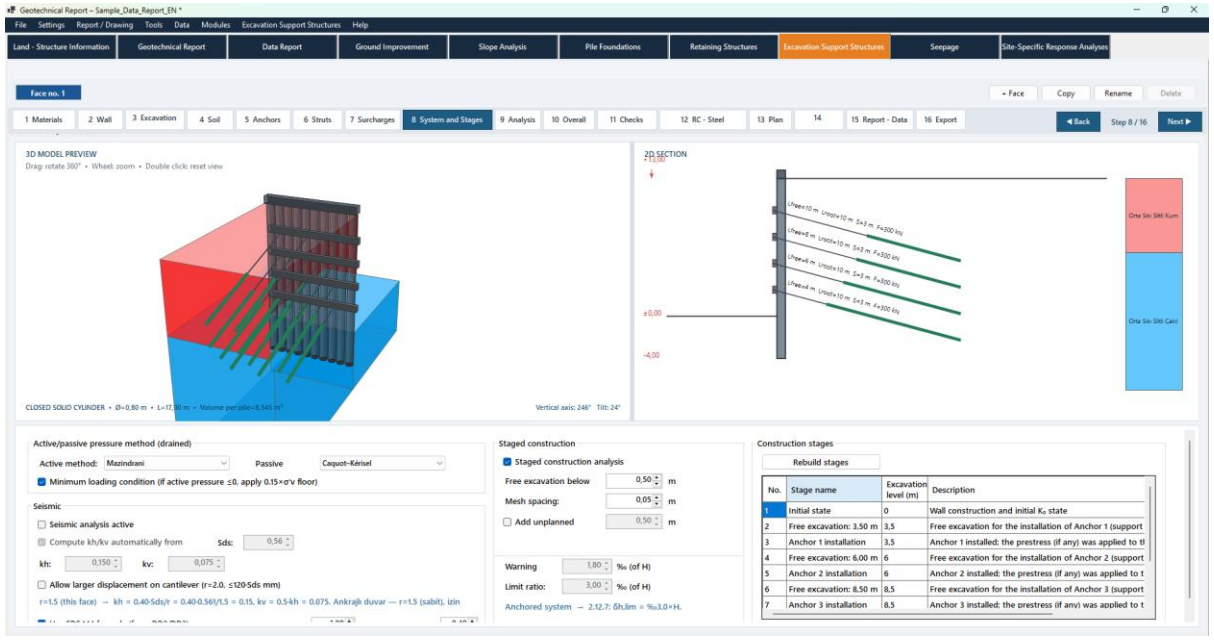


Figure 9. Construction stages generated for a face with four anchor rows: free excavation and anchor installation are separate stages

3.7 Pile and anchor layout

The pile positions are taken from the plan. For bored piles and Berlin soldier piles there is one member at each end, and the spacing is reduced so as to fit the face length: the number of members is ⌈L/s⌉ + 1 and the actual spacing is s′ = L/⌈L/s⌉ ≤ s. The face elevation, quantity takeoff, report and DXF table use the same piles; there are no two separate counts. Since diaphragm panels and sheet piles are placed side by side without gaps, this rule does not apply to them: for a diaphragm the panel width is given in the Settings window (default 2.50 m) and

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the last panel becomes the closure panel; for sheet piles the plan spacing equals the profile width (number ⌈L/b⌉).

The anchor positions are likewise determined from the plan. The “First anchor position” column in the Anchors table offers two options: midway between two piles (default) and on the pile axis. The first anchor is placed at the selected position; subsequent anchors are placed along the face according to the number of piles. The drawing, quantity takeoff and report give the same number.

Since the pile spacing is s’ ≤ s, an anchor spacing chosen as a multiple of s (for example a = 2s) may drift away from the pile midpoints. It is recommended that the anchor spacing be chosen as a multiple of the actual spacing of the piles in plan (s‘).

3.8 Secant (intersecting) piles and jet-grout block

If the piles intersect (spacing smaller than the diameter) and the system is a cantilever, the piles are assumed to alternate between unreinforced and reinforced: the design spacing is taken as twice the pile spacing, the flexural stiffness is calculated from the reinforced piles only, the reinforcement is halved in the quantity takeoff and the distinction is marked in plan.

A jet-grout block can be defined in the passive zone below the excavation base (Wall › “Jet-grout block…”). The block is treated as a composite soil with composite strength and stiffness; if the passive wedge is larger than the block width, a reduction is applied. In the global stability calculation the block also appears with its composite strength; each zone is solved with the material of its own layer.

3.9 Pore water pressure from the Seepage module

If the box in the Excavation and Water group is ticked, the pore water pressure u(z) can be transferred from the Seepage module. The user is asked during the transfer; if “No” is selected, the classic calculation is preserved exactly.

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4. Analysis Method

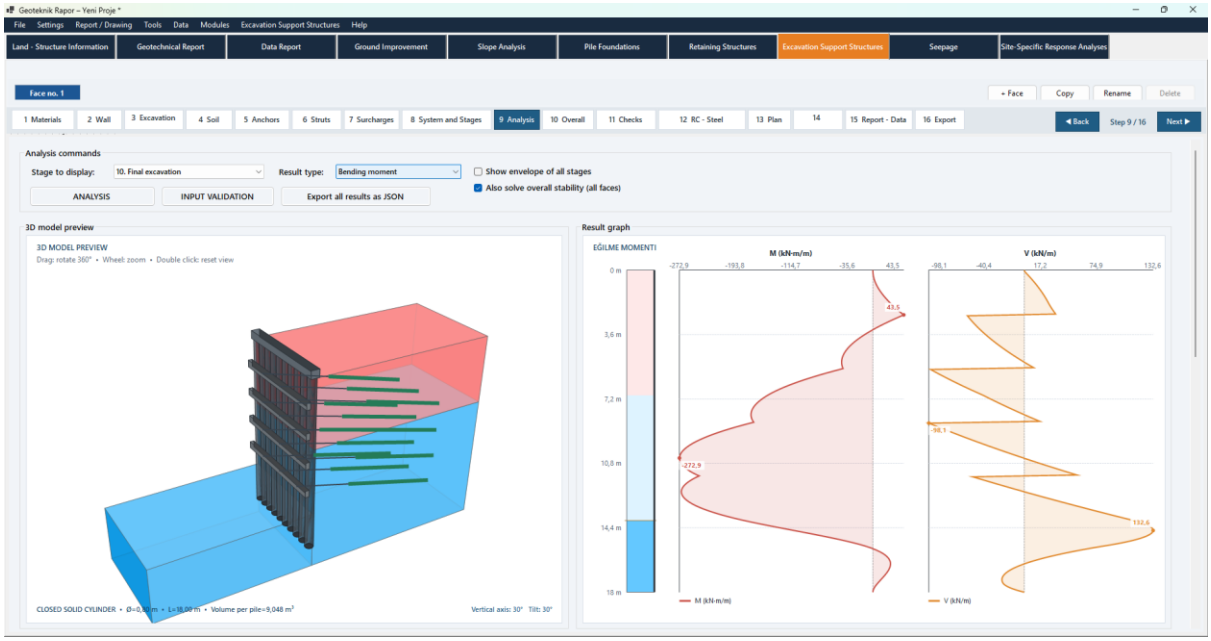


Figure 10. 9 · Analysis tab: bending moment and shear force diagrams at the final excavation stage

4.1 Lateral earth pressure coefficients

Separate methods are selected for active and passive pressure; there is a third choice for the undrained case. The at-rest pressure coefficient is calculated from the form of the classic relation extended for an inclined surface, and if the user supplies a value by hand, it applies absolutely.

On an inclined surface the plain relation can give $K_a > K_0$

The plain relation can push the active coefficient above the at-rest coefficient on a steep back slope; in that case the stiffness of the soil spring turns negative and the program produces a spurious failure. The at-rest coefficient is therefore calculated with its form extended for inclination; the inclination is defined in the upward direction only.

One of the methods that can be selected on the active side includes a correction based on a logarithmic spiral slip surface. The program checks the range of validity of this correction: outside the range it falls back to the classic solution without correction and warns; in any case the result cannot fall below the value given by the planar wedge, because the spiral solution cannot be below the planar solution. When the ratio of the interface friction angle to the internal friction angle exceeds a given value, it is reported that the result may be a few per cent higher than the published table — that is, conservative on the safe side.

The seismic coefficients are calculated from the classic pseudo-static relation and deliberately include neither the spiral correction nor the cohesion term; in this way, when the seismic coefficients are zero, the result reduces exactly to the static value. If the back slope remains too steep relative to the seismic inertia angle, the code's no-root branch is used and this is reported.

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4.2 Soil springs

The soil is represented by horizontal springs on both sides of the wall; the stiffness of each spring comes from a subgrade modulus method. Six methods are offered and the choice changes the result markedly.

Table 3. Subgrade modulus methods

Method	Assumption
Default method	Derived from the oedometer modulus and the wall stiffness; the exponent of the modulus is greater than one, so it gives very large subgrade moduli for rock-like moduli and the program reports this.
Reference-displacement method	Sets up a pressure gradient by dividing the difference between the passive and at-rest coefficients by a given reference displacement; the cohesion contribution is a separate term.
Classic depth-increasing method	A base value derived from bearing capacity factors plus a term increasing with depth.
Pressuremeter-based method	From the pressuremeter modulus and the rheological factor; at small diameters it is fixed at a lower dimension.
Linear-with-depth method	Starts from zero at excavation level and increases linearly with depth; a model set up for the passive side.
Elasticity-based method	From the modulus of elasticity, Poisson’s ratio and the wall stiffness.

One of the methods in the list is disabled because the placement of parentheses in the source expression is ambiguous; when it is selected, the elasticity-based method is used.

4.3 Spring solver

The wall is discretised with beam elements having horizontal displacement and rotation degrees of freedom at each node; the soil springs on both sides operate between their active, elastic and passive limits. When a spring reaches the active or passive limit its stiffness is not set to zero; a very small tangent stiffness is retained — this prevents the system from turning into a mechanism and the solution from becoming meaningless.

There is no boundary condition at the toe

No horizontal displacement or rotation boundary condition is applied at the bottom node of the wall. The wall is a free-ended beam held only by the soil; the adequacy of embedment is not imposed by a boundary condition but emerges from the solution itself.

The solution is carried out with a method that keeps the stiffness matrix constant over the iterations; each step is thus a back-substitution and hundreds of steps are completed in reasonable time. Two conditions are required together for convergence: the displacements must settle and the set of spring states must not change. Under-relaxation, oscillation capture and monitoring of the residual norm are included; the residual norm is not a convergence criterion and is reported for information only.

The initial at-rest stage is the reference state, and rigid body motion is suppressed in this stage; the displacements of the subsequent stages are thus measured from a true zero.

4.4 Staged memory

Each stage starts from where the previous one left off

When staged construction is on, each spring is re-anchored at the point where the previous stage left it; matching is done by depth, so the node mesh does not need to be the same between stages. This means that a support cannot undo the displacement that occurred before it was installed; it holds only what comes after. If staged construction is turned off, each stage is solved from zero and the supports appear more effective than they really are.

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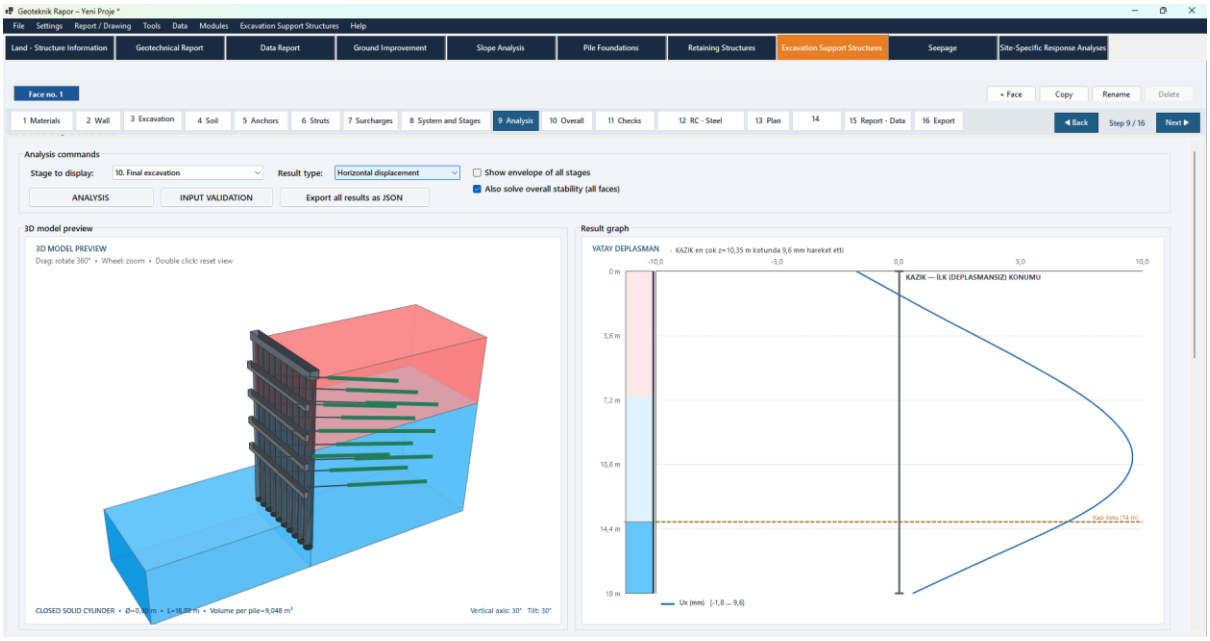


Figure 11. 9 · Analysis tab: horizontal displacement diagram of the wall at the final excavation stage

4.5 Converting surcharges to lateral pressure

There are two families. The first is the classic elastic solutions: the strip load as the integral of the line solution over the strip width; the point load with the classic vertical stress increase relation. The second is an approach developed for deep excavations that gives the horizontal stress directly — it is not multiplied by the active pressure coefficient. The second is the default, and the strip load is integrated by dividing it into many thin line loads. The choice is made with the “Use Ou method” box on the Settings › Excavation Support › Surcharge Method tab. Although the second family is not multiplied by the active pressure coefficient, the lateral pressure is capped: it can be at most Ka·q for a strip load and at most Ka·σv,max for line and point loads. Here Ka is the Rankine coefficient from the ϕ’ of the layer at that depth, and σv,max is the largest vertical stress directly below the load at the same depth (Flamant 2Q/(π·ζ) for a line load, Boussinesq 3Q/(2π·ζ²) for a point load).

4.6 Minimum loading requirement

In a cohesive soil, the calculated active pressure can drop to zero or become negative. In such a case a given fraction of the effective vertical stress is applied as a floor pressure. This requirement is on by default and is written in the report.

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5. Checks

The Checks tab runs all checks with a single command and for all faces; the results are divided into ten categories: deformation limits, wall strength, anchors and struts, embedment and passive resistance, hydraulic checks, global stability, soil stiffness, settlement and adjacent structures, construction and code. The anchor and strut rows of a face are refreshed only when that face is checked again; when all faces are checked together, the rows of another face are not deleted.

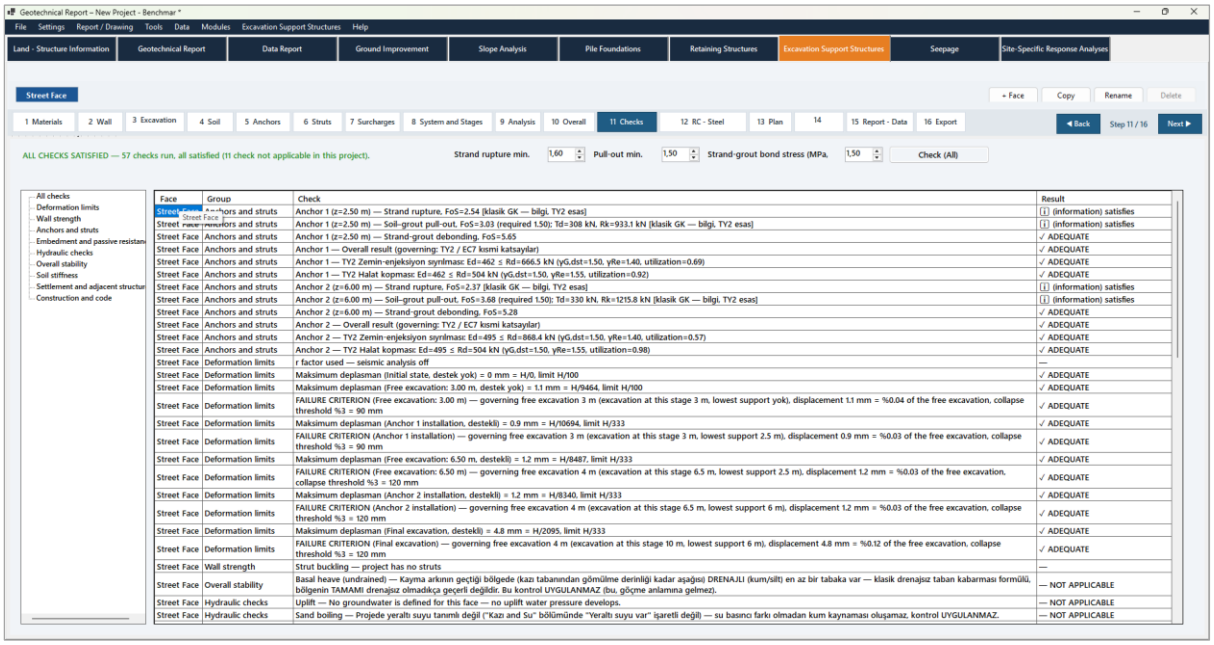


Figure 12. 11 · Checks tab: category tree and the result of each check

5.1 Embedment check

Embedment is checked by moment equilibrium about a pivot: the overturning moment of the active pressure is compared with the restoring moment of the passive pressure. The thrusts are taken from the nodal stresses of the solution. Separate pivots and separate required factors of safety are used for cantilever and supported systems.

The required embedment is searched first in coarse and then in fine steps; if the search fails, the result says so explicitly. The mobilisation ratio of the passive resistance is reported separately and flagged above a given level: fully mobilising the passive resistance means an unacceptable displacement.

The embedment check is static

No seismic increment is applied in this check; wall friction is taken to the extent it is contained in the selected pressure method. Both points are written next to the result.

5.2 Global stability

Global stability is calculated with the solver of the Slope Stability module. The section is read-only: the model is derived entirely from the excavation support inputs, and no separate slope model is built.

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The wall is not a rigid block but a support member

Treating the wall as a rigid block forbids the slip surface from passing through it and inflates the factor of safety on the unsafe side. In this module the wall is a support member: its own shear and moment capacity enters the resistance side. The moment capacity comes from the real axial load–moment diagram and the real reinforcement; if it cannot be calculated, no global stability analysis is made and the user is warned; no default capacity is assumed.

Anchors and struts are transferred as supports. The capacity of an anchor never falls below its prestress. Surcharges are transferred as strip loads, and there is a check that prevents double counting; a strip load flagged as a building is modelled as a structure region if its foundation depth is 0.30 m or more (3.4). In global stability a strut is a reaction member:

- A strut is a passive, compression-only reaction member; it cannot drive the sliding mass. Its capacity comes from its structural strength, not from the reaction given by the solver.
- If the strut does not resist movement on a slip surface, its contribution is taken as zero (it is not counted as driving).
- Surfaces that are not driven towards the excavation (negative driving moment) are invalid in all methods.
- **Effect on results:** since a strut cannot drive the sliding mass, unrealistically low factors of safety do not occur in braced sections.

Restricting the search to code-compatible surfaces only is an option; however, it does not count as an accuracy improvement. The wedge and undercutting mechanisms that are switched off do occur in reality and may govern in some sections; the program states this explicitly.

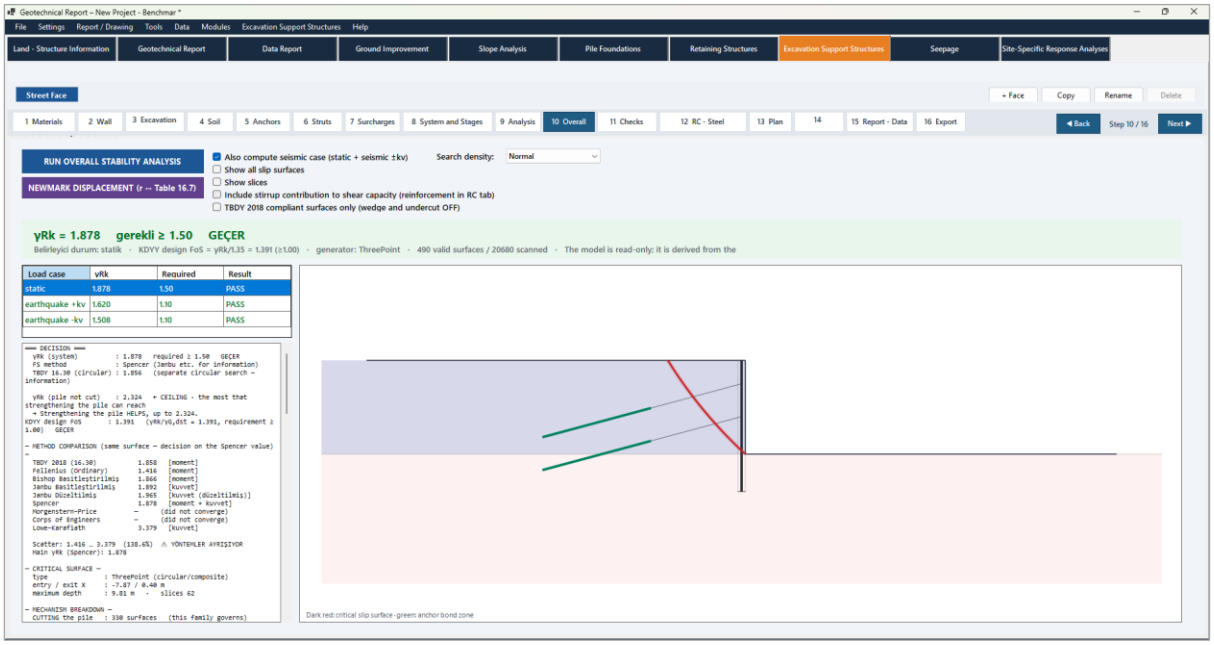


Figure 13. 10 · Global tab: critical slip surface, search steps and Newmark displacement result

5.3 Anchor checks

Three failure modes are calculated for each anchor and the governing one is reported: rupture of the tendon, pull-out of the bond zone from the soil, and insufficient bond between tendon and grout. The skin resistance and bond stress can be entered by hand or derived; the source used is written. For permanent support the factors of safety are raised by a multiplier.

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In addition, the anchor head and plate, the geometry of the anchor wedge and deep-block stability are checked. The deep-block check is invalid and is not made if the midpoint of the bond zone falls inside the active wedge; instead, the program says to extend the free length or change the inclination. In the seismic case the increase in anchor force is calculated separately.

In the strand library, the breaking load of a single strand is the product of the tensile strength and the nominal area: 260.4 kN for a 0.60-inch strand and 781.2 kN for the default three-strand anchor (tensile strength assumed 1860 MPa).

The soil–grout pull-out capacity is obtained from $R_k = \pi \cdot D \cdot L_b \cdot \tau_f$. The τ_f (bond–soil adhesion) on the Anchors tab is a stress in kN/m^2 ; it is converted to a force by multiplying by the bond perimeter $\pi \cdot D$. For example, for D = 0.15 m, L_b = 10 m and τ_f = 135 kN/m^2 , $R_k \approx$ 636 kN. If the bond diameter has not been entered, the perimeter cannot be calculated; in that case the value is taken as force per bond length (kN/m) and this is stated in the calculation note.

The τ_f source is selected on the Settings › Anchor τ_f/τ_c tab: user input (the value on the Anchors tab), total stress ($\tau_f = \alpha_a \cdot S_u$) or effective stress ($\tau_f = K_1 \cdot \sigma'_v \cdot \tan\phi'$). When derivation is selected, the value is calculated from the layer at the midpoint of the bond zone and the cell in the Anchors table is locked; the check and the PLAXIS export use the same τ_f value. If a field pull-out test is available, it should take priority; derivation does not replace a test.

On the Settings › Anchor τ_f/τ_c tab, the hint “In sand K1 ≈ 1–2 (Littlejohn 1972); depends on the installation method and grout pressure — sourced values below” appears next to the K_1 box; the “K1 — SOURCED VALUES” block below it lists the sources. Littlejohn (1972) states that, in a relation of the same form, the coefficient is normally in the range 1–2 in sand and depends on the installation method and grout pressure; the value measured in dense fine to medium sand at a grout pressure of about 350 kPa is 1.4. BS 8081 gives the same relation but no numerical range for the coefficient. No sourced K_1 range was found for post-grouted anchors, clay/silt or rock. The program default of 1.00 is a program assumption and should be confirmed by field pull-out tests. When the effective stress path is selected, the report writes the justification line for K_1.

The E values used in the anchor stiffness and in the PLAXIS export are read from the lower section of the same tab (“ANCHOR STIFFNESS — E VALUES”). “Cement grout E [GPa]:” defaults to 10 GPa and is written as the embedded beam E of the bond zone in PLAXIS. “Strand E [GPa]:” defaults to 195 GPa (prestressing strand); the program’s anchor spring $k_t = E_t \cdot A_t / L_f$ and the $EA = E_t \cdot A_t$ of the PLAXIS node-to-node anchor are calculated with this modulus. The E of reinforcing steel (200 GPa) is not used for the anchor tendon. “Grout unit weight [kN/m³]:” defaults to 25 and is written as the embedded beam w.

Two options are off by default. “Root stiffness with equivalent E (grout + strand, area-weighted)” calculates the bond zone E as $E_{root} = (E_g \cdot (A_g - A_t) + E_t \cdot A_t)/A_g$. “Include root elongation in the anchor spring” connects the free length and the bond zone in series: $1/k_t = L_f/(E_t \cdot A_t) + L_{b,eff}/(EA)_{root}$; $L_{b,eff}$ = ratio·L_b (“Lb,eff / Lb ratio:”, default 0.50). If a bond zone E different from the default (10 GPa) is stored for an anchor in the project file, that value is used for the anchor and the grout E setting is not applied to it. The material table of the report contains rows for the prestressing strand and the cement grout; the anchor section gives the E values used, the formula and a stiffness table per anchor (E_t, A_t, $E_t \cdot A_t$, L_f, E_{root}, $(EA)_{root}$, $L_{b,eff}$, k_t).

If “Show Eurocode 7 Design Approach 2 (DA2) verifications” is ticked on the Settings › Partial Factors tab, the anchor verdict is given with partial factors: $E_d = \gamma_{G,dst} \cdot T_d \le R_d = R_k/\gamma_{Re}$ (T_d the anchor design load). In this case the classic factors of safety are shown for information and do not enter the overall result; the Checks tab and the report follow the same rule.

5.4 Strut check

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Strut buckling is checked with the elastic Euler load or with the code's strength relation that is sensitive to section class; the default is the latter. The design load comes from the solver, not from the preload, and the governing stage is written. Load combinations are calculated separately and the largest governs; optionally, thermal force and accidental vertical load can also be added.

5.5 Hydraulic checks

Table 4. Hydraulic checks

Check	Coverage and applicability
Base heave	Safety against upward heave of the excavation base in undrained soil. The entire zone extending from excavation level over the embedment must be undrained; if a drained layer enters it, the check is not applied and the reason is written — taking the undrained strength as zero and declaring it "inadequate" would be wrong.
Piping (sand boiling)	Safety against the seepage force arising from the head difference between the two sides. If no groundwater is defined in the project, the check is not made; sand boiling cannot occur without a pressure difference. Meaningful only for a drained excavation base; in undrained soil, base heave should be used.
Uplift	Safety against pressurised water beneath an impermeable layer lifting the base; a jet-grout plug is also evaluated if needed.

5.6 Surface settlement and adjacent structures

The surface settlement behind the wall is given side by side by two independent methods. The first is a geometric method derived from the area between the deformed and undeformed shapes of the wall. The second is an empirical envelope derived from hundreds of measured excavations: the maximum settlement, the settlement shape (triangular or trapezoidal) and the distance of influence are given according to soil class.

Limits of the empirical envelope

The envelope is for supported and reasonably constructed excavations; an excavation that has deformed badly, been supported late or come close to base heave exceeds this envelope. In soft clay the published band is wide; the program uses the middle value and says so. Consolidation settlement due to dewatering is not included in the envelope.

For the foundations of adjacent structures, the shallow foundation bearing capacity and whether the foundation lies inside the active wedge are also checked; separate limits are used for angular distortion in the static and dynamic cases.

5.7 Failure criterion

The number is withdrawn

If the displacement exceeds a given percentage of the free excavation height, the small-strain assumption is invalid. In that case the program presents no number: it says that the numerical results of the calculation should not be trusted and that the system must be redesigned. This is a deliberate withdrawal of a reported result.

5.8 Governing method and search in global stability

The governing factor of safety is found with the Spencer method, and the search is also made with Spencer. The TBDY 16.30 value is shown for information from a separate circular search; if the search is restricted to "code-compatible surfaces only", the TBDY value governs. When Spencer cannot find a root on a candidate surface, that surface is not skipped without notice: on circular and composite surfaces the value of the simplified Bishop method is considered as a fallback and a warning is written. Polygonal surfaces without a root are discarded; the only exception is the building undermining wedges below. Spurious roots below the reasonable range are eliminated (lower limit 0.8).

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- [RAPOR] A Bishop fallback value is rejected unless corrected Janbu confirms it on the same surface within [0.5 ; 2]; the diagnostics then show the “FALLBACK CHECK” warning.
- On “undermining” wedges running from the building base to the excavation corner, a surface where Spencer gives no root is not discarded. It is evaluated with corrected Janbu and enters the FS if Lowe–Karafiath confirms it on the same surface within [0.5 ; 2]; the diagnostics show the message “WARNING — UNDER-BUILDING / UNDERMINING WEDGE” and the governing method is shown as corrected Janbu.

Since the Spencer solution is time-consuming, the full solution is made only for the best candidates that pass the pre-screening; solutions are cached and run in parallel. The effect of this acceleration on the factor of safety is negligible. The global stability calculation runs in the background, with progress display and a Cancel button.

The “Search density:” list on the Global tab offers Fast, Normal (default), Detailed and Wall. Wall is the sparse search with local refinement of the Retaining module; when it is selected in Excavation Support, wedge and undermining surfaces remain on and the wall-body window is not applied.

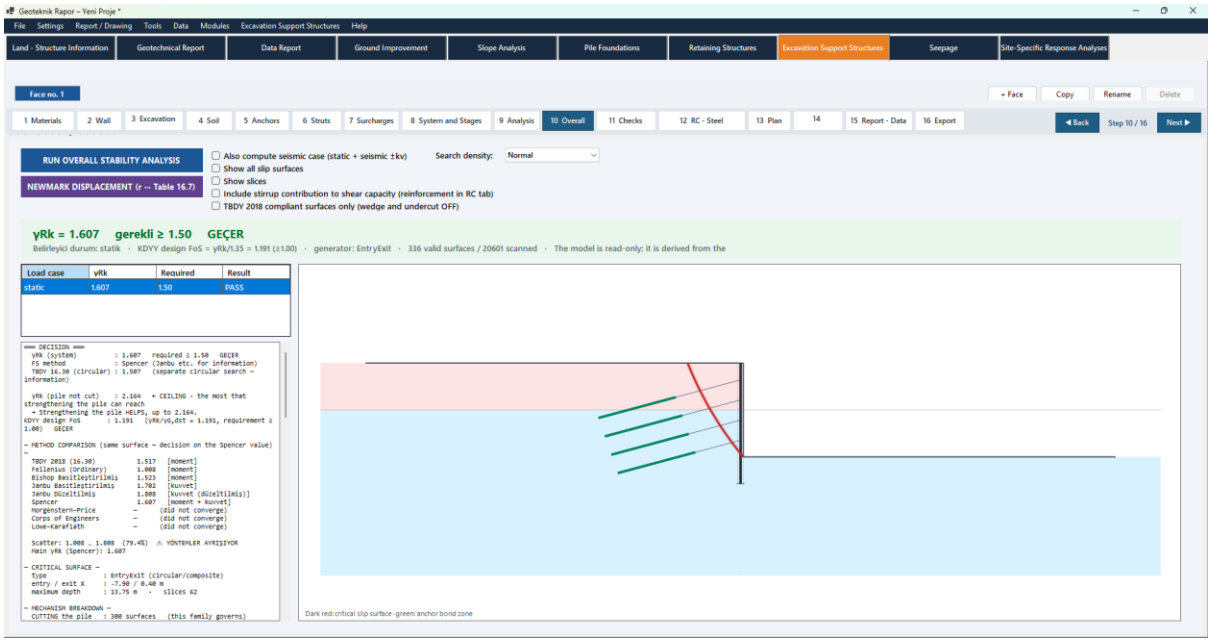


Figure 14. 10 · Global tab: governing Spencer result, comparison of methods and critical slip surface

The increase of cohesion with depth can be entered as $c_u(z) = c_{u0} + c_{u,inc} \cdot z$ (z measured from the top of the layer); if $c_{u,inc}$ is entered as zero, the default from the settings (0.5 kPa/m) is taken and this is stated. If the critical surface touches the base or the side boundaries of the model, the warning “factor of safety depends on model depth” is given. Adjacent buildings (strip loads flagged as buildings) with a foundation depth of 0.30 m or more enter the global stability model as structure regions (3.4).

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6. Earthquake

The earthquake effect is taken as pseudo-static, and a single earthquake check stage is added at the end of the construction stages. The horizontal and vertical coefficients are either entered by hand or derived automatically from the design spectral acceleration coefficient. The derivation is per face; two faces with different support arrangements receive different coefficients in the same project.

6.1 Reduction factor r

The reduction factor depends on the permanent displacement that the system allows and is derived from the support system: in an internally braced system no displacement is allowed and the factor is one; in an anchored system an intermediate value is used, and this is not a choice; in a cantilever system a larger value is taken if the user declares that a larger displacement is permitted. The displacement allowed by the selected value is compared with the displacement occurring in the earthquake check stage, and a warning is given if it is exceeded.

A saturated layer with high pore water pressure overrides everything

If below the water table there is a layer flagged “high pore water pressure expected”, the reduction factor is reduced to one whatever the support system, and the reason is written together with the layers concerned. If no water is defined in the project, no layer falls under this criterion.

6.2 Newmark displacement check

Whether the selected reduction factor is really defensible is checked with an estimate of permanent displacement. The program runs the global stability solver repeatedly with the bisection method until it finds the critical horizontal coefficient; the criterion is not the raw factor of safety but the ratio of the factor of safety to the required value. While searching for the critical horizontal coefficient, the criterion is read from the factor of safety of the seismic case when $k_h > 0$; even if the static case governs, k_c is not derived from a case that the earthquake acceleration does not affect at all.

This check is time-consuming: a full global stability solution takes seconds. The critical horizontal coefficient is therefore first searched on a fixed set of surfaces and then confirmed with a full search; this shortens the time considerably and affects the result only negligibly. The check runs in the background, with progress display and a Cancel button. The same solver as for global stability is used; only the horizontal seismic coefficient is varied.

A displacement of 0.0 mm does not mean that no seismic analysis has been made. If the critical horizontal coefficient k_c is equal to or greater than the peak horizontal acceleration coefficient $k_{max} = 0.40 \cdot S_{DS}$ (or if k_c exceeds the upper limit of 2 g), the block does not slide at all; “sliding does not start” is shown on screen and an explanation to the same effect is given in the report. If $S_{DS} = 0$ is entered, no Newmark calculation is made and the message “no earthquake; displacement calculation is unnecessary” is shown.

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7. Reinforced Concrete and Steel Design

The design tab collects the section design of the wall and the auxiliary members. The design actions come from the analysis; the user can also enter them by hand if desired. A design multiplier is requested for each member, and this multiplier has a lower limit.

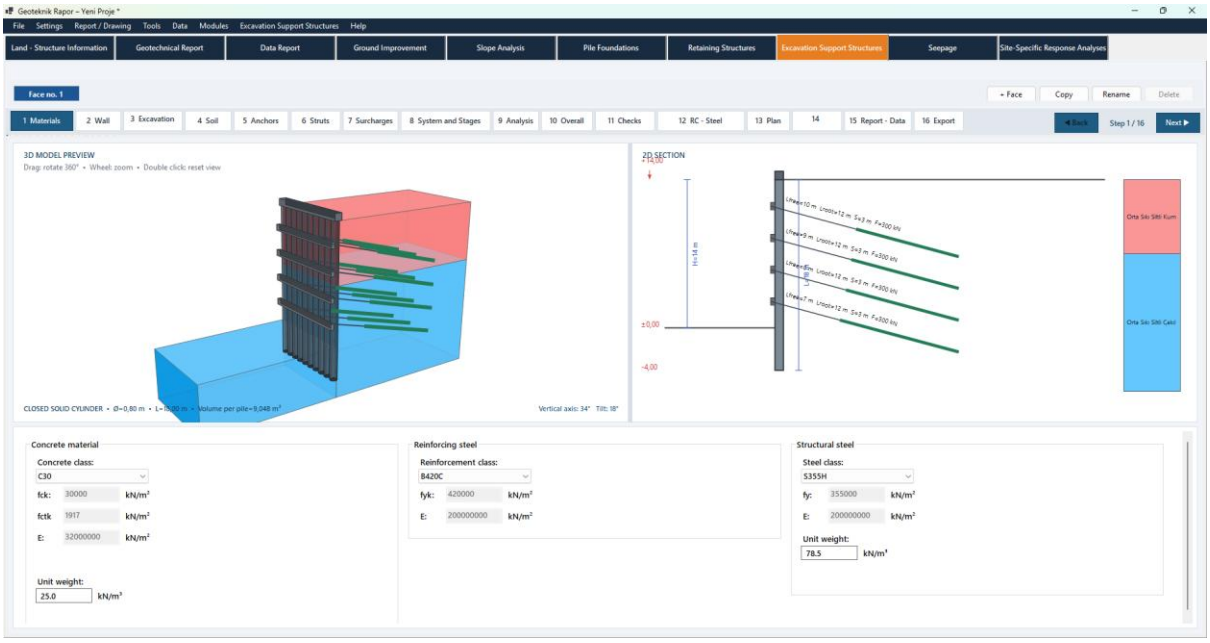


Figure 15. 1 · Materials tab: concrete, reinforcing steel and structural steel grades

Table 5. Design members

Member	Calculated
Pile — circular section	Axial load–moment interaction, shear, longitudinal reinforcement ratio, stirrup spacing selected as the smallest of several criteria, and confinement zone requirements.
Diaphragm wall — one-metre strip	Axial load–moment interaction for a rectangular section; reinforcement can be selected automatically or given by hand after unlocking the diameter lock.
Steel wall	Bending, shear and buckling checks for sheet pile and Berlin walls.
Capping beam	Flexural and shear design; top, bottom and side face reinforcement. The TS 500 beam requirements are checked: minimum tension reinforcement, minimum stirrups ($A_{sw}/s \geq 0.3 \cdot f_{ctd}/f_{ywd} \cdot b_w$), stirrup spacing ($s \leq \min(d/2; 20\ cm)$) and minimum section dimensions ($b \geq 200$ mm, $h \geq 300$ mm).
Waler beam	All anchor and strut rows flagged with a waler beam are scanned and the most critical one is shown; if desired, the maximum force can be given by hand. The steel waler is designed separately.
Berlin lagging	Bending and shear as a simple beam; the span is found by subtracting the profile width from the soldier pile spacing.

Arching in the lagging is an assumption

The pressure on the lagging is taken as a fraction of the active pressure; the program's default is in the middle of the band common in practice. However, arching does not develop in saturated sand, running silt and very soft clay; there the ratio should be raised to one, and the program detects this situation and warns. In addition, the calculation is for the final state — in reality lagging is installed progressively; for timber, long-term loading and moisture class are not taken into account and the allowable stress is chosen conservatively.

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For the confinement zone requirements, the code's relation specific to spirally reinforced and circular columns is used; if the selected transverse reinforcement type is neither spiral nor circular, the program says so. The provision that a given share of the relation is mandatory even at low axial load levels is applied.

Bar diameters can be restricted with the permitted lists given in the settings; automatic design uses only the ticked diameters. A diameter can be forced by hand by unlocking the diameter lock.

In the capping beam the top and bottom face reinforcement is at least four bars each, in the waler beam at least three bars each. In the waler beam the number of top and bottom bars is kept equal and entered in a single field ("Top/bottom bar count (each face)").

The minimum tension reinforcement rule of the capping beam is selected in the "CAPPING BEAM MINIMUM TENSION REINFORCEMENT" section of the Settings › Concrete cover and diameter lock tab. The default is the TS 500 beam rule: with "Minimum factor k:", $A_{s,min} = k \cdot f_{ctd}/f_{yd} \cdot b \cdot d$, k = 0.80 (adjustable between 0.30 and 2.00). If "Use a fixed ratio (ρmin·b·d)" is ticked, the ratio in the "Fixed ratio ρmin [‰]:" box is used (default 3‰). If the selected rule falls below the TS 500 minimum, the required area is raised to the TS 500 minimum. The report states the rule used and any such increase.

After every analysis the reinforcement is selected automatically according to the face's own envelope actions; faces that you have changed by hand are preserved. Automatic pile design uses the same criteria together as the verdict on screen: N–M capacity, longitudinal reinforcement ratio, shear and the TBDY ρ_s requirement in the confinement zone. If the N–M capacity is insufficient after the stirrups have been selected, the longitudinal reinforcement is increased and the stirrups are selected again; if no combination works, the densest reinforcement is placed and the inadequacy is reported explicitly. Stirrup spacing candidates go down from 25 cm to 5 cm.

If the shear force V_d exceeds the upper limit V_{max}, the program gives the message "Maximum shear force capacity exceeded"; in this case making the stirrups denser is not enough, and the pile or wall section must be enlarged. The Ø80 / 1.00 m / 90×90 starting section of a new project was chosen for this reason.

When the analysis is complete, no window opens for reinforced concrete inadequacy; inadequacy is examined on the Reinforced Concrete - Steel tab. The program warns before a report is produced if there is an inadequate section.

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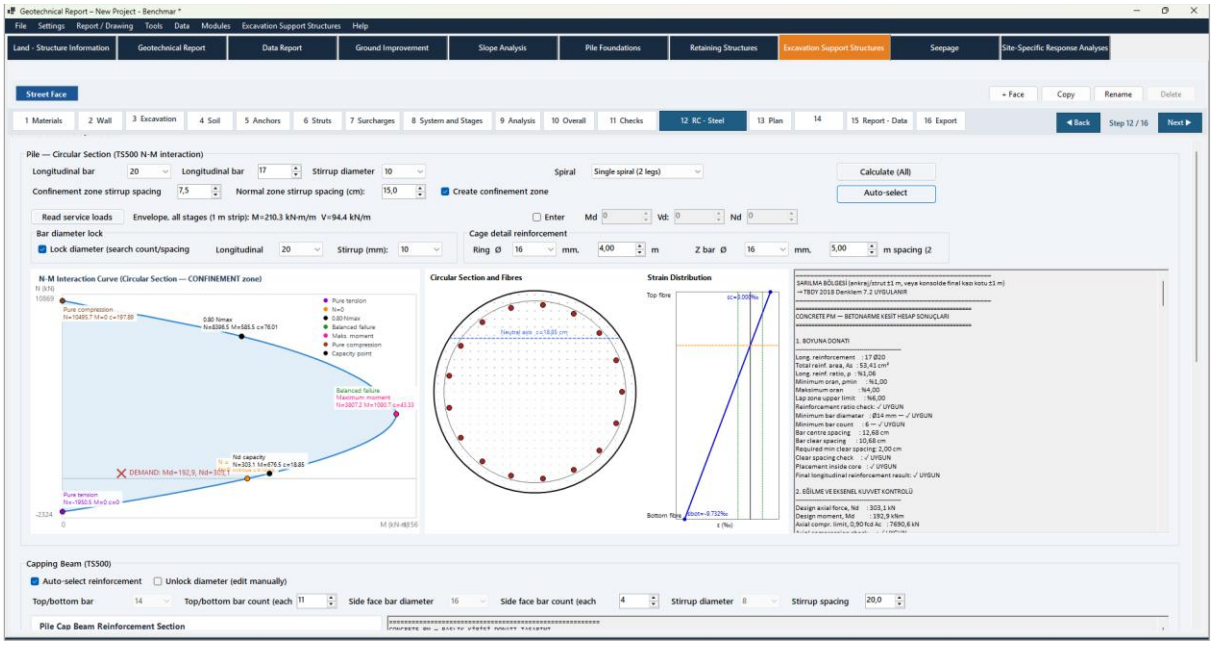


Figure 16. 12 · Reinforced Concrete - Steel tab: circular pile section, N–M interaction curve and strain distribution

8. Settings

There are two levels. Project settings — pressure methods, subgrade modulus method, staged construction, earthquake and serviceability limits — are on the System and stages tab and are stored in the main project file. Central settings, once saved, come as defaults in every new project; they open as Excavation Support tabs in the main program's single Settings window.

Table 6. Central settings headings

Tab	Contents
General Settings	Whether the analysis runs automatically when the project is opened ("Run analysis automatically when project opens", on by default); when it is on and the inputs have issues, the input check window opens.
Factors of Safety	Minimum factors of safety for anchor tendon rupture and pull-out (clamped within the 1.50–2.50 band), tendon–grout bond stress τ_c, anchor head and plate, strut buckling, yielding limit between piles (arching), seismic anchor force multiplier; a multiplier that raises all factors for permanent support.
Reinforcement Design	Permitted bar diameter lists for piles, diaphragm walls and beams; stirrup hook allowance, Z-bar arm length and bending angle, double stirrup arrangement.
Surcharge Method	Whether the Ou method is used for the lateral pressure of point, line and strip surcharges ("Use Ou method"; see 4.5).
Partial Factors	Display of Eurocode 7 DA2 verifications (when on, the anchor verdict is given with DA2); anchor action factor $\gamma_{G,dst}$, resistance reduction factors γ_{Re} for anchor and steel rupture, design multiplier for internal forces, angular rotation limit.
Anchor τ_f/τ_c	Source of the skin friction τ_f and of the tendon–grout bond τ_c; the α_a, K_1 (with hint and sourced values) and ξ factors; the "ANCHOR STIFFNESS — E VALUES" section (see 5.3). If derivation is selected, the bond–soil adhesion cell in the Anchors table is locked.
Dil / Language	Program language; the interface, drawings and report change together (requires restart).
Concrete cover and diameter lock	Covers of bored piles, diaphragm walls, capping beams and waler beams; minimum tension reinforcement rule of the capping beam (see 7).
Drawing settings	Whether pile numbers continue across faces; soil hatch pattern scale (ANSI38, default 20); diaphragm panel width (default 2.50 m).

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Tab	Contents
Anchor test program	Test type and bond zone soil; for acceptance tests, the upper limit of the test load, the minimum number of tests per face and the minimum test proportion.
KDYY factors	Model uncertainty factor γ_{sd} (cannot go below one); displacement and rotation limits; strut thermal force; lateral support load combinations and SLS variable action factor; strut compressive strength; uplift and piping partial factors; alarm levels (load cell, anchor load deviation, piezometer); anchor corrosion protection; ULS-GDA second solution; jet-grout base plug.

If the settings file cannot be found or read, the program reverts to the defaults and reports this.

[RAPOR] The “Design code…” command in the Settings section of the Excavation Support menu opens a small window. The code to which the calculation is made is selected here. Only codes implemented in the program (Active) can be selected; the others appear greyed out with the note “Not available in this version.” The design code is not a central setting; it belongs to the project and is stored in the main project file. The default is KDYY 2026 (+ TBDY 2018); EN 1997-1 and FHWA GEC-7 are not available in this version (greyed out). The selection is written at the start of Section 4 of the report.

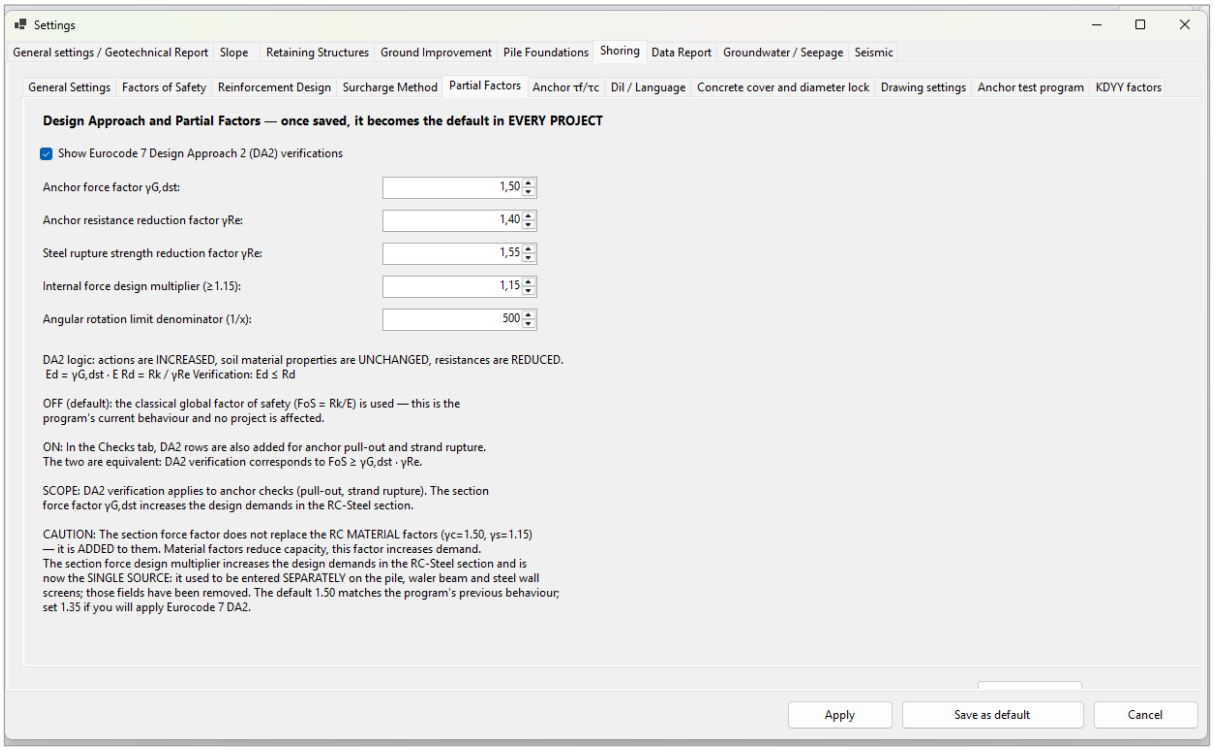


Figure 17. Settings window, Partial Factors tab: design approach and anchor partial factors

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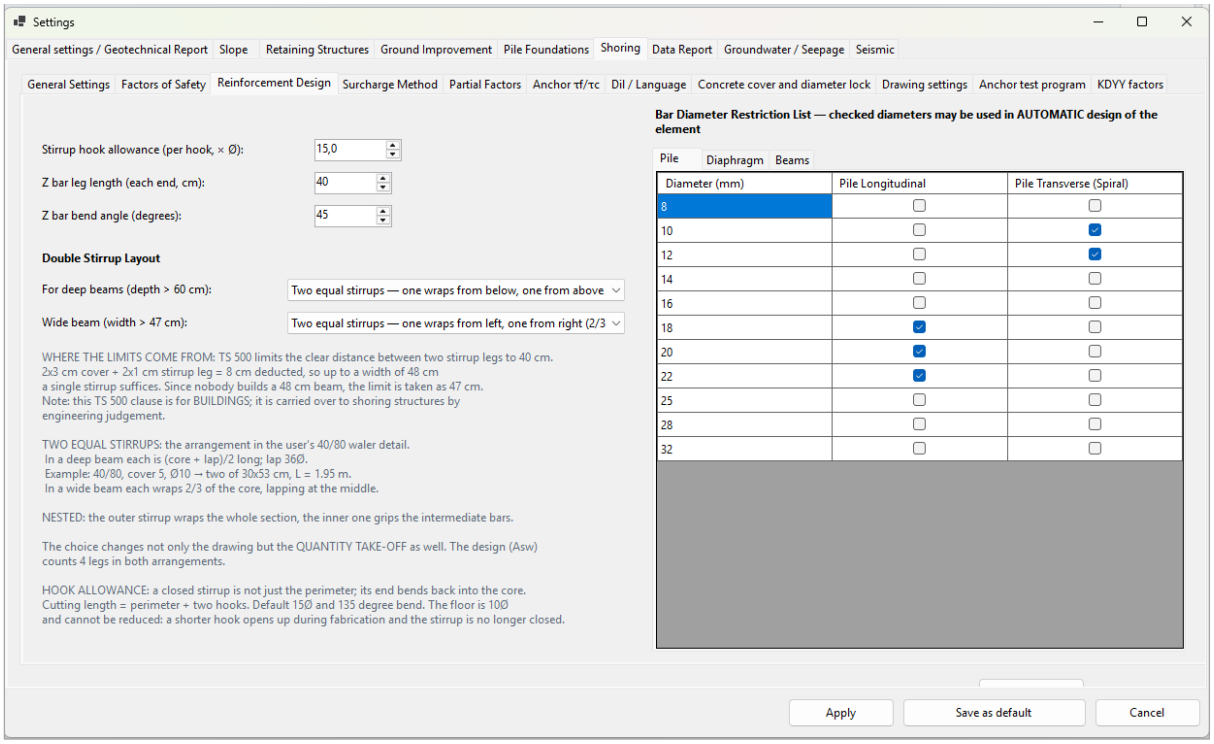


Figure 18. Settings window, Excavation Support › Reinforcement Design tab: stirrup hook allowance, Z-bar, double stirrup and bar diameter lists

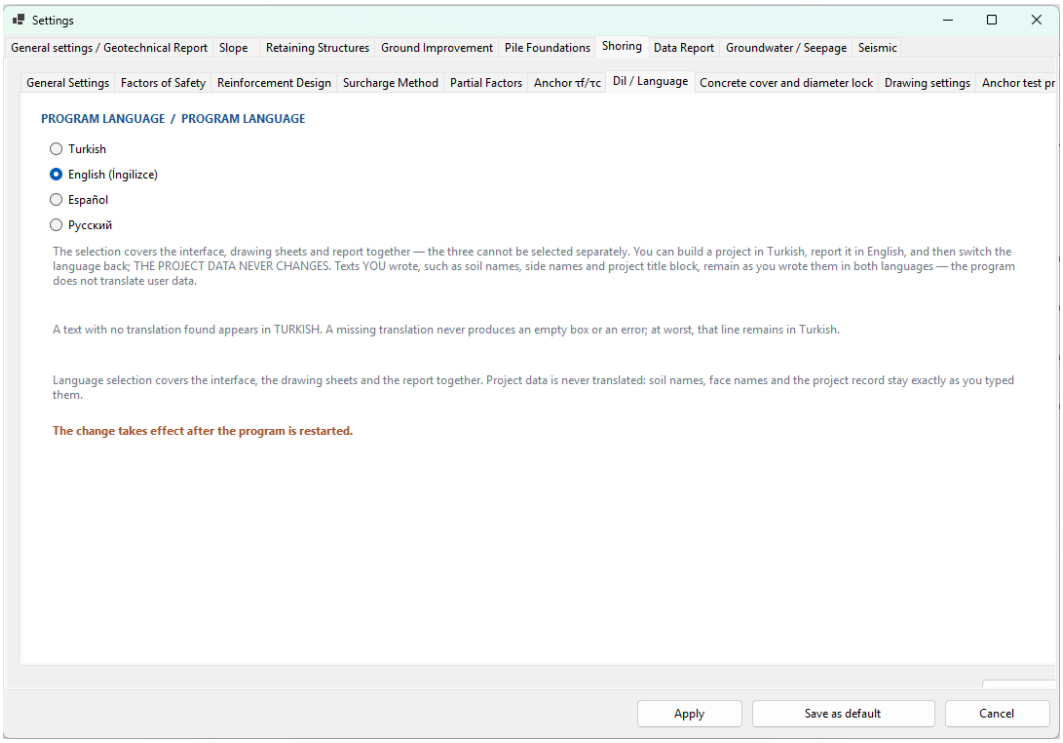


Figure 19. Settings window, Excavation Support › Language tab: choice of program language

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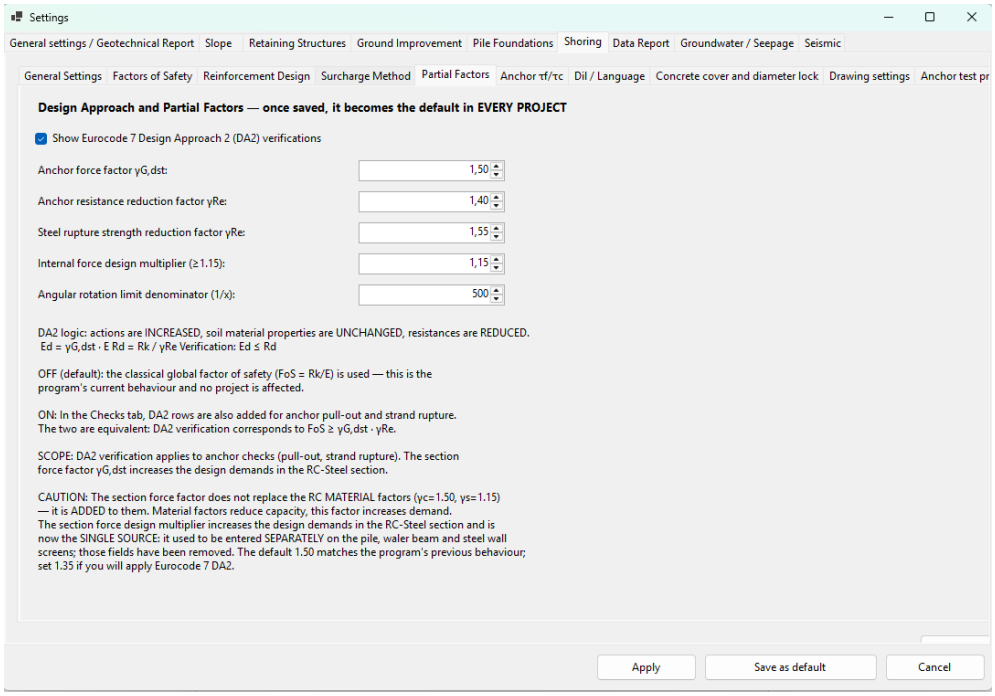


Figure 20. Settings window, Excavation Support › KDYY factors tab: model uncertainty, displacement limits, strut thermal force and load combinations (Turkish interface shown)

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9. Verification

The calculations in this module have been checked against independent verification examples and hand calculations.

9.1 Comparison with published tables, handbook examples and closed forms

The table below gives selected comparisons of the program results with published tables, code handbook examples and closed-form solutions. Difference = (program − reference) / reference. In the comparison with the Caquot–Kérisel table, the largest deviation in the cells outside the δ/ϕ′ = 1 column is 0.20%.

Table 7. Comparison with reference values

Example	Reference	Reference value	Program	Difference (%)	Tolerance
K_a, ϕ′=30°, δ/ϕ′=0.5	Caquot–Kérisel table	0.303	0.3030	+0.01	1%
K_a, ϕ′=30°, δ/ϕ′=0.67	Caquot–Kérisel table	0.300	0.3004	+0.14	1%
K_a, ϕ′=35°, δ/ϕ′=0.5	Caquot–Kérisel table	0.247	0.2474	+0.17	1%
K_a, ϕ′=40°, δ/ϕ′=0.5	Caquot–Kérisel table	0.200	0.2004	+0.20	1%
K_a, ϕ′=25°, δ/ϕ′=1	Caquot–Kérisel table	0.363	0.3741	+3.06	5%; program higher
K_a, ϕ′=30°, δ/ϕ′=1	Caquot–Kérisel table	0.304	0.3146	+3.48	5%; program higher
K_a, ϕ′=35°, δ/ϕ′=1	Caquot–Kérisel table	0.256	0.2654	+3.67	5%; program higher
K_a, ϕ′=40°, δ/ϕ′=1	Caquot–Kérisel table	0.215	0.2242	+4.28	5%; program higher
K_p, ϕ′=20°–40°, δ=0 (5 examples)	Rankine closed form (Kérisel–Absi δ=0 column)	2.0396 – 4.5989	2.0408 – 4.5850	+0.06 to −0.30	0.5%
Mazindrani K_a and K_p, c′=0, β=0 (10 examples)	Rankine closed form	0.2174 – 4.5989	same	0.00	0.1%
K_0, ϕ′=30°, OCR=1 and β=0	Jáky	0.500	0.500	0.00	0.1%
K_0, ϕ′=30°, OCR=1, β=20°	Jáky's form extended for inclination	0.67101	0.67101	0.00	0.1%
Cantilever wall: active thrust P_a (kN/m)	Hand calculation (closed form)	620.667	620.667	0.00	0.5%
Cantilever wall: passive resistance P_p (kN/m)	Hand calculation (closed form)	1824.0	1822.9	−0.06	0.5%
Cantilever wall: factor of safety	Hand calculation (closed form)	1.6793	1.6783	−0.06	0.5%
Bored pile V_{cr}, D=80 cm, C30 (kN)	TS 500 Eq. 8.1	485.14	485.14	0.00	2%
Stirrup shear strength V_w, ϕ10/15, 2 legs (kN)	TS 500 Eq. 8.5	279.19	279.19	0.00	2%
Concrete tensile strength f_{ctk}, C20–C50 (6 classes)	TS 500 Table 3.1	1.57 – 2.47 MPa	same as table	−0.30 to +0.20	1%
Anchor test: acceptance test proof load (kN)	KDYY Handbook T4	437.5	437.5	0.00	—
Anchor creep coefficient α_{cr}	KDYY Handbook T4-4	0.482	0.4821	+0.01	0.5%

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Example	Reference	Reference value	Program	Difference (%)	Tolerance
Apparent free tendon length L_{app} (m)	KDYY Handbook T4-3	14.22	14.2210	+0.01	0.2%
Against uplift: design resistance $(G+F)\cdot\gamma_{G,stb}$ (kN)	KDYY Handbook P2-7	8699.6	8699.6	0.00	0.05%
Piping: hydraulic head h_r, example P2 (m)	KDYY Handbook P2-8	1.62	1.6162	−0.23	0.5%
Piping: hydraulic gradient i, example P3	KDYY Handbook P3-8	0.85	0.8484	−0.18	0.5%
Steel strut compressive strength P_n (kN)	KDYY Handbook P1 (ÇYTHYDE Chapter 8)	12591	12591.2	+0.002	0.2%
Bearing capacity factor N_q, $\phi'=30°$	Vesić (1973)	18.401	18.4011	+0.001	0.1%
Bearing capacity factor N_γ, $\phi'=30°$	Vesić (1973)	22.402	22.4025	+0.002	0.1%
Cohesionless strip footing q_k (kPa)	Relation set up by hand	778.8	778.80	0.00	0.5%
Undrained clay, lateral resistance p_u (kPa)	Broms (1965): $9\cdot s_u\cdot B$	432	432	0.00	0.01%

In the $\delta/\phi' = 1$ column the program gives an active coefficient 3.06% to 4.28% higher than the published table; the program warns in this case, and the difference is on the safe side.

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10. Outputs

10.1 Report

When the Report button is pressed, the common “Excavation Support — report pre-check” window appears first and lists errors and missing items face by face: face definition, support length or excavation depth, soil layer, analysis result, non-converging stages and project name. The list is not added to the report; the report can be produced with “Continue anyway”, and the default button is Cancel. Then blocking issues such as an inadequate reinforced concrete section are checked and the report content is selected.

In the content selection, it is decided which sections and which charts per stage are to be included. All sections are on by default and there is a summary report option. The report starts with the project introduction, the inventory of surrounding structures, roads and infrastructure, the geotechnical site characterisation and the project assumptions; then comes a separate section for each face: introduction and geometry of the face, support arrangement, construction stages, initial analysis parameters, stage-by-stage results and envelope values.

These are followed by the design, quantity takeoff, monitoring layout and official form sections. The monitoring layout section sets out the quantities to be measured, the measurement systems, placement rules, reading frequency, alarm levels and points to watch during excavation — in an excavation support project, monitoring is the continuation of the calculation.

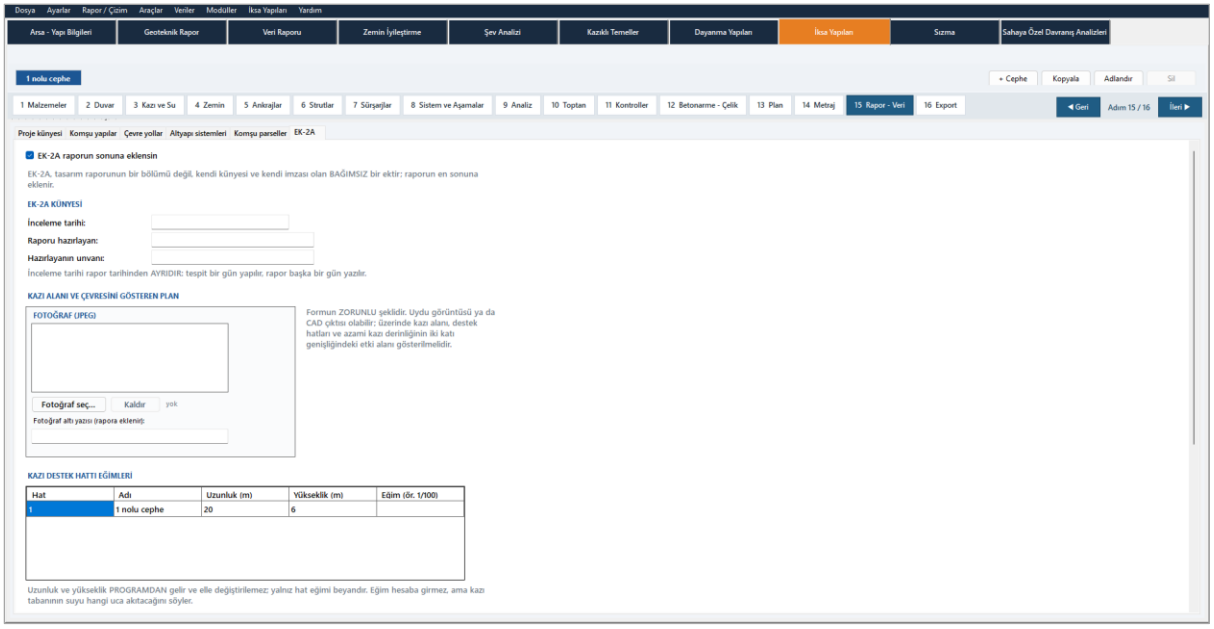


Figure 21. 15 · Report - Data tab, ANNEX-2A: project details, photograph of the excavation area and inclinations of the excavation support line (Turkish interface shown)

In the report, text paragraphs outside tables are justified; headings and figure and table captions are centred. “Page n / N” is written in the bottom right-hand corner of the page.

10.2 Drawing

The drawing consists of the section sheet, the reinforcement elevation and the face elevation, and the detail sheets: reinforcement cage details, longitudinal reinforcement detail, capping beam detail, waler beam detail and waler–anchor connection detail. In addition, a fixed sheet of construction parameters and details common to all projects is produced.

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Layers are separate: concrete, ground, longitudinal and transverse reinforcement, Z-bar, ring, anchor, beam, text, dimension, table, axis, frame, detail, instrumented monitoring and anchor free zone. The soil profile sheet and the water symbol in the section are produced with the soil drawing common to all modules and use the ZEMIN-TARAMA, ZEMIN-SINIR, ZEMIN-SU, ZEMIN-YAZI and ZEMIN-KOT layers. The number of sheets into which the face elevation is divided is set on the Plan tab and does not affect the analysis.

In the bored pile reinforcement detail, the longitudinal reinforcement and spiral, the ring and the Z bar are drawn in separate panels; the spiral development is a side view of the helix. The Z bar is drawn at its own length and appears in the cage schedule as the row “Z bar (cage stiffening)”. These developments are drawn in the same way as in the Pile Foundations module. The title block of each sheet states the concrete, reinforcement and steel grades selected on the Materials tab.

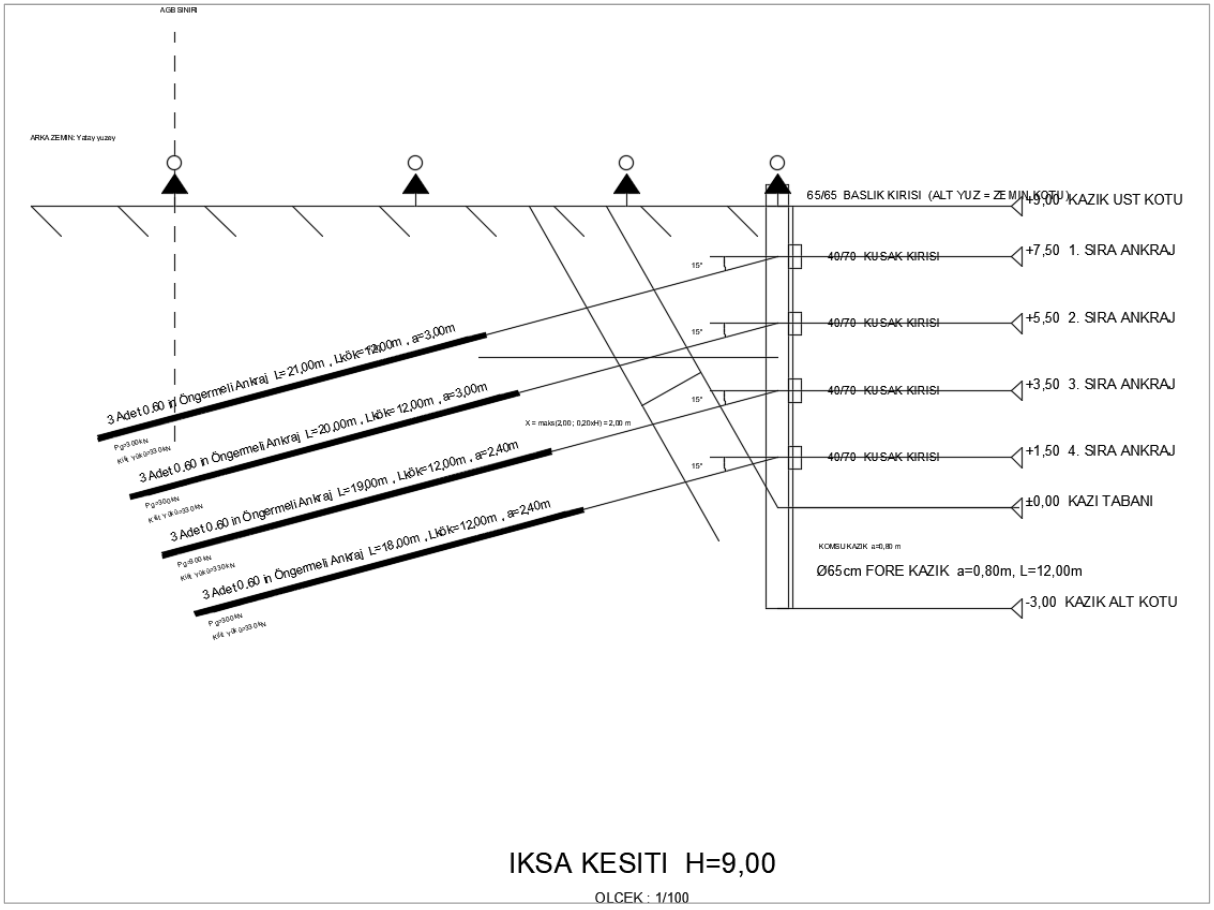


Figure 22. Excavation support section sheet produced by the program (H = 9.00 m, four rows of prestressed anchors) (Turkish interface shown)

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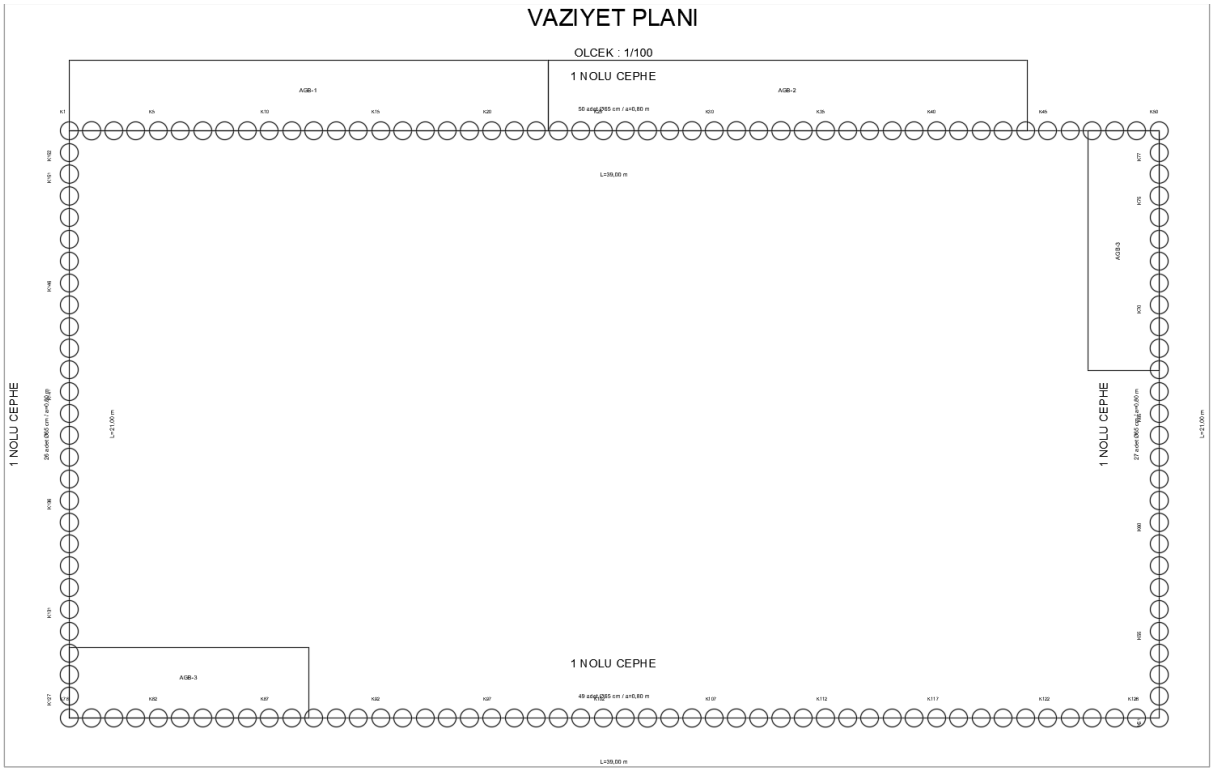


Figure 23. Site plan produced by the program: pile layout and numbering along the face (Turkish interface shown)

10.3 Quantity takeoff

The quantity takeoff is collected in five groups: piles with waler and capping beams, anchors, steel sheet piles, steel wall accessories and the project total. Reinforcement quantities are read automatically from the Design tab; the number and depths of anchor rows come from the Anchors tab, and the profile and length from the Wall tab. A tender item proposal can be shown for each group; the sheet pile quantity is measured with the measurement method of a published item description.

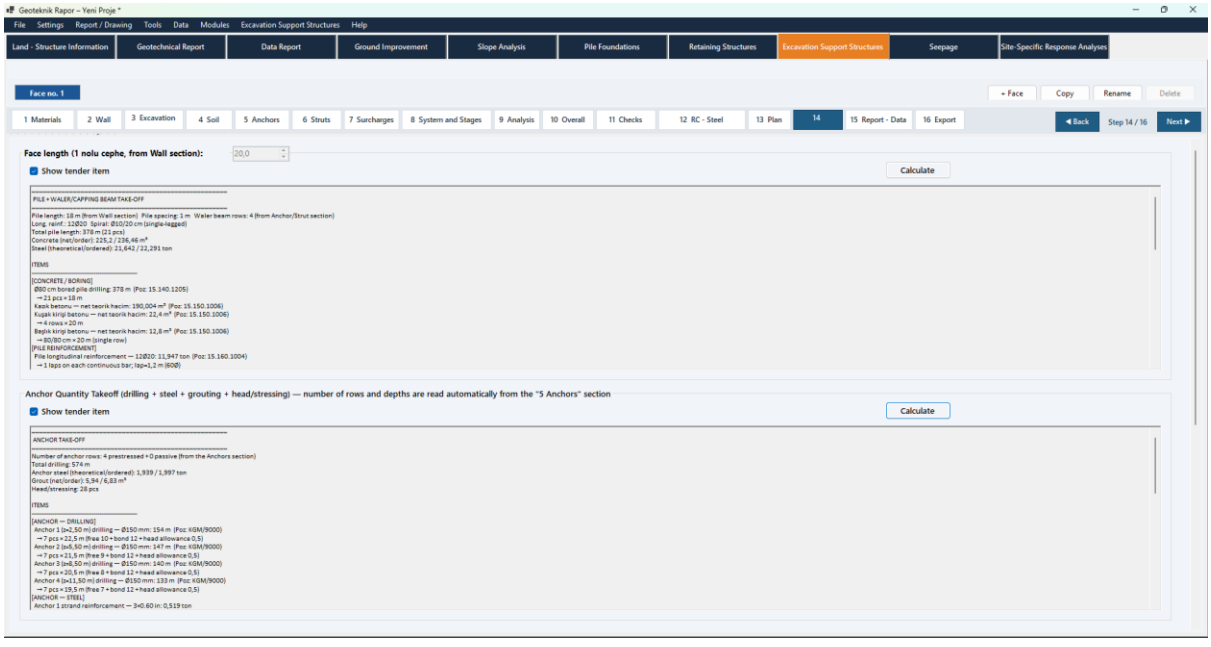


Figure 24. 14 · Quantities tab: pile, waler and capping beam, and anchor quantities

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Passive (non-prestressed) anchors also enter the anchor quantity takeoff: on site they are drilled, the tendon is placed and the bond zone is grouted. Drilling (free length + bond length + 0.50 m head allowance), tendon steel and bond grout ($\pi \cdot D^2/4 \cdot L_{bond}$) are counted with the same rules and waste allowances as for a prestressed anchor. The head, plate and wedge set are also counted for passive anchors; stressing, lock-off and test load are counted only for prestressed anchors.

Passive items are listed separately in “PASSIVE ANCHOR” groups and shown with a subtotal; in the tender item, the passive head is written as “ÖZEL-PASİF-ANKRAJ-BAŞLIK” (special passive anchor head). The quantity summary table in the report has a “Type” column.

10.4 PLAXIS export

The “Export to PLAXIS” button produces the complete PLAXIS 2D model of the selected face. The commands are copied to the clipboard; in PLAXIS 2D Input they are pasted into the box opened with Ctrl+F9 (“Run commands…”) and run. The command order and syntax have been verified step by step in real PLAXIS sessions. The export is regenerated each time from the current project data; it is not a separate tool.

The “Export to PLAXIS” command opens a small options window: face (in a multi-face project), PLAXIS 2D version (CONNECT Edition V20, V21, V22 and V23/V24), generation of the stages, and inclusion of comment/warning lines (#) in the script. The [EXPORT TO PLAXIS] button copies the script to the clipboard and writes a one-line status in the window; the script text and the warning list are not shown on screen. Since comment lines can block the PLAXIS command box, this option is off by default. The choices are saved and come back the same at the next opening. Numbers in the script are always written with a decimal point.

Table 8. Scope of the PLAXIS export

Component	Exported
Model boundaries	Model width and depth calculated from the excavation depth and wall length
Soil	A Hardening Soil material for each layer (unit weights, drainage type, strength and stiffness) and soil polygons split according to the excavation steps
Wall	Plate material (EA, EI, w, ν) and geometry; interfaces on both faces
Anchors	Free length as node-to-node anchor, bond zone as embedded beam row; spacing and prestress force; bond skin resistance written as $T_{skin,max} = \tau_f \cdot \pi \cdot D$ (kN/m) from the same τ_f value as the check; the bond zone E and w and the free length EA = Et·At come from the E values on the Settings › Anchor τf/τc tab (5.3)
Struts	Fixed-end anchor material and geometry
Surcharges	Distributed, strip and line loads
Groundwater	Stepped water line for both sides and global water level
Stages	Initial phase; installation of plate and interfaces; in each excavation stage, removal of the relevant soil polygon, activation of anchors with prestress and of struts; resetting of displacements at the first excavation; a Safety phase from the last stage and, if earthquake is selected, a pseudo-static phase (k_h, k_v)

Points to watch in the export

The export takes a single face each time; in a multi-face project you are asked which face to export.

The Hardening Soil parameters are derived from the soil data in the program; reviewing the material values in PLAXIS before solving is the engineer’s responsibility.

Since the PLAXIS command box does not accept comment lines, only the commands are copied to the clipboard; comment and warning lines are placed in the script only if requested in the options window, and the script is not shown on screen.

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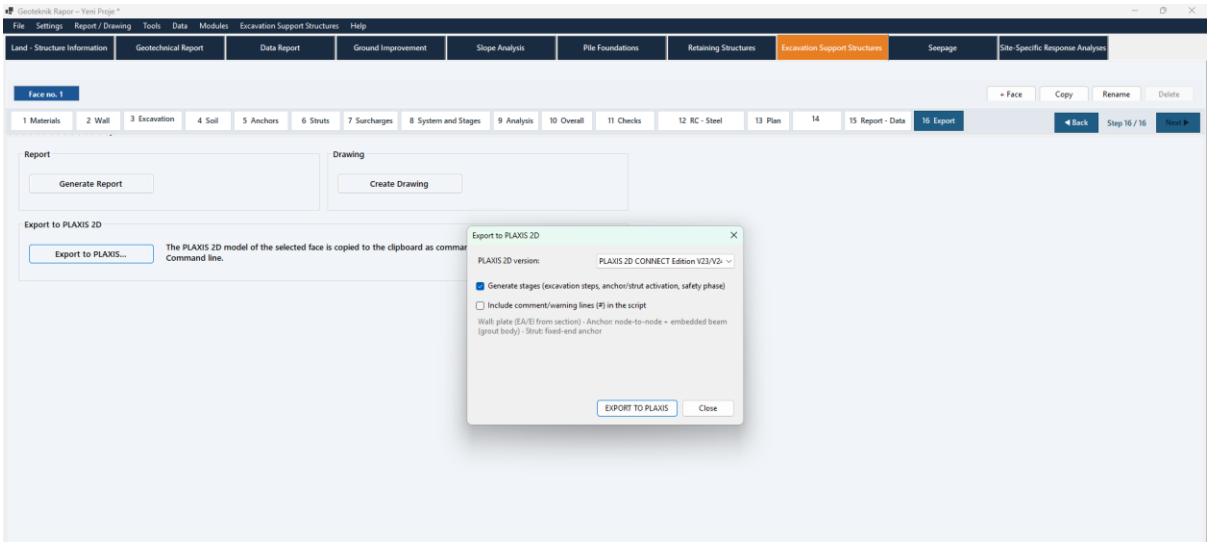


Figure 25. 16 · Export tab: export to PLAXIS 2D and the options window

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11. Points to Watch

11.1 When building the model

- The support system is not selected; it is derived from the presence of anchors and struts. This directly changes the seismic reduction factor and the required factors of safety.
- The excavation-side slope is applied only in the continuously descending geometry. Giving a slope to a bench would penalise the passive resistance a second time.
- Water depths on both sides are measured from the top of the wall; the same number gives the same water level on both sides.
- A layer's "high pore water pressure" flag is not a display preference: if such a layer lies below water, the seismic reduction factor drops to one.
- Stages are not entered by hand; after an input changes, the stages must be regenerated.
- If staged construction is turned off, each stage is solved from zero and the supports appear more effective than they are.
- For bored pile and Berlin faces the number of members is ⌈L/s⌉ + 1 and the spacing is reduced; when choosing the anchor spacing, base it on the actual spacing of the piles in plan (s').
- In a new project the pile is Ø80, the centre-to-centre spacing 1.00 m and the capping beam 90×90 cm; if $V_d > V_{max}$ results, increasing the stirrups is not enough — enlarge the section.

11.2 In analysis and checks

- The subgrade modulus method changes the result markedly; for rock-like moduli the default method gives very large values and the program reports this.
- The embedment check is static; the seismic case requires a separate evaluation.
- If the mobilisation ratio of the passive resistance is high, the displacement may be unacceptable even if the number is satisfied.
- In global stability, scanning only code-compatible surfaces does not count as an accuracy improvement; the mechanisms switched off do occur in reality.
- The deep-block check is not made if the bond zone falls inside the active wedge. This is not a shortcoming but a notice of invalidity; the anchor geometry must be corrected.
- There are cases in which the base heave and piping checks are not applied, and the reasons are written; "not applied" and "inadequate" are not the same thing.
- If the displacement exceeds a given percentage of the free excavation height, the program withdraws the number; instead of using that number, the system must be redesigned.
- In lagging design, the arching assumption is invalid in saturated sand, running silt and very soft clay.
- A result drops by itself when its input changes; a result that remains on screen does so because it is still consistent with its input.
- The governing method in global stability is Spencer; if the critical surface touches the model boundary, the factor of safety depends on model depth and the model must be enlarged.
- If the τ_f source for anchors has been set to derivation, the bond–soil adhesion in the table is not used; to use your own value, set the source to "User input". When Eurocode 7 DA2 is on, the anchor verdict is given with partial factors; the classic factors of safety are for information only.

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12. Scope and Limits

Table 9. Scope and limits

Topic	Status
Wall types	There are four types. Shotcrete and soil-nailed walls are not a separate type; a soil nail can only be modelled approximately as a passive support.
Embedment check	Static; no seismic increment is applied.
Axial bearing beneath the wall	Calculated for a single pile; the group effect is not taken into account. For contiguous and closely spaced piles the real settlement may be larger (not on the safe side). Negative skin friction and time-dependent consolidation are not taken into account either.
Surface settlement envelope	For supported and reasonably constructed excavations; does not include consolidation settlement due to dewatering.
Anchor free zone	A single weighted average friction angle is used for the wedge; in layered soil the real plane is kinked.
Deep-block check	Invalid and not made if the midpoint of the bond zone is inside the active wedge.
Disabled subgrade modulus method	Disabled because the source expression is ambiguous; even if selected, it falls back to the elasticity-based method.
Toe boundary condition	The toe of the wall is free; the adequacy of embedment emerges from the solution.
Seismic pressure coefficients	Calculated from the classic pseudo-static relation; they include neither the spiral correction nor the cohesion term, so the coefficients reduce exactly to the static value when zero.
PLAXIS export	The full model is exported (Section 10.4); a single face each time. The Hardening Soil parameters should be reviewed in PLAXIS.
Unit system	Fixed at kN–m in this version.

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