GeoteknikPro

STUDIO — RETAINING STRUCTURES

Version 3.0.1

USER GUIDE

and Calculation Methods Document

Stone · Reinforced concrete · Gabion · Reinforced earth · Caisson foundation · Anchored wall
Overturning · Sliding · Bearing capacity · Global stability · Newmark · Settlement · Reinforced concrete design

In accordance with TBDY 2018 Chapter 16 and TS 500

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Symbols and Units

The module runs its internal calculation in the tonne-force and metre (t–m) system; the units shown on screen and in the report are in this system. The force conversion is defined in a single place (1 tf = 9.807 kN) and the unit weight of water in this system is 1.000 t/m^3. The analysis is carried out under the plane-strain assumption, for a unit width (1 m) along the wall.

Table 1. Symbols used in this guide

Symbol	Description	Unit
H	Wall height — total, including the footing	m
B	Base width — derived from the geometry	m
D_f	Embedment depth	m
γ	Natural (moist) unit weight of the soil	t/m^3
γ_{sat}	Saturated unit weight of the soil	t/m^3
c′	Effective cohesion	t/m^2
c_u	Undrained shear strength	t/m^2
ϕ′	Effective angle of internal friction	°
δ	Wall–soil interface friction angle	°
β	Backslope inclination (from the horizontal)	°
ψ	Angle of the pressure face from the horizontal	°
θ	Seismic inertia angle, $\arctan(k_h/(1\mp k_v))$	°
K_a, K_{at}	Static and total (seismic) active pressure coefficients	—
K_{ad}	Dynamic increment coefficient, $K_{at} - K_a$	—
K_p	Passive pressure coefficient	—
K_0	At-rest pressure coefficient	—
P_a, P_{ad}	Static active thrust and dynamic increment thrust	t/m
P_w	Water pressure resultant	t/m
P_p	Passive resistance resultant	t/m
V, U	Total vertical load and base uplift force	t/m
e	Eccentricity of the base resultant	m
B′	Effective (contact) base width	m
q_{min}, q_{max}	Minimum and maximum base pressure	t/m^2
q_t	Design bearing capacity for the base	t/m^2
R/E	Ratio of resisting moment to overturning moment	—
V_{th}, R_{th}	Horizontal design demand and base sliding resistance	t/m
k_h, k_v	Horizontal and vertical pseudo-static seismic coefficients	—
S_{DS}	Short-period design spectral acceleration coefficient	—
r	Reduction coefficient tied to the permissible displacement (Table 16.7)	—
γ_R	Partial resistance factor (overturning, sliding, passive, bearing)	—
E_s, m_v	Modulus of elasticity and coefficient of volume compressibility	MPa · cm^2/kg
f_d	Design compressive strength of the masonry body	t/m^2

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1. Introduction

1.1 What the module does

The Retaining Structures module carries out the external (global) design of a retaining structure according to TBDY 2018 Chapter 16. The user defines the wall geometry, the soil profile behind it, the water condition, the loads and the earthquake parameters; the program computes the lateral pressure coefficients and thrusts, solves the static case and the two earthquake cases separately, performs the overturning, sliding, bearing capacity and base pressure checks, and selects the governing case.

In addition, checks that depend on the wall type are made: horizontal joint sliding and body crushing in a stone wall, row interfaces in a gabion, internal stability in reinforced earth, the shear check of every lift in a caisson foundation, and section design with reinforcement in reinforced concrete. Global stability, settlement and the Newmark permanent displacement check run in separate windows.

Several wall alternatives can be defined within the same project and all of them solved side by side in a single comparison matrix. This is how the module is meant to be used as a design tool: not one solution but several are produced, and a choice is made among them.

1.2 Scope

The module solves the external stability and the section design of the wall for a single final condition. Slope stability scanning is done in the Slope module and staged excavation in the Excavation Support module; the global stability check searches the surfaces around the wall. Wall displacement is evaluated with the Newmark permanent displacement estimate, and loads from the superstructure are taken as input. The analysis rests on the plane-strain assumption; the three-dimensional view is a visualisation only.

1.3 Who it is for

The module is intended for users trained in geotechnical and reinforced concrete design. The program performs the calculation, states its assumptions explicitly and reports every value it clips; the suitability of the parameters for the site and the final engineering decision remain the user's responsibility.

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2. Screen and Workflow

2.1 Screen layout

The main program's shared ribbon sits at the top with the toolbar below it; at the bottom of the screen are four status cards and a message line. On the left is the four-tab input panel, on the right a two-pane view: the section in the middle and the three-dimensional model at the far right. At the very top, a strip shows all wall alternatives in the project side by side.

Retaining Structures data is saved and opened together with the main program's single project file (*.geos); the module has no separate save or open command. While the Retaining Structures tab is active, the module's own menu appears in the shared ribbon: the New Project (this module only) command resets only this module's data and leaves the other modules of the project untouched. Report and drawing commands live in the shared Report / Drawing menu, and the settings are on the Retaining Structures tab of the single Settings window at the top.

Table 2. Input tabs

Tab	Content
Wall Parameters	System and wall type selection, common dimensions and the geometry group of the selected type; in reinforced concrete, also the anchor table. Irrelevant groups are hidden, not greyed out.
Soil Parameters	A single soil profile table, selected backfill, ground surface shape and inclination.
Water / Loads	Groundwater condition and the water depths on both sides, dynamic permeability choice, surcharge table.
Analysis	Base drainage condition, stone joint parameters, tie beam, site history, earthquake parameters and access to the module settings.

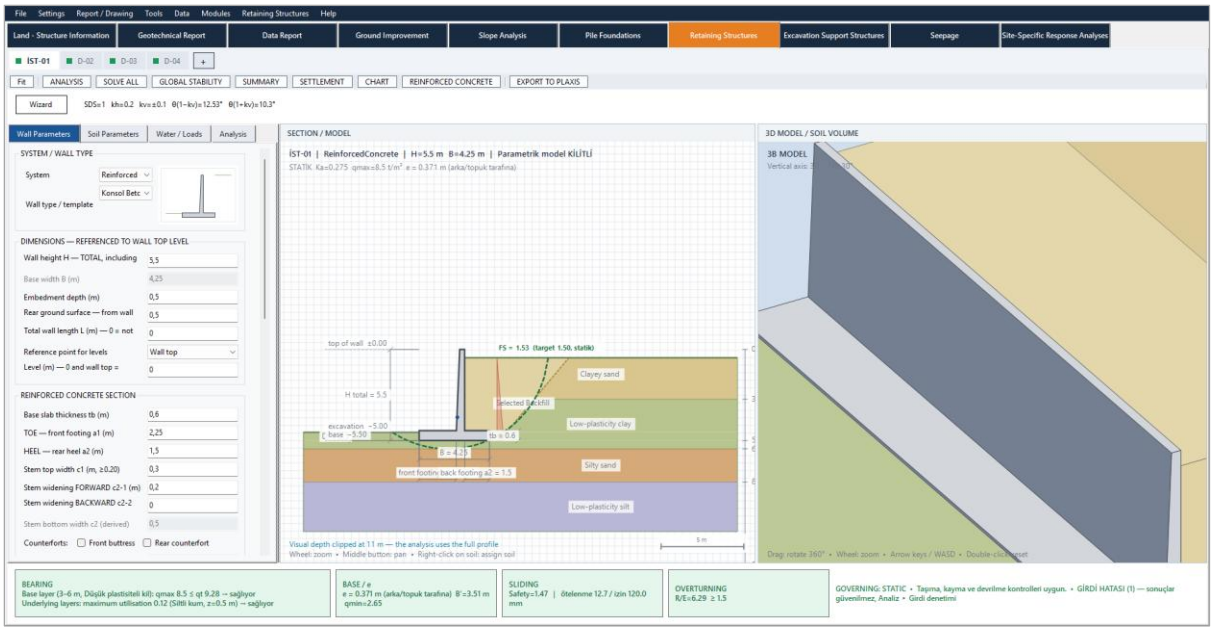


Figure 1. Retaining Structures main screen: alternative strip, four-tab left panel, section and 3D model, status cards at the bottom

2.2 Status cards — always live

The four cards at the bottom of the screen continuously show the results of the governing case: BEARING (q_{max} and the design bearing capacity), BASE / e (eccentricity, effective base width and minimum pressure), SLIDING (safety ratio and, where computed, the displacement) and OVERTURNING (R/E with the target value). The message line beneath them states the governing case and any warnings: a weak underlying layer, a base key defined while passive resistance is off, an r choice that exceeds the code limit, errors found by the input audit,

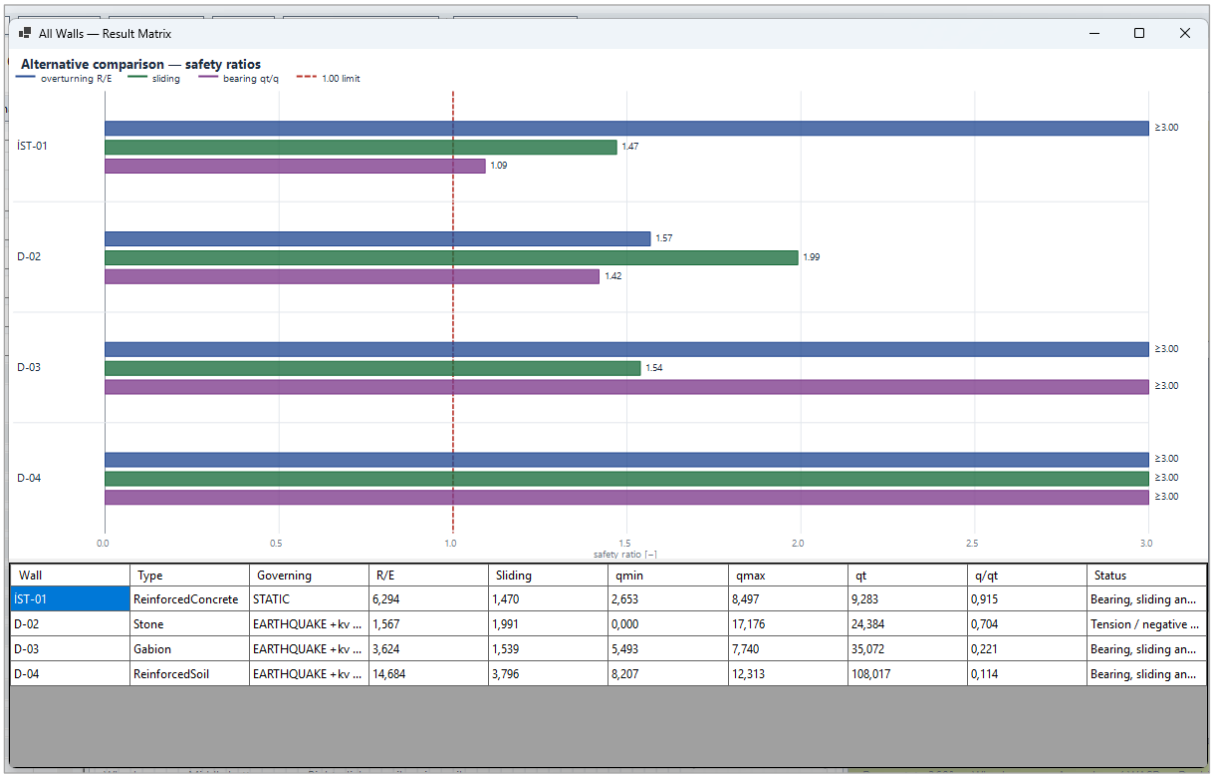
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inadequate MSE internal stability, and exceedance of the permissible displacement. For an MSE wall a fifth card, INTERNAL, appears and shows the most critical utilisation ratio and the status of internal stability. For a reinforced concrete wall with inadequate rebar detailing, the red note “Rebar detailing NOT SATISFIED (Reinforced concrete)” appears next to the cards.

2.3 Alternatives

In the strip at the top, every wall alternative is represented by a card carrying a status dot: green if all checks pass, red if at least one fails, grey if not yet solved. A new alternative can be added, and the active wall can be copied or deleted; at least one alternative must remain in the project.

The SOLVE ALL command solves all alternatives and opens a result matrix: for every wall the type, governing case, overturning ratio, base pressures and bearing ratio appear side by side; in the bar chart above, the bearing bar is inverted so that all three bars read in the “larger = safer” direction. The numbers in the matrix are shown with three decimals. The overall stability of all walls can also be computed with a single command (7.3).



Wall	Type	Governing	R/E	Sliding	qmin	qmax	qt	q/qt	Status
İST-01	ReinforcedConcrete	STATIC	6,294	1,470	2,653	8,497	9,283	0,915	Bearing, sliding an...
D-02	Stone	EARTHQUAKE + kv ...	1,567	1,991	0,000	17,176	24,384	0,704	Tension / negative ...
D-03	Gabion	EARTHQUAKE + kv ...	3,624	1,539	5,493	7,740	35,072	0,221	Bearing, sliding an...
D-04	ReinforcedSoil	EARTHQUAKE + kv ...	14,684	3,796	8,207	12,313	108,017	0,114	Bearing, sliding an...

Figure 2. All Walls — Result Matrix: safety ratios of the alternatives side by side

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3. Ways of Building the Wall Model

A wall model can be built in five ways: the pre-dimensioning wizard, entering the dimensions by hand, reading a stone wall section from DXF, entering a stone wall section from a point table, and building reinforced concrete walls in bulk from an Excel list. Whichever way is used to start, the geometry can be edited by hand afterwards.

Table 3. Comparison of the five ways

Way	Scope	When to prefer it
Wizard	Reinforced concrete, stone and gabion	When the dimensions are not yet known; to start from the net retained height and search for a section that satisfies the checks
Manual entry	All types	When the dimensions are known from the project section; to correct a section produced by the wizard
DXF section	Stone wall only	When the wall body has been drawn in CAD — the only way for irregular polygonal bodies
Point table	Stone wall only	When the section corners are known as numbers, with no need for CAD
Excel list	Simple cantilever RC wall only	When the project has many reinforced concrete walls and their dimensions are to be given in bulk in a list

3.1 First way — the pre-dimensioning wizard

The wizard starts from the net retained height and searches for a section that satisfies the checks. The net height is the difference between the front ground surface and the rear ground surface; the embedment depth and footing thickness are added beneath it. This distinction prevents the number the user enters from being confused with the total height of the wall produced.

Table 4. Wizard inputs

Group	Inputs
Wall	Wall type (cantilever RC, stone gravity wall, gabion) and the net retained height.
Earthquake	S_{DS} and the r choice according to Table 16.7; every option is listed together with the displacement it allows.
Limits	Whether the toe and heel projections are feasible, whether the embedment depth may be increased, and the maximum value for each; also an upper bound on the crest width (Maximum crest width). Zero means unlimited.
Soil	Whether selected backfill is placed behind the wall, whether a reinforced concrete footing is provided under a stone wall, and the infinite surcharge q (t/m²). The default of q is the sum of the infinite loads on the active wall, and all checks of the wizard run with this q.
Gabion box	Box dimensions for gabion. Because gabions cannot be manufactured in intermediate sizes, the wizard enlarges the base in box steps.

The search proceeds by enlarging the projections in centimetre-scale steps; the embedment depth and — in reinforced concrete — the base key are also enlarged where permitted. The goal is to satisfy all of the eccentricity, sliding, overturning, bearing and (in stone) joint checks. In reinforced concrete the section check also runs inside the search, and at the end the selected r value is verified with the Newmark displacement check.

The right panel has three tabs: a live preview of the section, a table of the search steps (at every step B, projections, embedment, eccentricity ratio and the four check ratios) and the assumptions and warnings. The search-step table makes it traceable how the result was found.

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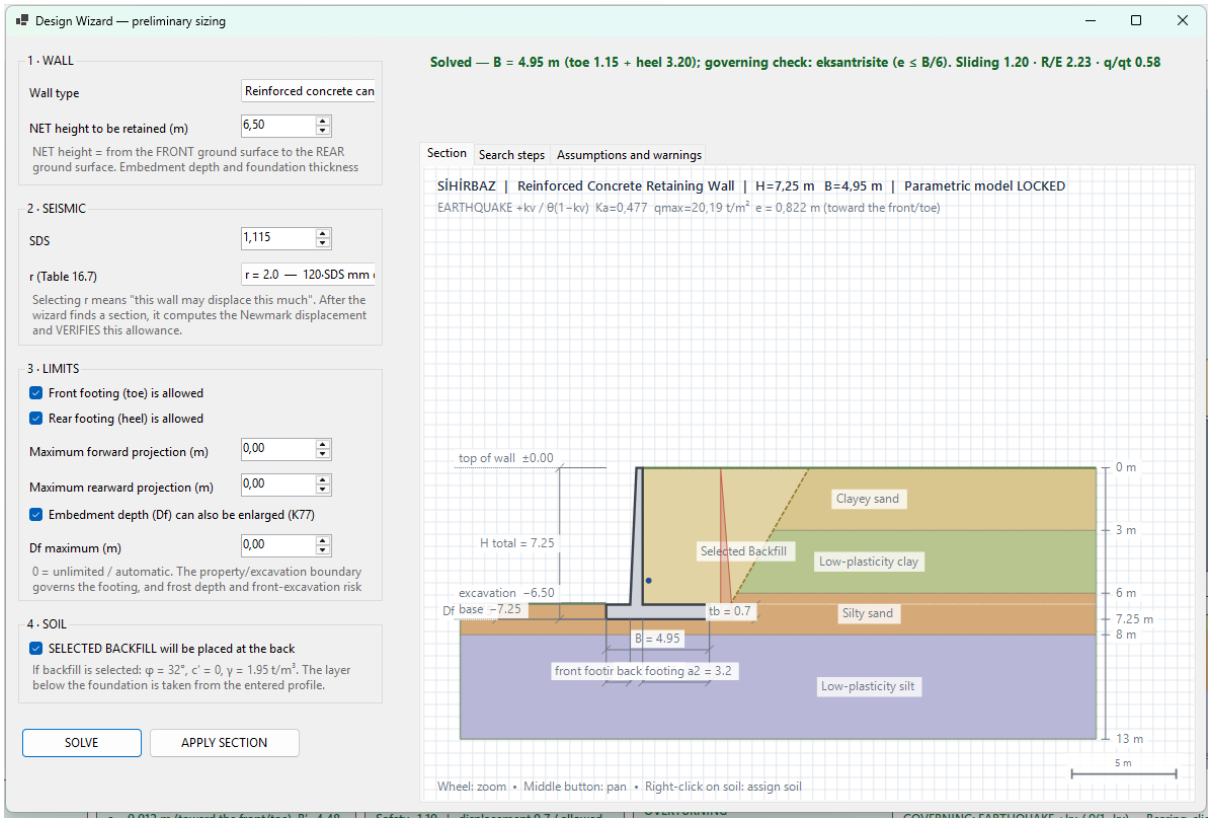


Figure 3. Design Wizard — pre-dimensioning window: inputs and preview of the section found

The wizard applies the geometry and the infinite surcharge

The “APPLY SECTION” command copies the wall type, earthquake parameters, height, embedment depth, backfill preference and the geometry of the type. It also sets the infinite surcharges of the wall to the single q value of the wizard: if q = 0 the infinite loads of the wall are removed; if the wall has no infinite load, one is added. Strip, line and point loads are not touched; if the load list has changed, an information box is shown. The soil profile, water, the wall name and the module settings stay as they are. The wizard is a pre-dimensioning tool; it does not change the rest of the project.

When a height beyond which a cantilever RC wall is not recommended is exceeded, the wizard stops and states the reason; at such a height an anchored or counterforted solution is needed.

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3.2 Second way — entering the dimensions by hand

On the Wall Parameters tab, first the system (stone, reinforced concrete, gabion, reinforced earth) and then the wall type is selected. Only the relevant geometry group is shown for the selection; the others are hidden. Numeric fields are processed not on every keystroke but when the field is left or Enter is pressed, so a half-typed number does not break the geometry.

The base width B is derived

The B field is read-only for all wall types; it is computed from the dimensions entered. In reinforced concrete the stem bottom width is derived in the same way, and in gabion both B and H follow from the box arrangement and the H field is disabled. There is a single field for each quantity: two fields mean, sooner or later, two numbers that disagree.

The small preview next to the wall type draws the silhouette of the actual polygon, not of the selected template; it shows only the silhouette. Its purpose is to see at a glance what the selected type produces.

3.3 Third way — reading a stone wall section from DXF

A stone wall with an irregular polygonal body cannot be described by dimensions; it has to be drawn. This way is for stone walls, and the only thing taken from the file is the wall body.

Only the body is read from DXF

Import updates only the wall body. The soil profile, water condition, surcharges, drainage and tie beam data stay as they are in the program; even if the drawing contains anchors, reinforcement or other elements, only the body outline is taken.

The reader works with ASCII DXF and reads LINE and LWPOLYLINE entities; if the file is binary DXF the program asks for it to be saved from CAD as “ASCII DXF”. Closed loops are built from the pieces read; if there is more than one closed loop, the one with the largest area is taken as the body and the number of loops found is reported.

The unit is inferred from the unit definition in the file header and its consistency with the size of the geometry is checked. Millimetre, centimetre, metre, inch or foot can be chosen from the unit box in the preview window. The chosen unit is used as is; if it is inconsistent with the geometry the program warns.

Table 5. Checks performed on import

Check	Rule
Closed loop	At least one closed loop must exist; if none is found, no import takes place.
Self-intersection	A polygon that crosses its own edges is rejected. This check runs before the area check: a bow-tie polygon has zero signed area, so in the reverse order the user would see a misleading reason.
Height	The body height must lie within a reasonable range; a section outside it is a sign that the wrong unit was chosen.
Flat top surface	The top surface of the wall must be flat; a sloping crest is not accepted and must be corrected in CAD.
Top and base width	Both must be above a lower bound.
Number of corners and shape	Too many corners and an inverted-trapezoid shape (top wider than base) produce a warning; they do not stop the import.

The preview panel lists the height, base width, top width, section area and number of corners together with the warnings; next to it the section is drawn to scale with a one-metre scale bar. After the Apply command the wall type becomes stone, the template becomes “DXF”, and the height, base width and top width are derived from the polygon read. For a stone wall built from DXF or from the point table, if the front ground surface still has its default flat shape, it is rebuilt from Df when Df is changed; if another front ground surface has been drawn, it is left untouched.

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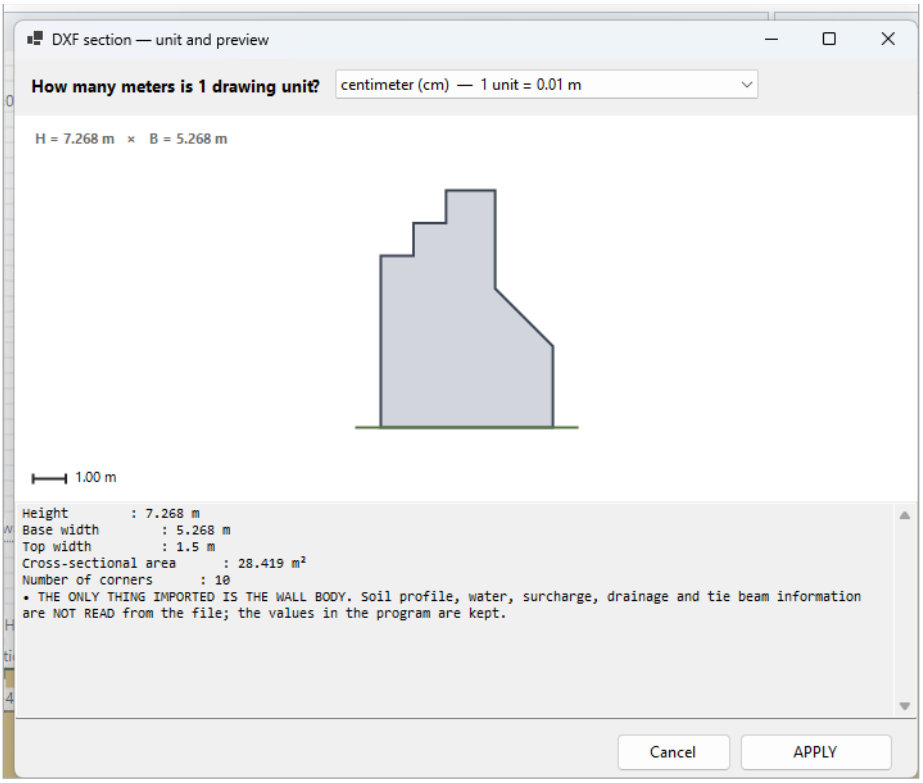


Figure 4. DXF section — unit and preview window: the body read, dimensions and warnings

3.4 Fourth way — entering the section from a point table

If the section corners are known as numbers, CAD is not needed. In the point table window the x and y values are entered in order around the section perimeter — clockwise or anticlockwise, it makes no difference. The polygon need not be closed by hand; the last point is joined to the first. The unit is metres, so no unit check is made.

The table is pre-filled with the polygon currently defined, so a section that came from DXF or was produced from a template can be corrected here numerically. The checks are the same as on the DXF path; in addition, coincident points are removed and at least three points are required.

3.5 Fifth way — Excel wall list

If the project has many reinforced concrete walls, the walls can be built in bulk from an Excel list. This way is for the simple cantilever RC wall only: no base key, counterfort, load-relief slab or anchor is built, no groundwater is defined, and the saturated unit weight is taken equal to the natural value (γsat = γ).

Walls › Create Wall Template (Excel)… first asks how many wall rows are wanted (1–200) and then saves the template. At the top of the template is a common block applied to all walls (SDS, r, soil ϕ, c′, E and mv), pre-filled from the active wall. In the table below it every row is a wall: wall number and name, wall height (excluding base), minimum stem and base thickness, minimum and maximum toe and heel projection (blank = unlimited), wall top elevation, backfill and soil unit weight, embedment Df, retained ground level, wall length L, backfill c and ϕ, and infinite surcharge q. The headings of the required columns are marked with an asterisk: height, stem and base thickness, the two unit weights, Df and backfill ϕ. The template is written in Turkish or English according to the interface language and contains a section sketch. The program recognises the columns not by their headings but by hidden key rows; a file in which these rows have been deleted is rejected.

Walls › Import Walls (Excel)… reads the completed file and opens a preview: the status of every row (to import, with warnings or NOT IMPORTED) and its details are shown, and the rows to be imported are selected in the

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Import column. A row with a required field blank or not a number is not imported. After confirmation every wall is solved in the background by the wizard in minimum-thickness mode (with the entered projection limits and q, base key off, Df fixed) and the analysis is run; if stopped with Cancel, the walls solved up to that moment remain. The soil profile is copied from the active wall and updated with the common block. If the wizard cannot find a section that satisfies all checks within the limits, the wall is still added and a warning is written. The new walls are added to the alternatives strip, existing walls are not deleted, and the first new wall becomes active. Finally a summary window lists the wizard result, the warnings and the notes for every wall.

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4. Wall Types and Geometry

There are four systems and nine templates beneath them. Four dimensions are common to all types: the total height H (from the top of the wall to the underside of the footing — footing included), the derived base width B, the embedment depth D_f and the depth of the rear ground surface measured from the top of the wall.

H is the total height for every type

The H entered is the total height from the top of the wall to the underside of the footing. In reinforced concrete the stem height is H minus the base slab thickness; when a reinforced concrete slab is placed under a stone body the stone body gets shorter, the wall does not get taller. So it is impossible to enter 4.5 and see 5.0.

4.1 Stone (gravity) wall

There are three templates: KGM type (chart-based), stepped (rear steps) and trapezoidal / custom (from angles). To these is added the free polygon coming from the DXF and point-table paths.

KGM type — the chart is read, B is derived

In this template the user enters the crest width and the height; the slope height H above the wall is not taken from the user, the program computes it (see below). The K value read from the chart sets the back line of the body and the rest of the polygon is built automatically: flat crest, front-face batter, back-face batter, flat or inward-inclined base; in the mortared charts also a chamfer at the rear top corner and a vertical back, in the dry charts a vertical back or a single batter. At intermediate values the chart is rounded up to the next step; since the chart's own logic is stepped, no interpolation is applied and the rounding is on the safe side.

When an inward-inclined base is chosen, the deepest point of the body can drop below the total height. The program fits the shape to the target height: the body is shortened by the overshoot and rebuilt, and the total height becomes exactly H. With a flat base no shortening is needed.

KGM stone wall charts: four kinds

A KGM-type stone wall is built with one of the stone wall shapes in the Highway Design Manual (Karayolu Tasarım El Kitabı). The chart is chosen from the four-item chart box on the Wall Parameters tab. The chart tables are built into the program; the program reads the table itself and the K value read appears in the report and in the audit information.

Table 6. KGM stone wall chart types

Chart	Wall kind	h in the table	K dimension	Back face
Figure 4.15	Mortared stone wall, normal fill	Total wall height (h + D_f)	Horizontal distance from the top-left corner to the flat behind	Chamfer, vertical back and back batter
Figure 4.18	Mortared stone wall, excavation support	Total wall height (h + D_f)	Horizontal distance from the top-left corner to the flat behind	Chamfer, vertical back and back batter
Figure 4.19-A	Dry stone wall, firm non-flowing ground	Exposed height	Crest width	Vertical back and back batter
Figure 4.19-B	Dry stone wall, soft non-flowing ground	Exposed height	Crest width	No vertical back; single batter (default 1:5)

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In the mortared charts (4.15 and 4.18) the h in the table is the total height of the wall; no distinction is made between net and total height. In rock, taking the total height instead of the net height is on the safe side. In the dry charts (4.19) K equals the crest width; the base width box is therefore disabled and B = K is taken. When 4.19-B is selected the back batter is set to 1:5.

The slope height H above the wall is computed as follows: from the point where the front face of the wall meets the passive soil, a 1:1 (45°) line is drawn backwards; the difference between the level where this line meets the rear ground surface and the wall top level is H (zero if negative). The whole mass is treated as soil; in rock the real H would be smaller, so this assumption is on the safe side. The H field is read-only.

When the chart range is exceeded the calculation continues; the input audit issues a warning and K is read from the last value of the chart: h > 12 m for 4.15 and 4.18, h > 4 m for 4.19, H exceeding 10 m in 4.15 or 20 m in 4.18, and in 4.15 an embedment normal to the front ground of less than 1.00 m. Information lines state that H is computed from the 1:1 line and that, although 4.15 allows a stepped (toothed) foundation in sound rock, the calculation assumes a flat base.

The base of a stone wall (custom or stepped template, no RC slab) can be inclined towards the heel by 0° to 15°; the default of the base inclination box is 0°, at which the results equal the un-inclined calculation. On an inclined base the loads are resolved into components normal and tangential to the base axis, and the inclination factors are built accordingly. In design mode (wizard, template, point entry) only the favourable direction (heel side deeper) and at most 15° can be entered; the opposite direction or more than 15° counts as an error. In DXF import (existing wall) mode both directions are free, and the unfavourable direction produces a warning.

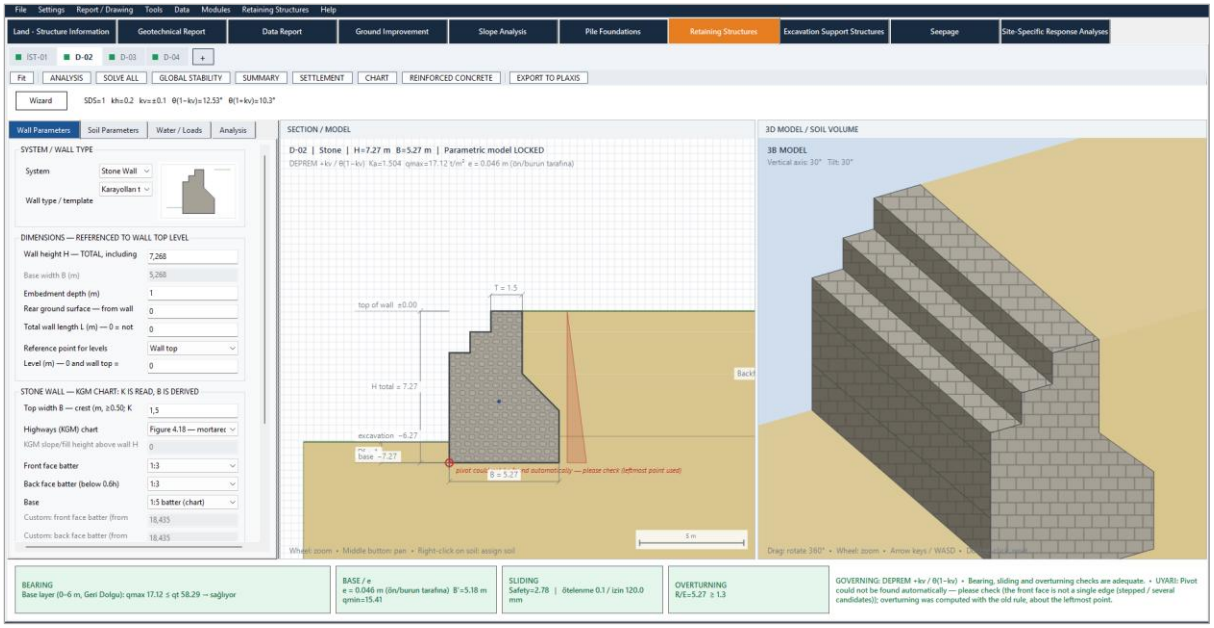


Figure 5. KGM-type stone wall: chart and slope choices on the Wall Parameters tab, section and 3D model

Reinforced concrete base slab under the stone body

The stone body can be seated on a reinforced concrete slab; the slab can extend forwards and backwards. The polygon is still a single one — the slab rectangle is added to the stone outline — and the area, centroid, base width and water column are all read from the same polygon. The weight is composite: the slab area is counted with the concrete unit weight, the rest with the stone unit weight. When a horizontal tie beam is selected, the RC slab is switched on automatically.

4.2 Cantilever RC wall

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The section is defined by the toe projection, the heel projection, the base slab thickness and the stem dimensions. The stem starts with a width at the top and may widen forwards and/or backwards towards the bottom; the widenings are entered in metres, not as angles. The base width is derived from the sum of these dimensions.

Optional elements: front buttress and rear counterfort (with projection, top depth, thickness and axis spacing), base key (width, depth and position from the toe) and load-relief slab (distance from the top of the wall, length and thickness). The load-relief slab cannot be combined with a rear counterfort; this exclusion is enforced both in the interface and in the geometry builder.

The load-relief slab counts only if it is long enough

The slab reduces the pressure only when it is long enough to cut the active wedge. The required length is the sum of the heel projection and the projection, at the active wedge angle, of the height below the slab. For a short slab the reduction is not counted even partially — all or nothing — but the slab is still drawn and designed in its own right.

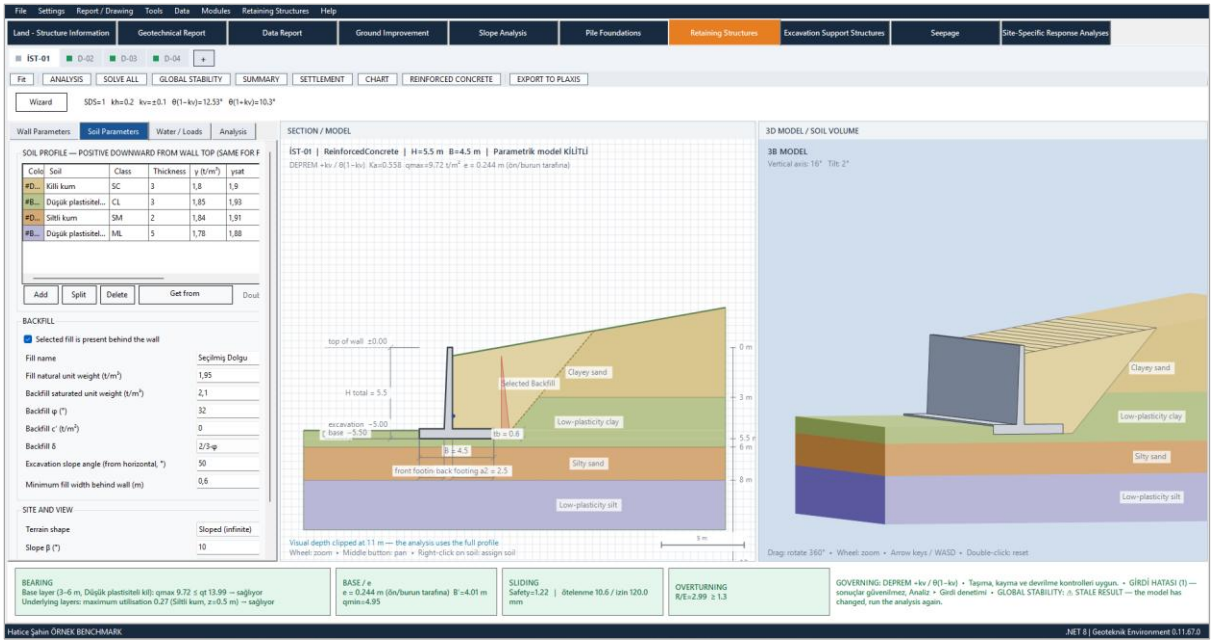


Figure 6. Cantilever RC wall: sloping backslope, selected backfill, section and 3D model

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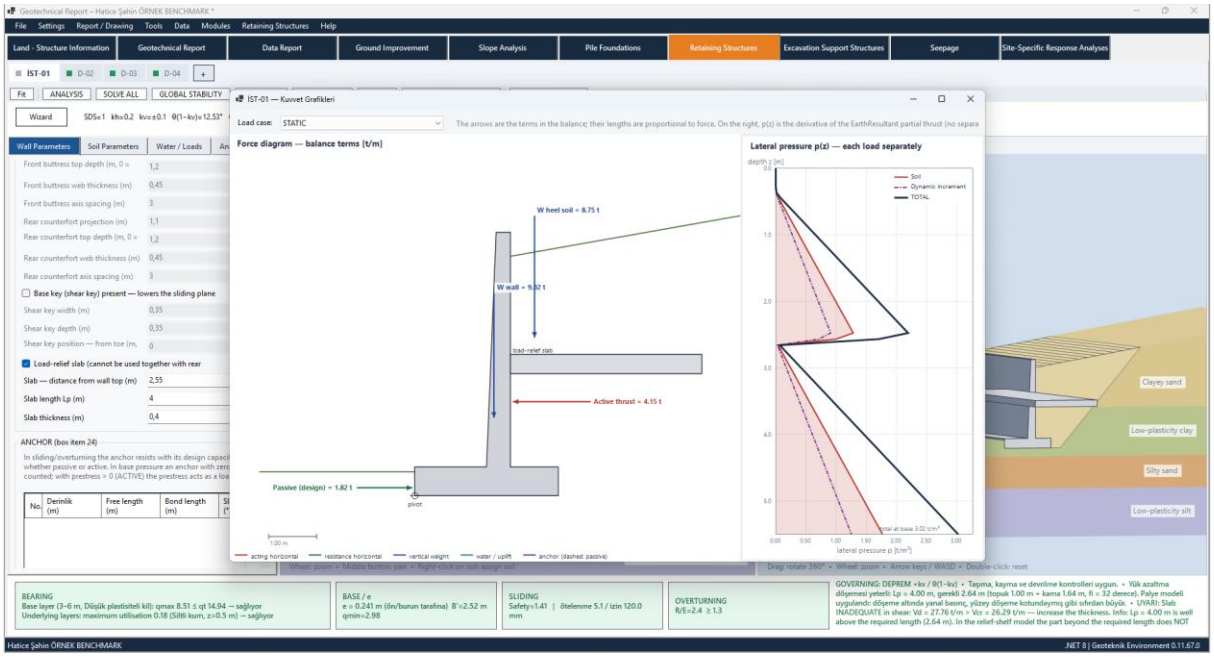


Figure 7. RC wall with load-relief slab: force diagram and the lateral pressure distribution cut at the slab level

4.3 Gabion wall

A gabion wall is built from an arrangement of boxes. The arrangement type is one of three: leaning backwards (front face stepped), leaning forwards (back face stepped) or row-based manual alignment. In the row table, the number of boxes, box dimensions and alignment of every row are entered; the table is ordered from bottom to top. There is no batter here: the boxes are aligned on one face and the other face is stepped.

The height and base width are derived from the arrangement; the H field is therefore disabled for gabion. The friction coefficient and cohesion for the row interfaces are entered separately; the default cohesion is zero — the interlocking of the wire mesh is not counted as strength, which is on the safe side.

An upper row cannot extend beyond the outer edge (towards the front face) of the row below; if it does, a warning is given and the upper row is limited, and the calculation is not corrupted.

In gabion wall design the arrangement can be produced automatically; if desired, every row can also be arranged individually by the user, leaning forwards, leaning backwards or centred. The analyses are refreshed continuously according to these choices.

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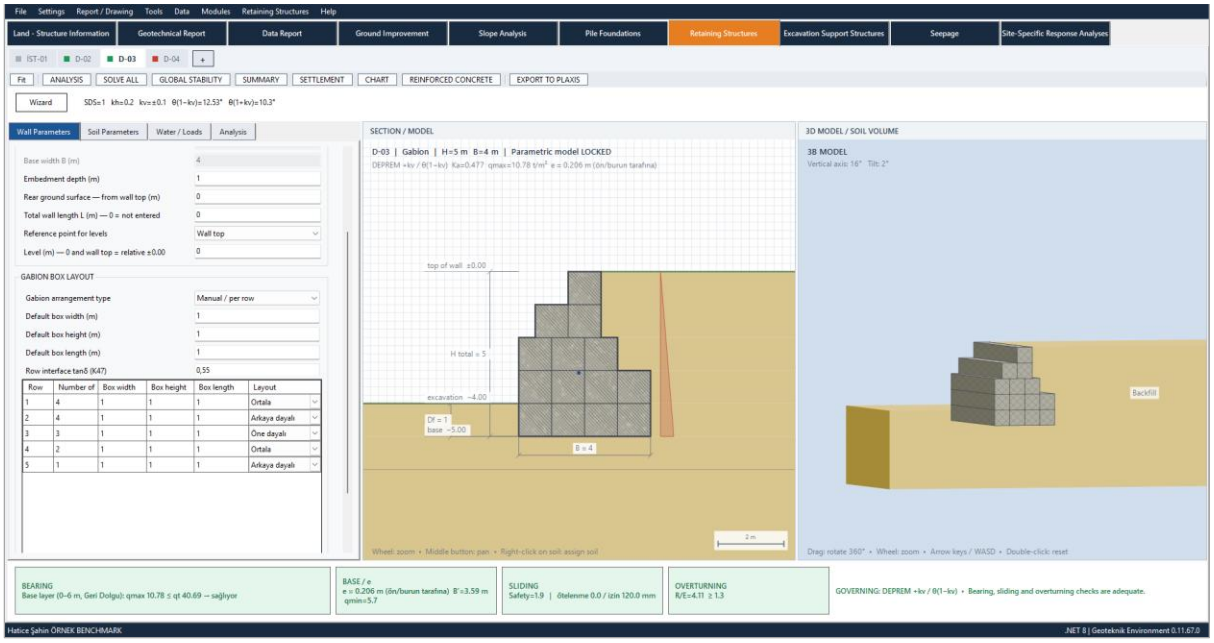


Figure 8. Gabion wall: box layout table, row-based arrangement, section and 3D model

4.4 Reinforced earth / MSE (strip)

In an MSE wall the body is the reinforced fill mass. The inputs are: strip length, vertical and horizontal strip spacing, facing inclination, the facing element type (RC panel, block/segmental, wrap-around) with its thickness and height, the reinforcement type (steel strip, steel mesh, geosynthetic) and the strength parameters of the reinforcement. For steel reinforcement the corrosion allowance and yield strength are entered, for geosynthetics the tensile strength and the reduction factors.

The external checks (overturning, sliding, bearing) are made as for the other types; in an MSE wall, however, passive resistance is not counted at all and the wall inertia kh·W is always included, regardless of the setting. The surcharge distance is measured from the outer face of the facing panel; a load on top of the reinforced block enters the external stability only as a vertical load in the base pressure and is not counted as a resistance in sliding and overturning. In addition, internal stability — rupture and pullout for every strip row — is computed in a separate window and any inadequacy is written to the status bar and to the INTERNAL card.

The MSE calculation follows FHWA NHI-10-024. The input fields change with the selected reinforcement type and only the relevant fields are shown. For steel strip and steel mesh the reinforcement width and thickness, the corrosion allowance and the yield strength are entered; for mesh also the transverse wire diameter and spacing and the longitudinal wire diameter (0 = b×t model). For geosynthetics the tensile strength, the reduction factors RFid, RFcr and RFd, the α and F* factors, the polymer type (PET, PP, HDPE; the range of the reduction factors is checked against it), the connection CRcr and the connection-zone RFd are entered. The connection strength can be entered for all types (0 = not entered). The internal stability method is chosen as ASD (allowable stress) or LRFD (load/resistance factors); the FHWA manual is LRFD based, and the ASD working ratios, which are not in the manual, are used with a warning.

In the seismic case the seismic tensile increment Tmd is added to internal stability (FHWA NHI-10-024, Chapter 7). For this, PGA, S1, Fpga and Fv and whether the site class is A/B (rock) are entered; if PGA = 0 is entered, SDS/2.5 is used. The increment is distributed equally over the rows and the total tension is taken as 1.35·Tmax + Tmd. If the rear ground is sloping, internal stability is computed for the sloping backfill. If there is an earthquake, a facing batter greater than 8°, a sloping rear ground, a strip, line or point load, or an infinite surcharge above 2 t/m², compound stability is also computed automatically: circular surfaces passing through the reinforced zone are searched with the Bishop method, the reinforcement cut by the surface is counted as a

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discrete resistance, and the target factor of safety is 1.30 or 1.50, depending on the “Wall supports a structure / foundation” box described below.

“Wall supports a structure / foundation” box: Tick this if the wall supports a structure (building foundation, bridge abutment, etc.). When ticked, the compound stability target is FS ≥ 1.50; otherwise FS ≥ 1.30 (FHWA NHI-10-024, Sect. 4.4.9 / 4.4.10). The target used and its reason are stated in the internal stability notes and in the written calculation of the report.

In the Force Charts window an MSE wall has two tabs: External equilibrium (forces) and Internal stability (reinforced soil). The Internal stability tab contains the row table and the charts “Row forces · Tmax / Ta / Pr”, “Stress · ratios · T(x)” and “K/Ka · mobilised friction · lengths”. In the type-specific check section of the Word report every row is written on its own line in the “Row-by-Row Internal Stability Check” table; in DXF the MSE sheets and the MSE_METRAJ table are produced (12.2).

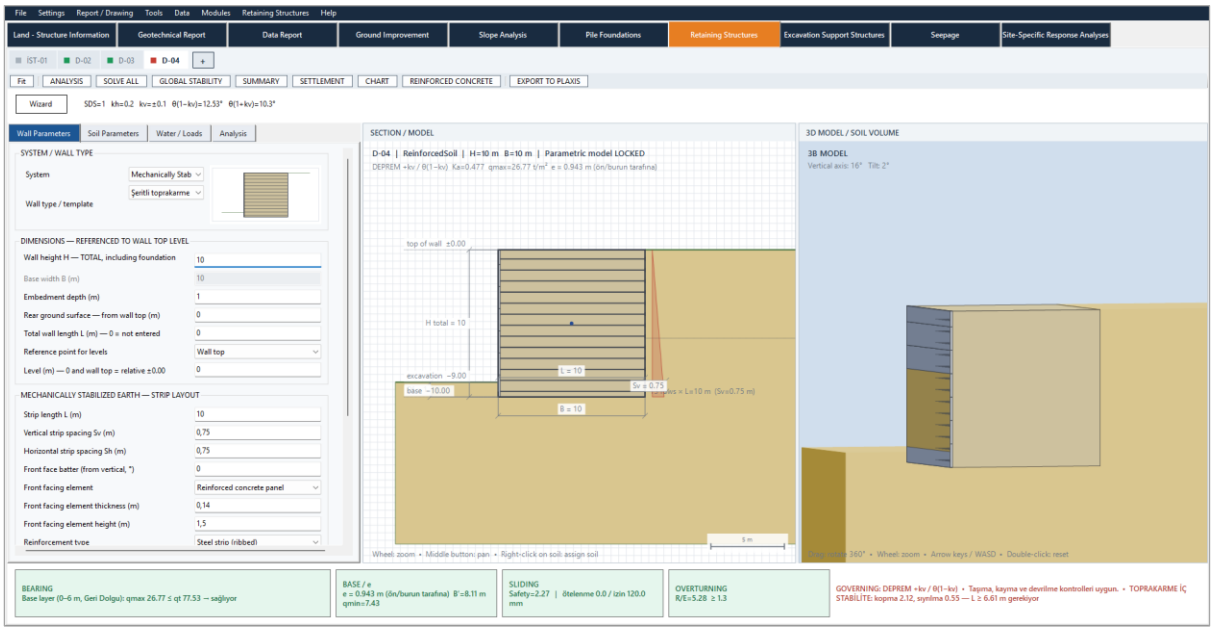


Figure 9. MSE wall: strip layout and reinforcement inputs, section and 3D model

4.5 Caisson (well) foundation

A caisson foundation is a stepped body built from the bottom up inside hand-dug shafts; the body gets thinner as it rises. The first level is the lowest lift. The rear (soil) face is vertical, the front (excavation) face is stepped, and the footing projects only forwards — a footing projecting backwards would run under the neighbouring foundation.

The number of lifts is limited, and when the limit is exceeded the program stops, saying that this is no longer a caisson foundation. There are lower bounds on lift thickness and height; a new lift is always added on top and is proposed thinner than the previous one. Every lift has its own shear check. The vertical load from the superstructure, its eccentricity, the horizontal load and the moment are entered separately.

Anchor rows can be entered for a caisson foundation just as for an RC wall. In the external checks a passive anchor is a resistance and is counted divided by the safety factor; in the section calculation it is not counted at all, because the force of a non-prestressed anchor develops only as the element displaces. An active anchor enters the section calculation; but since the caisson is built from the bottom up, every lift is computed for two situations (anchored and unanchored stage), the unfavourable one governs the design and the report states which one governed. The horizontal component of the anchors comes only from the rows above the section. With the relevant setting on, the passive thrust is capped at the sum of the active thrust and the surcharge thrust (full development of passive resistance would initiate settlement of the neighbouring structure); any clipping is

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stated in the message. The front and rear face reinforcement are evaluated separately by sign: if the anchor prestress exceeds the thrust, tension develops on the front face.

In a caisson foundation the embedment depth equals the footing thickness and H is derived from the sum of the lift heights and the footing thickness; these two fields are disabled as inputs. Earthquake analysis is off by default (Settings › Well Foundation): while off, S_{DS} = 0 is taken, the earthquake action does not enter the calculation and does not appear in the report.

4.6 Anchors

The anchor table is shown for reinforced concrete walls (caisson foundation included) and is counted in the calculation only there. For every row the head depth, free length, bond length, inclination, horizontal spacing, drill-hole diameter, prestress, steel area, steel yield strength and bond stress are entered.

Zero prestress means a passive anchor

If the prestress is entered as zero the anchor is passive: its force develops as the wall moves, it is a resistance and is divided by the safety factor. If the prestress is greater than zero the anchor is active and its force acts like a load. The bond length must start behind the active wedge; an anchor whose free length is not long enough for this contributes zero.

For anchored walls a deep-block check by the Kranz method (stability of the mass behind the bond zone) is also made; however deep the bond zone goes, if that mass can slide the anchor is not holding on to anything.

Anchors enter the calculation in a reinforced concrete body (caisson foundation included). In a stone wall an anchor is counted only if the “Passive anchor / rock bolt on stone wall” box in the stone wall group of the Wall Parameters tab is checked (default off): the anchor is then counted only as passive and resists sliding and overturning with the design capacity Td = min(steel, bond); it is not counted in the base pressure or in the body section calculation. While this box is off, anchor rows entered for a stone wall, and for a gabion or MSE wall, are not deleted; they are not counted, and this is reported in the message line. If the wall type is changed to reinforced concrete, the rows are counted again. The drill-hole diameter is set on the Settings › Anchor tab; the default value should be replaced by the drill-hole diameter used on site. The same tab holds the factors for stone wall anchors: steel factor γs (default 1.15), bond factor γa (default 1.98 = 1.80 × 1.10), required Kranz FS (default 1.50) and the stone–mortar bond strength τ (0 = not entered; no pull-out check inside the body is made). If τ is entered and the bond capacity inside the body $\pi \cdot D \cdot L \cdot \tau / \gamma a$ is not sufficient, the program gives a warning. Reinforced concrete anchors are not affected by these factors.

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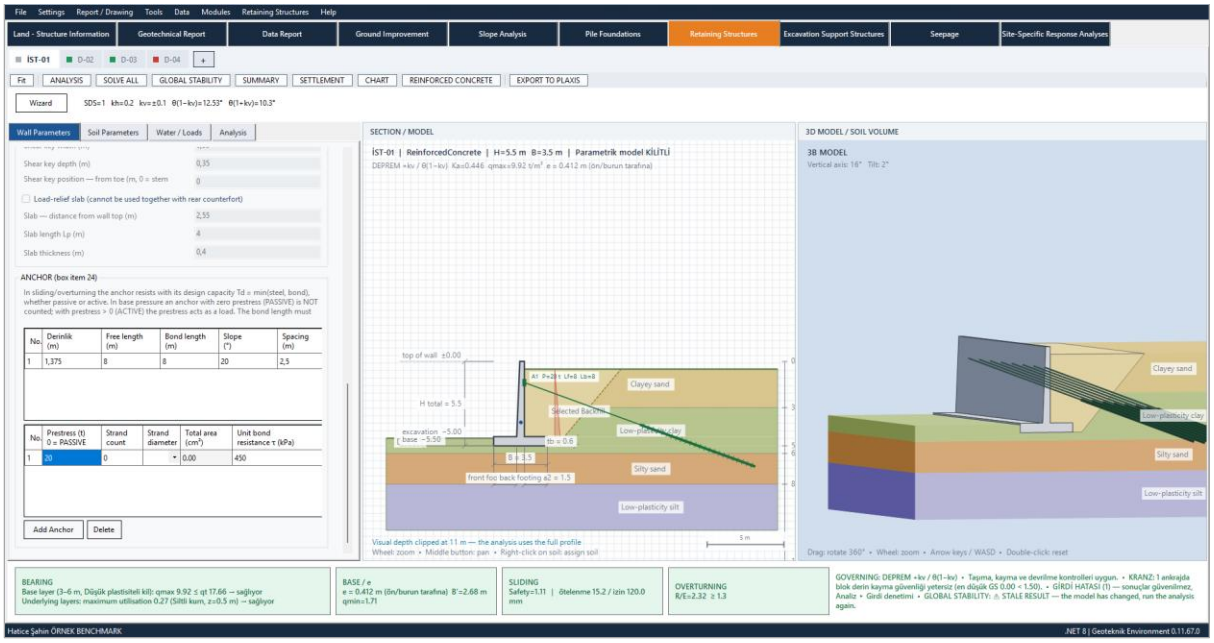


Figure 10. Anchored RC wall: anchor in the section and anchor row in the 3D model

4.7 Horizontal tie beam

In stone walls a horizontal tie beam is always present at the topmost level; no tie beam is placed at the bottom, because when a tie beam is selected a reinforced concrete base slab is placed under the stone body as a matter of course and the slab ties the body at its bearing plane. The intermediate levels are derived from the spacing entered and do not land on the slab. The tie beam does not reduce the earth thrust or the shear stress; it prevents the wall from breaking up into independent blocks. Its counterpart in the calculation is that the tie beam levels are excluded from the joint scan. The spacing cannot drop below a lower bound — below it the element ceases to be a stone wall and turns into a reinforced concrete frame. The tie beam is interrupted at the expansion joint between wall segments.

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5. Soil, Water and Loads

5.1 Soil profile

A single soil profile is entered, and the front and the back of the wall are both derived from it. Depths are measured positive downwards from the top of the wall. For every layer the name, colour, thickness, natural and saturated unit weights, angle of internal friction, effective cohesion, undrained shear strength, interface friction angle choice, modulus of elasticity and coefficient of volume compressibility are entered. There are two more boxes: whether high pore-water pressure is expected in the layer, and whether the layer is to be solved undrained in the short term.

The interface friction angle δ is chosen per layer: two-thirds of the angle of internal friction (default), one-third, or zero. This is a declaration rather than a preference; it is set according to the roughness of the wall back and the construction method.

The soil table has a Class (USCS) column. A class is proposed from the layer name (e.g. CL or CH for “Clay”); if the name and the class disagree, a warning is given.

The soil parameters can be taken from the Geotechnical Report module with a single command (the Get from GeoteknikRapor button on the Soil Parameters tab, or Import GeoteknikRapor soils on the Data menu). The transfer is a copy; no live link is created and later changes in the main report are not reflected here automatically — repeat the transfer if needed. What is transferred: layer name, levels, unit weights, angle of internal friction, cohesion, undrained shear strength, modulus of elasticity and coefficient of volume compressibility. Groundwater, earthquake parameters, surcharges, the δ choice and all geometry are entered separately in this module.

5.2 Selected backfill

If selected fill is to be placed behind the wall, the fill's own unit weights, angle of internal friction, cohesion and interface angle are entered separately; in addition, the inclination of the excavation slope and the minimum fill width behind the wall are defined. These two dimensions determine how much space the fill actually occupies.

If the fill is narrow and the active wedge cuts the excavation slope, the slip plane passes partly through the natural ground. In this case the program makes a mixed-wedge calculation: a trial-wedge (Coulomb) solution is set up for planar slip surfaces through the heel, and the weight and c and ϕ are mixed according to the segment lengths. The ratio of the mixed thrust to the backfill-only thrust (at least 1) is applied to the stability thrust; the thrust can only increase this way, never decrease. The calculation is for a flat rear surface, is not applied to MSE walls, and when applied a mixed-wedge note with the ratio used is written to the message line.

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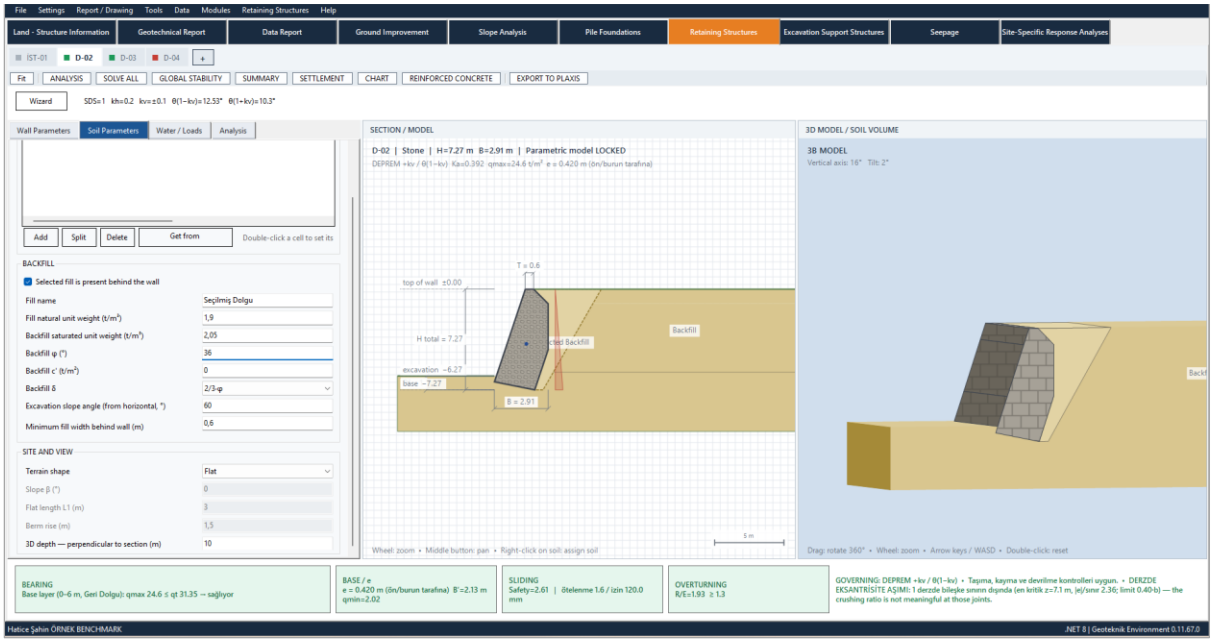


Figure 11. Soil Parameters tab: soil profile, selected backfill and ground surface shape inputs

5.3 Ground surface shape

The backslope can take one of four shapes: level, infinitely sloping, first level then sloping, or berm (first sloping then level). The closed-form active pressure coefficient is derived for an infinite plane surface; it cannot be applied directly to a broken surface.

A broken surface is replaced by an equivalent slope

For a broken surface the program measures the actual rise of the ground behind the wall over an influence length proportional to the wall height and derives an equivalent uniform slope from that rise. The equivalent slope can never exceed the actual slope and reduces to the limiting cases: to the entered slope for an infinite slope, to zero for level ground. The balance line writes the entered slope, the effective slope and the influence length used together.

5.4 Groundwater

Water levels are measured from the local ground surface: the rear water is entered positive downwards from the rear ground surface, the front water from the front (excavation) surface. By construction, water cannot rise above the surface. For a model without water a single box is ticked.

If the water levels differ on the two sides, two independent hydrostatic distributions are built and the base uplift is taken linearly from the water pressures at the two ends; no flow net is solved, and this assumption is stated in the report.

In the earthquake case the behaviour of the water depends on the permeability of the soil. If impervious is chosen, the water moves with the wall and no additional dynamic water pressure arises; if pervious is chosen, an additional dynamic pressure is added for the free water mass. The choice is presented on screen together with the permeability coefficient limit.

In the pervious case the additional dynamic water thrust is computed as $\Delta P_w = 7/12 \cdot (0.4\ S_{DS}) \cdot \gamma_w \cdot d_w^2$ (TBDY 2018, Eq. 16.20; pressure distribution Eq. 16.19). Here d_w is the height of the water column; the resultant acts at a depth of 0.6 d_w below the water surface. The reduction (r) used for the dynamic soil thrust is not applied to the water. ΔP_w appears as a separate term in the balance and the force diagram and as a separate curve in the pressure chart, and is added to the RC section forces.

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If there is granular selected fill behind the wall, the soil must be treated as dynamically pervious (TBDY 2018, 16.12.3.2). If “Impervious” is selected while the fill is granular, the input audit issues a warning; when granular fill is ticked, the default choice becomes “Pervious”.

The tension crack may be assumed to be filled with water (Settings › General; default on). The tension-crack water ½ $\gamma_w z_c^2$ is a separate term in the balance under the name “Tension-crack water”, a separate curve in the pressure chart, and enters the RC section forces. The Westergaard additional dynamic water pressure is not applied to the crack water; the hydrodynamic effect in a narrow crack is neglected.

5.5 Surcharges

There are four surcharge types and all are kept in the same table.

Table 7. Surcharge types

Type	Entered	Behaviour
Infinite	Intensity	Extends to infinity along the surface; added directly to the vertical stress.
Strip	Intensity, distance from the wall, width	A load strip of limited width; its lateral stress comes from the elastic solution.
Line	Load per metre, distance from the wall	A line load parallel to the wall.
Point	Load, distance from the wall	A point load; no lateral spreading is applied, the nearest vertical plane is taken — on the safe side.

Width is meaningful only for the strip load; for the other types the cell is disabled and shows a dash. Every load may also be given a depth from the top of the wall. The load level is the greater of the entered depth and the depth of the rear ground surface: the load is treated as buried only if the entered depth lies below the rear ground surface, and only the part below the load level is counted. Global stability and the PLAXIS export use the same rule; the drawing shows the load at its level on the lowered ground surface. In an MSE wall the load distance is measured from the outer face of the facing panel.

The lateral stress of strip, line and point loads is computed from the elastic (Boussinesq) solution with a reflection factor of 1.0: because the wall displaces, the doubling of the NAVFAC rigid-wall assumption (2× reflection) is not applied, and the coefficients used are half of the NAVFAC values. The lateral pressure is also 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 of the first rear soil layer and σv,max is the largest vertical stress directly below the load at the same depth. The program clips any value above this cap. These loads are independent of the seismic coefficient; the dynamic increment is applied to the soil thrust, not to the surface loads.

5.6 Minimum lateral design pressure

In a very soft soil, or one whose angle of internal friction is close to zero, the computed active pressure can come out smaller than any wall would realistically be designed for, even zero. A floor pressure is defined against this, with one of four forms: off, a fixed value, a ratio of the effective vertical stress (default), or equivalent fluid pressure. In the ratio form the coefficient is limited to a narrow range: below it the condition loses its meaning, above it the measured undrained shear strength loses its meaning.

The contribution of this pressure is tracked separately and is not mixed with the soil thrust; it appears as its own component in the pressure chart and as a separate line in the balance. Below a load-relief slab the minimum pressure is reduced by the slab ratio (σv,reduced / σv,full) in all three forms (ratio, equivalent fluid and fixed).

The minimum pressure is also applied in the tension-crack zone (Settings › General; default on). When the option is off it is zero in the crack zone; however, if the whole wall lies within the crack zone it is applied over the full height regardless of the layer type. Thus, in a soil with high cohesion and a low friction angle, the wall is not

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designed for zero lateral load. The minimum pressure depends on the effective vertical stress, while the crack water is added separately with γ_w; the same component is not counted twice.

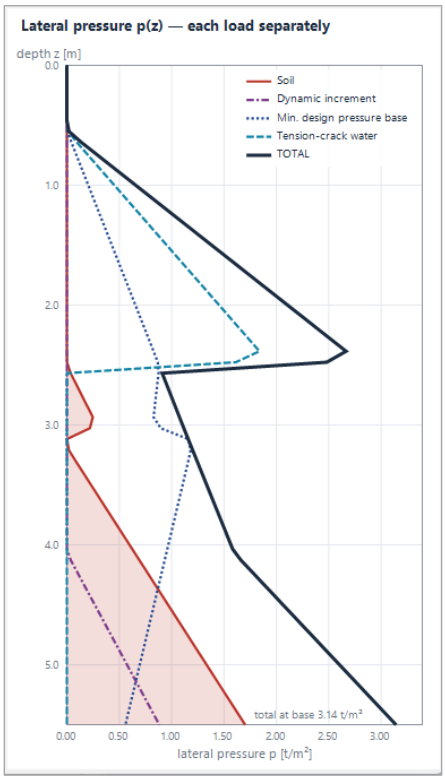


Figure 12. Force Charts: lateral pressure distribution with surcharge, tension-crack water and minimum design base components

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6. Earthquake Action

The earthquake action is taken as pseudo-static. The horizontal and vertical seismic coefficients are derived from S_{DS} and the selected r coefficient according to TBDY 2018; the header line shows these values together with the two seismic inertia angles.

Every model is solved for three load cases: static, vertical earthquake acting downwards, and vertical earthquake acting upwards. Which one is more unfavourable depends on the geometry and cannot be known in advance; therefore both are solved and the governing case is chosen by normalising every check against its own target.

6.1 The r coefficient and permissible displacement

The r coefficient is a reduction tied to the permanent displacement permitted for the wall: one if no displacement is permitted, larger values if a limited displacement is allowed. The choice is a commitment rather than a preference: the displacement allowed by the selected value must be compatible with the use of the structure.

The program checks this commitment. The Newmark permanent displacement check computes the critical coefficient corresponding to the onset of sliding of the wall and estimates the expected permanent displacement with two independent empirical relations; the result is compared with the value allowed by the selected r. If it is exceeded, the warning “the selected r is not verified” is written to the status bar.

If r is chosen greater than one in a model with water, a warning is produced according to the code limit for this case.

6.2 Separation of the dynamic thrust

The difference between the total active pressure coefficient and the static coefficient is the dynamic increment coefficient. The vertical earthquake multiplier is applied only to this dynamic increment; the static thrust remains without a multiplier. The wall weight takes the multiplier with the same sign as the soil — in an upward earthquake, the soil getting heavier while the wall gets lighter is not physical.

The wall's own inertia (horizontal seismic coefficient times weight, $k_h \cdot W$) is governed, as the “kh·W wall inertia”, by the setting “Use kh·W in the wall analysis?” on the Settings › Reinforced concrete tab; it is off by default. With the setting on, $k_h \cdot W$ enters the sliding, overturning and bearing balance, the internal forces of the stone body (shear, moment, crushing), the horizontal joint sliding and the gabion row interfaces together; with it off, it enters none of them. In an MSE wall kh·W is always included, regardless of this setting. Which state applies is stated explicitly in the balance and the report. The moment of the inertia is measured not about a single “wall centre” but about the weighted average of the individual centroids of the wall, the soil over the heel and — if present — the slope wedge. In the RC section design the stem's own inertia is added to shear and moment as a distributed load by a separate setting (“Use kh·W in the reinforced concrete design?”, default off); this setting does not change the stability.

The seismic passive pressure coefficient always stays below the static value; passive resistance growing under earthquake action is not physical.

The distribution of the seismic thrust increment (ΔPae) over the wall height is set by the “Distribution of the seismic earth-pressure increment over the height” option on the Settings › General tab: “Uniform — point of action H/2”, “Bulged (half-sine) — point of action H/2 (RECOMMENDED)” (default) or “Seed–Whitman — point of action 0.6H (outside the code)”. The total ΔPae does not change. The choice changes the stem section forces and the pressure diagram, and with Seed–Whitman also the overturning lever arm. The distribution used is written as a separate line in the balance.

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In a layer ticked as short-term undrained the static lateral pressure is taken as σv − 2·cu; in the seismic case the increment (Kae − Ka)·σv is added on top, and the increment is independent of cohesion. In a layer with ϕ = 0 the Mononobe–Okabe expression gives Kae = Ka = 1, so the increment comes out as zero. If the retained soil contains a ϕ = 0 layer while kh > 0, a warning stating this appears in the message line and a site-specific dynamic check is recommended.

7. Checks

The checks fall into three groups: external checks performed for every wall, checks specific to the wall type, and checks run on demand.

7.1 External checks

Table 8. Checks performed for every wall

Check	Basis
Overturning	The ratio of the resisting moment to the overturning moment is compared with the target of the case. Passive resistance is included in overturning at its full value by default (Settings › Factors of safety, “Include passive resistance in overturning”). With it off, overturning safety would fall as the wall is embedded deeper, because embedment would increase the active pressure and put nothing on the resisting side. In an MSE wall passive resistance is not counted at all in the overturning, sliding and base pressure checks. In an RC wall, if the front face of the base key is at most 0.15 m behind the toe, the overturning pivot is the tip of the key: the lever arm of the active thrust grows by the key depth d, passive resistance is taken in full over the depth D + d, and the soil block under the key is not added to overturning. This rule changes only the overturning ratio; if there is an anchor or caisson term, the pivot stays at the toe.
Sliding at the base	The horizontal demand is compared with the sum of the base resistance and a limited share of the passive resistance. The base resistance comes, in the drained case, from the net vertical load and the interface friction coefficient and, in undrained clay, from the contact area and the undrained shear strength. Only a limited share of the passive resistance is counted: $R_{th} + 0.3 \cdot R_{pt}$; here R_{pt} is the passive resistance divided by the partial factor (TBDY 2018, 16.9). In a front soil layer ticked as short-term undrained and with cu entered, the cohesion term of passive resistance is computed with cu instead of c’.
Base pressure	A single assumption is used: linear distribution if the eccentricity is less than one-sixth of the base width, a no-tension triangular distribution if it is larger. If the resultant falls outside the base this is an outright failure and is reported as such.
Bearing capacity	The TBDY 2018 bearing capacity equation, with shape, depth and inclination factors by the method selected in the settings. The layers below the footing are also scanned, and if a weak underlying layer is found it is written to the status bar.

The safety schemes of the static and earthquake cases are separate

In the static case higher targets are used for sliding and overturning; in the earthquake case the code's own values apply. The governing-case ranking normalises overturning against the target of each case; otherwise a numerically larger ratio could actually have a narrower margin.

7.2 Checks specific to the wall type

Table 9. Type-specific checks

Type	Check
Stone	Horizontal joint sliding: scanned along the wall at fixed steps and at the corner levels. At every joint everything above the joint is taken as a free body; the sum of the thrusts is checked against the joint cohesion and the friction arising from the effective normal force. Tie beam levels are excluded from the scan. Also body crushing: the maximum compression is compared with the design compressive strength

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Type	Check
	of the masonry. At the joint and in the body section, V = thrust + $k_h \cdot W_{above}$ and M = … + $k_h \cdot W_{above} \cdot \bar{y}$ are taken; the $k_h \cdot W_{above}$ term is included only while the “kh·W wall inertia” setting is on.
Gabion	Row interfaces: a gabion is not monolithic; every row interface is both a sliding and an overturning plane. At every interface the block above is taken as a free body; the sliding resistance is measured from the overlapping contact width of the two rows, and the overturning pivot from the front edge of the contact area.
MSE	Internal stability: for every strip row, rupture (tension in the strip against the design strength) and pullout (friction over the anchorage length behind the wedge) are computed and the required strip length is reported. Under earthquake the seismic tensile increment Tmd is added, and compound stability is computed when its conditions arise (4.4).
Caisson foundation	Every lift has its own shear check; in a stepped body the critical section is not always the lowest lift.
Reinforced concrete	Section design of the stem and footings, anchor provisions for anchored walls, and the Kranz deep-block check.

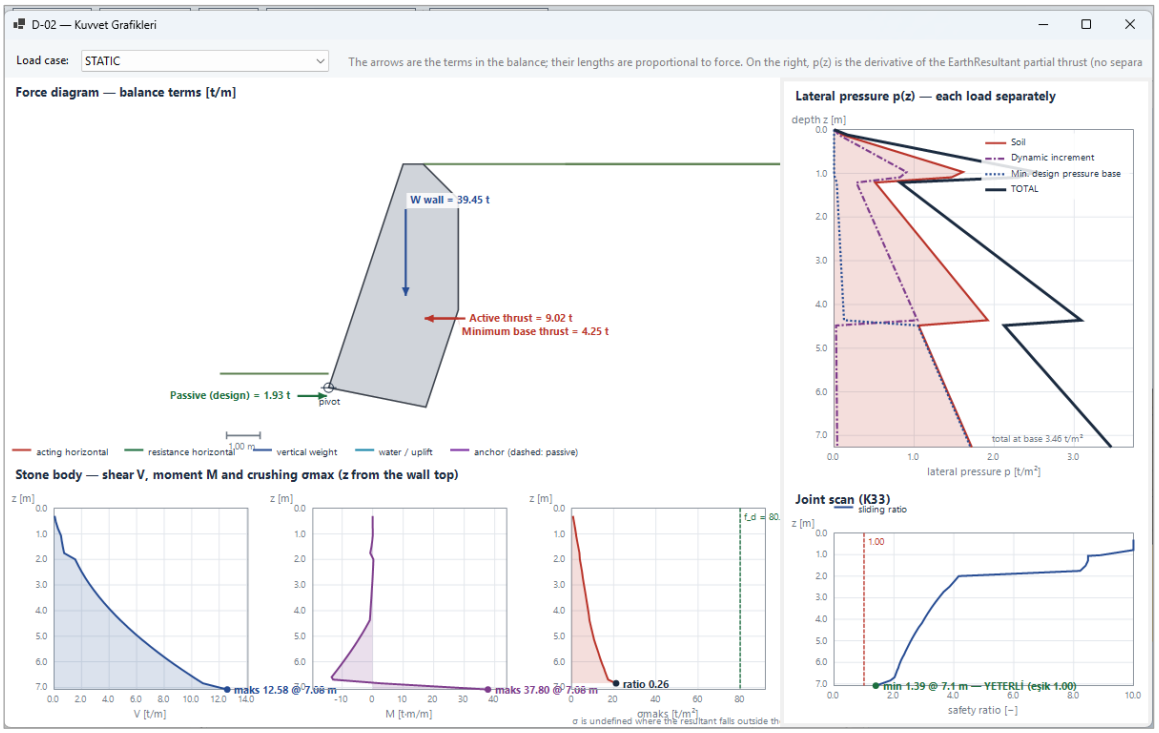


Figure 13. Stone wall Force Charts: shear, moment and crushing distributions in the body and the joint scan

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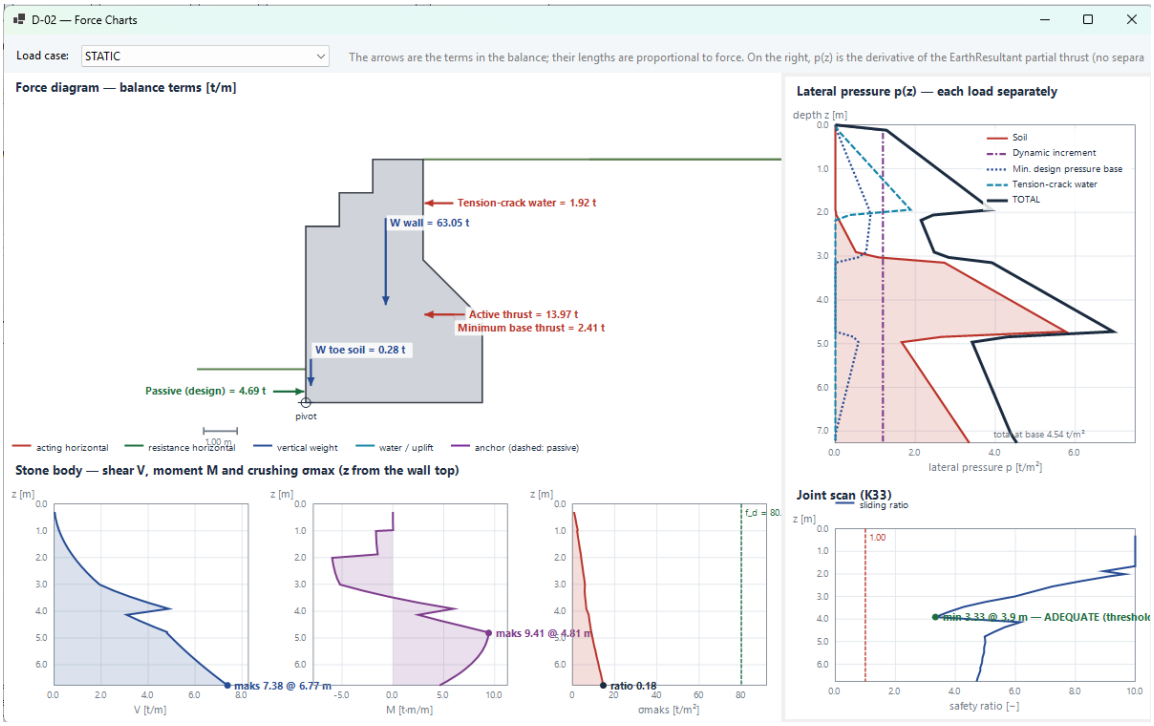


Figure 14. Gabion wall Force Charts: force diagram and sliding and overturning safety at the row interfaces

7.3 Optional checks

Global stability

Global stability searches for a slip surface around the wall by the limit equilibrium method. The wall body is modelled as a rigid block: its weight enters the calculation, and the slip surface cannot pass through it. This check does not run automatically on every input change; it is started with a separate button (GLOBAL STABILITY) and its result is kept together with a record of the inputs it was computed from. When the input changes the result is removed from the section; no stale number stays on screen.

Some simplifications are made in global stability, and all of them are written to the diagnostic notes: selected backfill is not modelled separately (safe side), line, point and buried surcharges are skipped, only layers with a defined undrained shear strength are solved undrained, and the last layer is extended to the bottom of the model.

Global stability: solver choice, method comparison and the rigid block

The governing solver is set by the “Overall stability governing solver” option on the Settings › Overall stability tab: Spencer (default) or TBDY 2018 (administrative requirement, Eq. 16.30). When TBDY is selected the governing solver becomes TBDY 16.30; the screen, the report and the result record state which one governs. TBDY 16.30 is formulated for circular surfaces and, on cohesive, steep surfaces, may give a lower result than Spencer because of the cohesion term; the option exists for code compliance. For the results of the two solvers on the same section, see 11.1.

Alongside the governing solver, Janbu (simplified and corrected), Bishop and similar methods are computed for information on the same surface, and the methods table is written to the screen and the report. If the spread between the methods exceeds 10% of the governing factor of safety, an “INTER-METHOD DIFFERENCE” warning is given; if the lowest method value falls below the target while the governing method satisfies it, an additional warning is written. Since Janbu ignores the inter-slice shear force, it is expected to come out markedly lower than Spencer when the upper end of the slip surface is very steep. The warning does not change the governing factor of safety; it asks for a visual check of the section and surface geometry.

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The slip surface cannot pass through the rigid block (wall body, base slab). The block check treats a surface whose two consecutive sample points lie on opposite sides of the block as having cut the block, and invalidates it; this rule prevents surfaces that pierce a thin, wide slab from being accepted as valid. Surfaces are generated by the three-point, entry–exit and centre-grid generators and, where the model has layers, also by the weak-layer and composite generators.

The search density is set by the “Overall stability search density” option on the Settings › Overall stability tab. “Wall — fast (default)” searches sparsely within a window around the wall body and refines locally around the best candidates (about 900–1 330 candidate surfaces per case). “Detailed — full search (slow)” performs a full search (about 21 000 candidates per case). With the Wall density the factor of safety may differ by about 2% from the full search; a result very close to the target should be confirmed with Detailed. Wedge (two-block) and undermining surfaces are always searched with the Detailed density; with the Wall density they are searched only if the “Also search wedge / undermining surfaces with the Wall density” box is checked (default off). The result box and the report state the density used and the number of candidate surfaces per case. The density is a numerical search setting and does not enter the input record: changing it does not make an existing result stale.

The overall stability of all walls can also be computed with a single command: Walls › Overall stability for all walls… or the ALL button on the toolbar. The window that opens states the number of walls and how many will be skipped because they have a current result and how many will be computed. A wall whose inputs have not changed and which has a successful result is skipped; if the “Force recompute all (including up-to-date results)” box is ticked, all walls are recomputed. Start runs the job in the background; several walls are solved at the same time (at most one less than the number of processor cores) and the search density from the settings is used. If stopped with Cancel, the results of the walls solved up to that moment remain. Finally a summary window opens: the static and seismic factors of safety, the targets and the status are written for every wall, a row that does not satisfy the target is red, and the Copy button copies the table to the clipboard. The “compute now” option offered before the Word report uses the same bulk run (12.1).

Settlement

Settlement is computed per layer with the modulus of elasticity and — where defined — the coefficient of volume compressibility; if the latter is entered, consolidation settlement is added. The pressure is taken net, by subtracting the overburden stress from the static base distribution, and is spread with depth by Boussinesq strip superposition; no crude spreading angle is used. The result is given at three points (toe, middle, heel) and as a rotation.

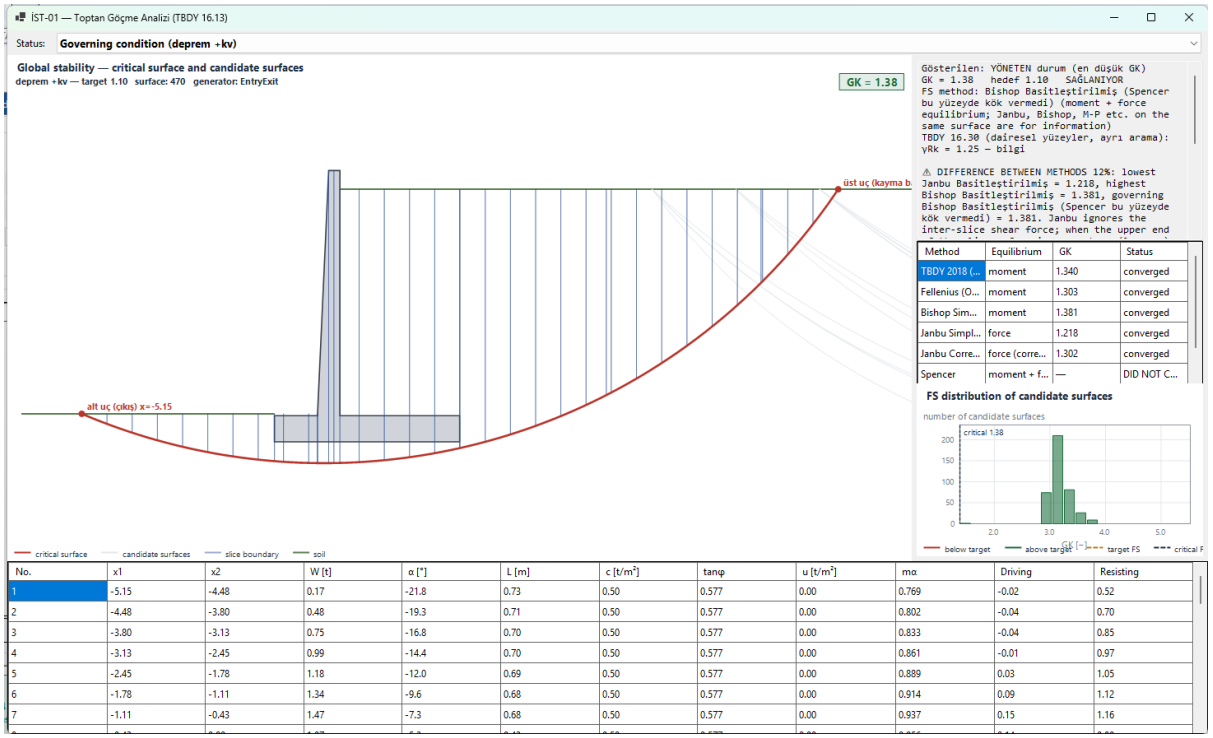
A layer with no modulus of elasticity is skipped and this is reported; no default value is used without notifying the user. The site history — cut or fill — determines which stress is subtracted in the consolidation settlement and is selected on screen.

Weak underlying layer and punching

The layers below the footing are scanned and, taking the spreading of stress with depth into account, the bearing capacity of every layer is checked on its own. A footing seated on a firm layer with an inadequate soft layer below it is a failure mode that a calculation looking only at the base check cannot see.

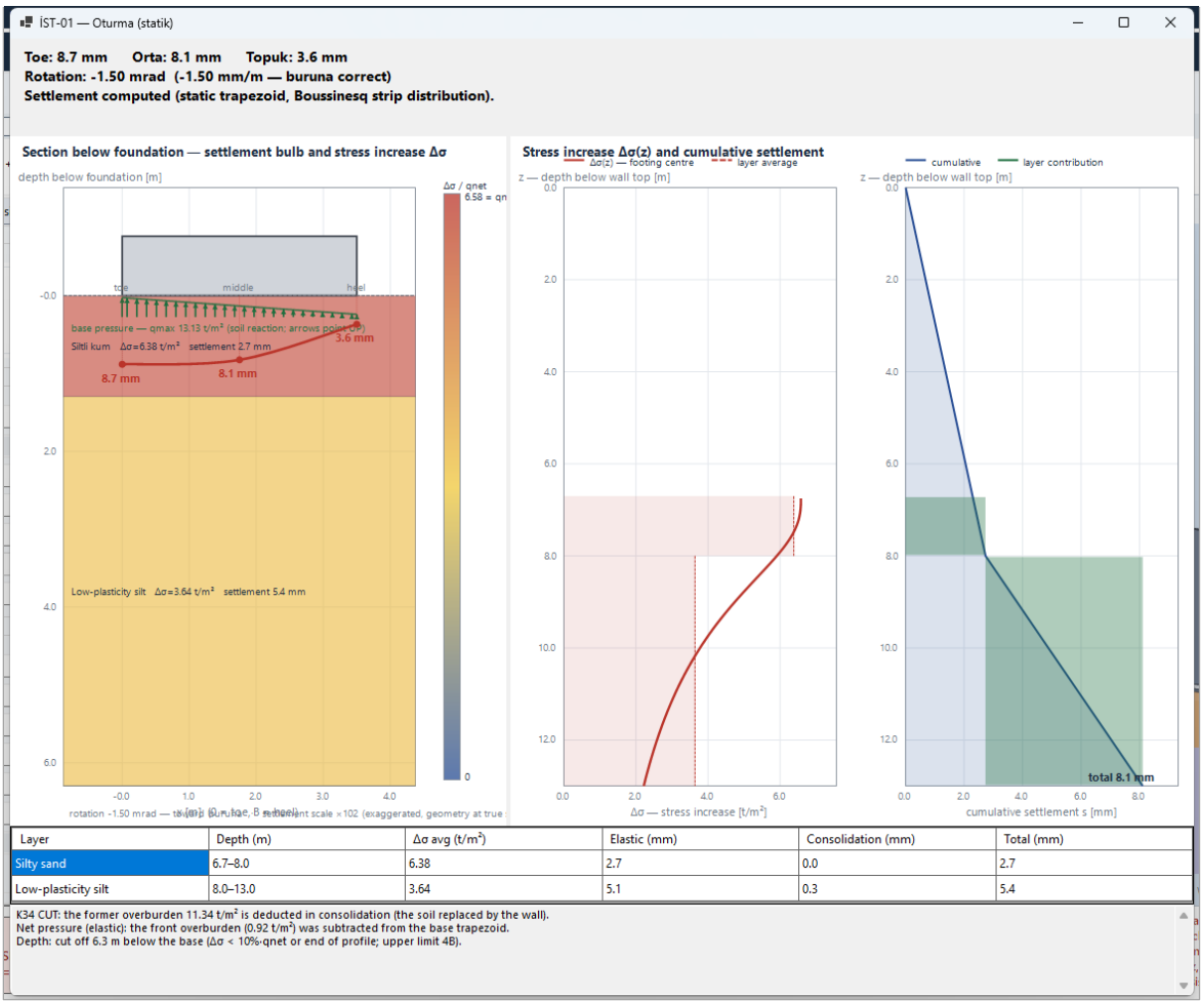
In a single-layer profile there is no second layer below the base. The row at base level (z = 0) is a reference only and does not compete with the other rows; the WEAK SUBLAYER warning is given only if a row with z > 0 exists. For walls with an inclined base, the z = 0 row is computed with the same normal and tangential force resolution and inclination rule as the main bearing check; but because the demand is taken as a uniform pressure (V_{net}/B') it does not come out exactly equal to the q_{max} of the main check. The governing check is the main bearing check.

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No.	x1	x2	W [t]	α [°]	L [m]	c [t/m²]	tanφ	u [t/m²]	mα	Driving	Resisting
1	-5.15	-4.48	0.17	-21.8	0.73	0.50	0.577	0.00	0.769	-0.02	0.52
2	-4.48	-3.80	0.48	-19.3	0.71	0.50	0.577	0.00	0.802	-0.04	0.70
3	-3.80	-3.13	0.75	-16.8	0.70	0.50	0.577	0.00	0.833	-0.04	0.85
4	-3.13	-2.45	0.99	-14.4	0.70	0.50	0.577	0.00	0.861	-0.01	0.97
5	-2.45	-1.78	1.18	-12.0	0.69	0.50	0.577	0.00	0.889	0.03	1.05
6	-1.78	-1.11	1.34	-9.6	0.68	0.50	0.577	0.00	0.914	0.09	1.12
7	-1.11	-0.43	1.47	-7.3	0.68	0.50	0.577	0.00	0.937	0.15	1.16

Figure 15. Global Stability Analysis window: critical slip surface, candidate surfaces, methods table and slice table



Layer	Depth (m)	Δσ avg (t/m²)	Elastic (mm)	Consolidation (mm)	Total (mm)
Silty sand	6.7–8.0	6.38	2.7	0.0	2.7
Low-plasticity silt	8.0–13.0	3.64	5.1	0.3	5.4

K34 CUT: the former overburden 11.34 t/m² is deducted in consolidation (the soil replaced by the wall).
Net pressure (elastic): the front overburden (0.92 t/m²) was subtracted from the base trapezoid.
Depth: cut off 6.3 m below the base (Δσ < 10%·qnet or end of profile; upper limit 4B).

Figure 16. Settlement window: section below the footing, stress increase Δσ(z), cumulative settlement and layer contributions

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8. Reinforced Concrete Design

In reinforced concrete walls the stem, the base slab and — where present — the counterforts/buttresses and the load-relief slab are dimensioned according to TS 500 and TBDY. The concrete and steel grades and the cover come from the settings. For the stem section forces, the static envelope is built by multiplying the earth and water thrust and the surcharge by 1.6 (TS 500), the earthquake envelope by 1.0. The design envelope is the maximum of the section forces computed separately for each of the three load cases.

The section forces do not come from a separate formula

The shear and moment at any level of the stem are derived from the partial integral of the pressure distribution down to that level and from the water and special surcharges — the very same terms used in the external checks. No second calculation path is opened for the same quantity; thus the balance, the joint scan and the RC section use the same numbers.

The flexural reinforcement is computed with the rectangular stress block assumption and the minimum reinforcement ratio is checked. A section that is inadequate is reported explicitly. Shear is compared with the capacity of the section without stirrups, and when it is exceeded the need for stirrups is stated. The shear check is scanned not only at the stem base but at all stem levels; when the stem thickness varies with height the most critical shear ratio may not be at the bottom section, and if such a section occurs it is written to the check table as a separate row, “Stem — most critical shear section”. At the stem–footing joint the shear-friction capacity is limited to $0.2 \cdot f_{cd} \cdot A_c$ (f_{cd} taken as at most 25 MPa).

The footings are solved as cantilevers with the base pressure distribution — including the no-tension triangular distribution. On the toe the cover soil above is neglected (safe side); on the heel the soil column above, the surcharge and the self-weight are counted downwards.

In a counterforted wall the stem panel is solved like a continuous slab between the counterforts, while the counterfort carries, as a cantilever, the demand of the strip of its own width. A scan table is produced for the axis spacing: the panel moment grows with the square of the spacing, the counterfort moment with the spacing, so the economical spacing is sought at the intersection of these two trends.

In a counterforted wall the stem works as a plate between the base and two counterforts, free at the top, and carries the load horizontally to the counterforts. The horizontal moment and shear of the panel are computed with the EM-27 tables if the plate aspect ratio lies within their range, otherwise with $M = p \cdot s^2/10$ and $V = 0.6 \cdot p \cdot s$. In the vertical direction the fixed-edge moment at the base is also taken as $M = p \cdot s^2/10$, $V = 0.6 \cdot p \cdot s$, decreases linearly to zero at a height s above the base, and is limited at every level by the cantilever value; as the counterfort spacing grows the behaviour returns to that of a cantilever. If the front and rear counterforts have different axis spacings, the panel is computed for the larger spacing.

The main counterfort reinforcement is given as number × Φ and must fit into the counterfort web in at most three layers; if it does not, a larger diameter or a thicker counterfort is requested. The main counterfort reinforcement has its own permitted diameter list (default Φ16–Φ36). The tension that the stem transfers to the counterfort ($T = p \cdot s$) is carried by two-legged horizontal U-ties at the counterfort–stem junction; these ties are given as separate bar marks for the lower, middle and upper zone. If Vd > Vcr in the counterfort web, a shear stirrup row computed to TS 500 Clause 8.1 is opened. At the ends of the counterfort a connection zone (step and tab) is always present and is at least 0.20 m; if it does not fit the geometry it is clipped and the input audit warns.

The Settings › Reinforced concrete tab also contains the following detailing options. “Densify horizontal reinforcement in the lap zone” (default on) adds an extra horizontal bar mark along the lap if the TS 500 Clause 9.2.5 condition is not met. “Horizontal reinforcement zones — buttressed panel” sets in how many zones the horizontal reinforcement of a counterforted panel changes (1, 2 or 3; 1 = single zone). A 90° hook is always made at the end of the stem starter bar inside the footing and enters the quantities; the anchorage is checked step by

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step and the verdict is written, for example “satisfied with hook + confinement reduction” or as too short even with the hook (the footing thickness must be increased). “Stem starter anchorage — hook reduction” is 0.75 by default (TS 500 Clause 9.1.2.2). “Confinement reduction” is 0.80 by default and is switched off by entering 1.0; this reduction is not part of TS 500.

In the reinforcement table of the Reinforced Concrete Design window the minimum reinforcement (As,min) is a separate column next to the required reinforcement (As,req). The verdict of the stem starter anchorage and the detailing warnings of the bar schedule (TS 500 Clause 9.2.5 confinement condition, laps of Φ > 30, hooks that do not fit, chair bars) are shown in a one-line status text at the bottom of the window, with the details in the tooltip. If there is an inadequacy, the note “Rebar detailing NOT SATISFIED (Reinforced concrete)” also appears on the main screen (2.2).

Permitted lists for the bar diameters can be defined in the settings; in the detailed reinforced concrete window the two faces and two directions of every member are seen separately, and the diameters and spacings chosen by the user are stored together with the wall. The restriction list is shown in Figure 18.

Hooks are taken according to TS 500: for a 90° hook the leg is 12Φ, for a 135° hook the tail is at least 10Φ and 70 mm, and for hooked anchorage ℓ_b is multiplied by 0.75. At the top of the stem, if the front- and back-face hooks do not fit within the clear width and clash, the hook wraps the reinforcement from outside: the back-face hook stays at the very top and the front-face hook ends one bar diameter lower; the drawing and the quantities use the same value. The lap of the vertical stem reinforcement is staggered by default (stages 1 and 2, $\ell_0 = 1.25 \times \ell_b$); if the option “Make vertical bar lap SINGLE” on the Settings › Reinforced concrete tab is ticked, a single stage is used, all bars are lapped at the same section ($\alpha_1 = 1.5$) and ℓ_0 becomes about twenty per cent longer.

In the footing, chair bars that sit on the bottom reinforcement and support the top reinforcement are placed by default; their diameter and number (default Φ12, 2 per m^2) are set on the same tab. The legs of the counterfort tie stirrups follow the inclined edge of the counterfort; the lengths are written as a range, the quantities take the mean length, and end stirrups too short for the ℓ_b length are listed as warnings.

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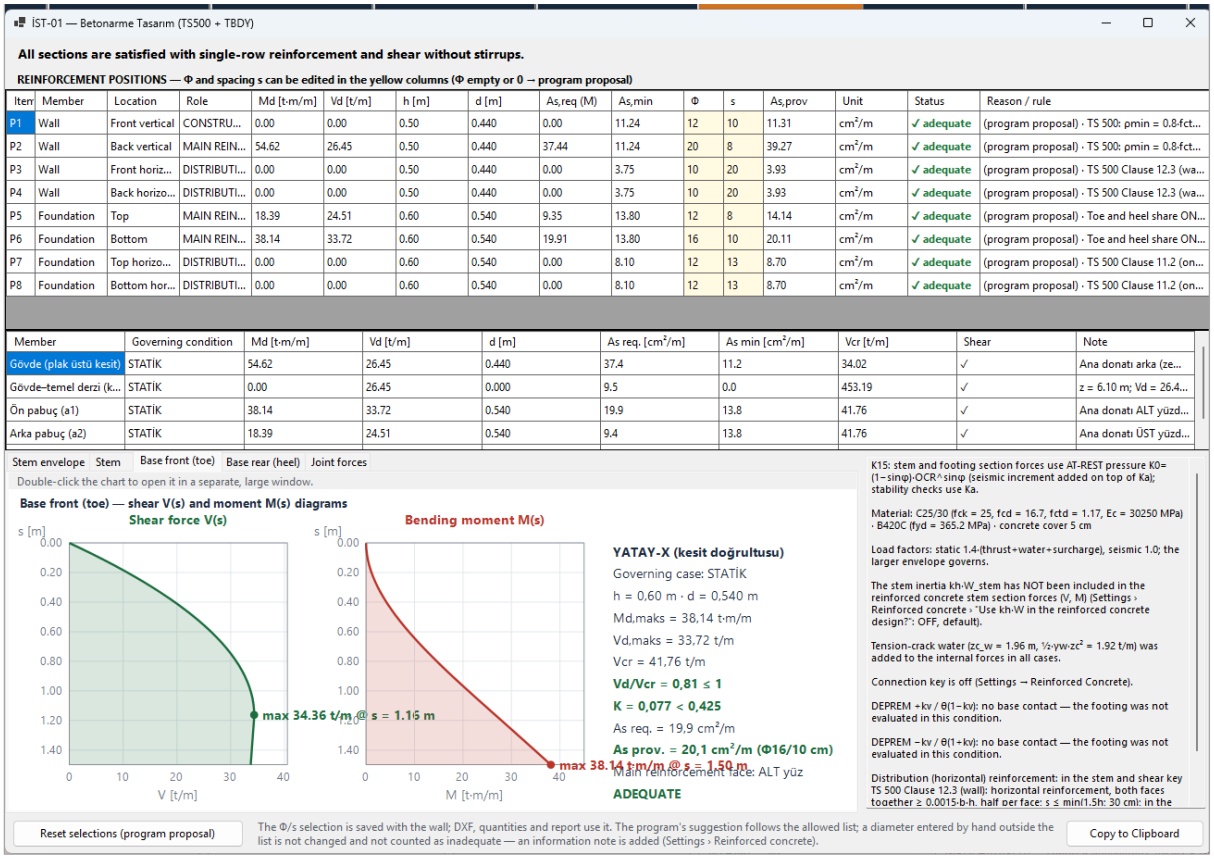


Figure 17. Reinforced Concrete Design window (TS 500 + TBDY): rebar positions, section checks and stem design envelope

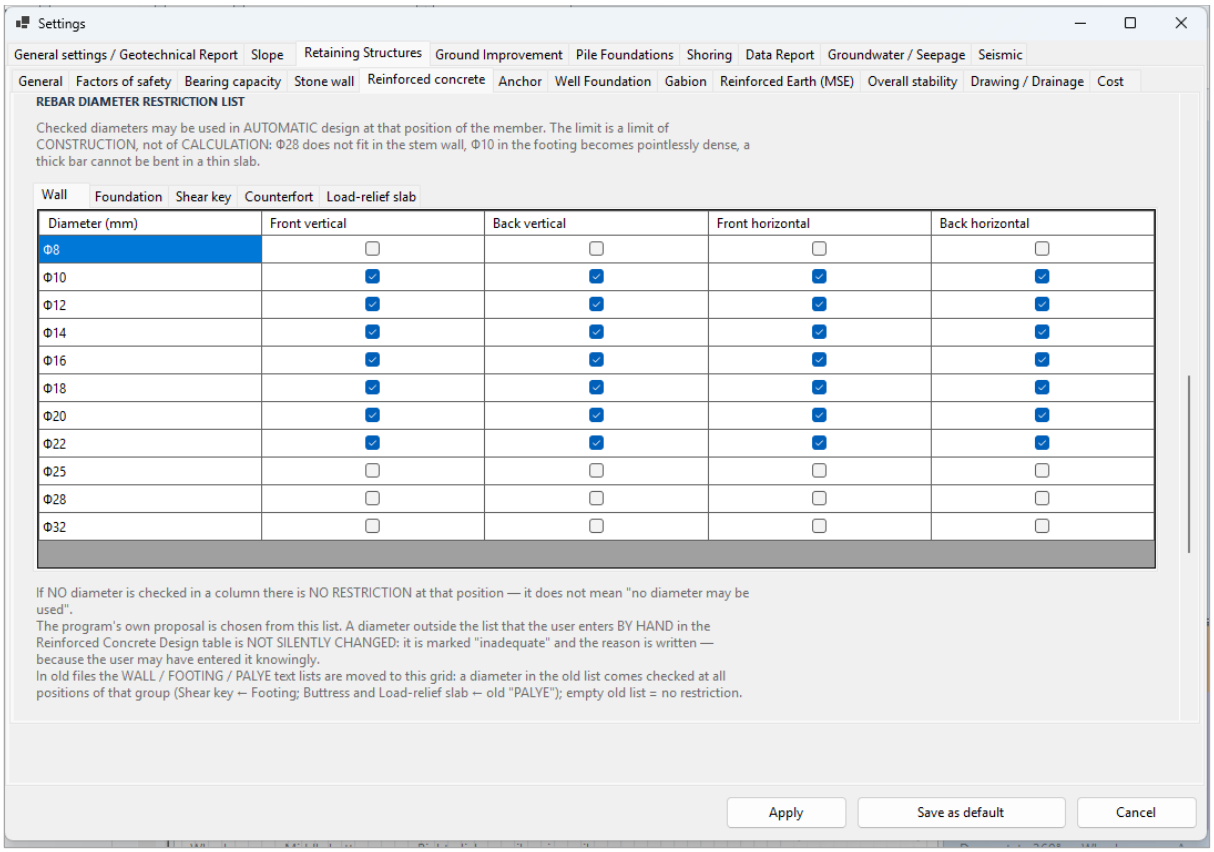


Figure 18. Settings › Retaining Structures › Reinforced concrete: rebar diameter restriction list (allowed Φ per position)

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9. Reading the Results

9.1 Force balance

The balance is a text dump that writes out each of the three load cases term by term: pressure coefficients, thrusts and their lever arms, weights and their lever arms, overturning and resisting moments, horizontal demand and resistances, base pressures. The purpose is to make the calculation traceable by hand — adding up the numbers in the dump gives the result on screen. The text can be copied to the clipboard.

Three more sections are appended to the end of the balance where relevant: the weak underlying layer and punching scan, the Newmark displacement check, and MSE internal stability.

9.2 Charts

The Force Charts window draws the terms of the balance as arrows for the selected load case; the arrow lengths are proportional to the forces. Next to it is the pressure distribution with depth, with the four components shown separately: soil, water, surcharge and dynamic increment.

The charts use the same numbers as the balance

Every number drawn comes from the same calculation that produces the balance. The components of the pressure chart are the numerical derivatives of the partial integrals and, summed down to the base, return to the thrust terms of the balance.

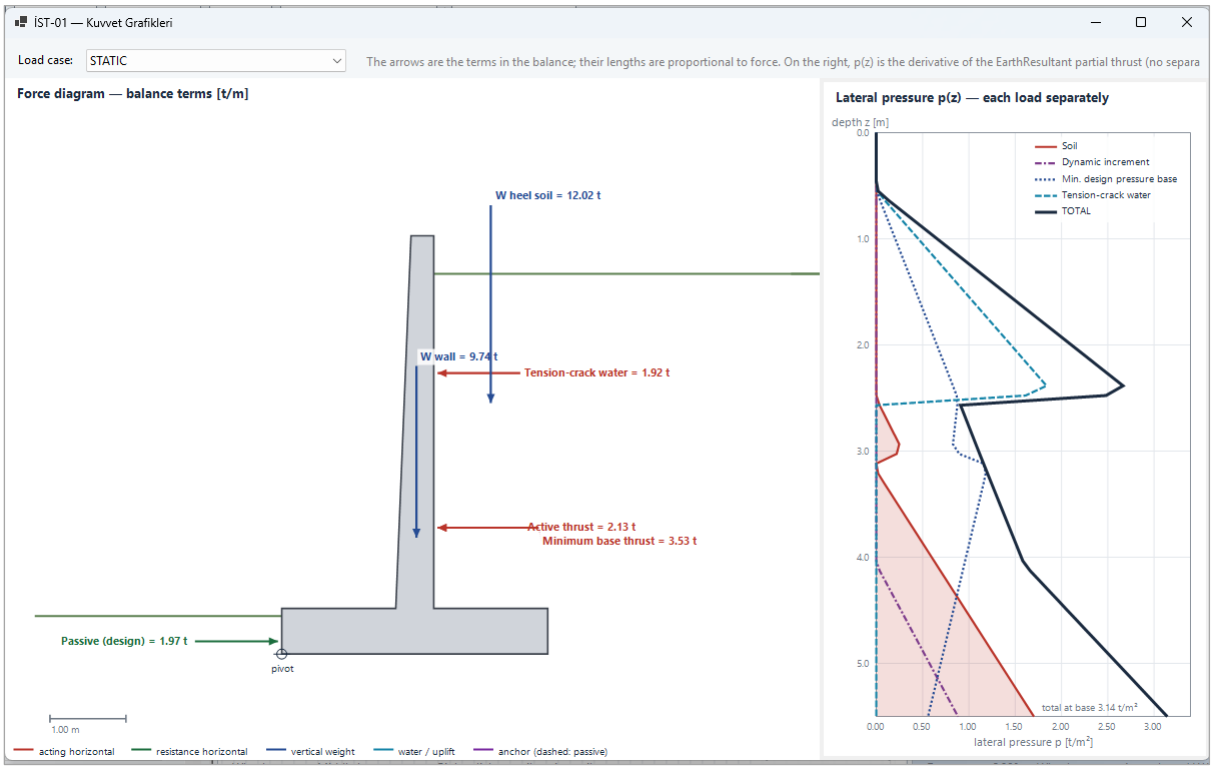


Figure 19. Force Charts window: force diagram of the balance terms and lateral pressure distribution

9.3 Input audit

The input audit finds the inconsistencies that the calculation would otherwise accept unnoticed and names them. The findings are collected at three levels: ERROR (results unreliable), WARNING and INFO; each is grouped by the field concerned. The audit does not affect the calculation; it only makes visible what a clipping or an assumption hides.

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Table 10. Examples from the input audit

Level	Example findings
Error	No soil layer at all; all three strength parameters of a layer being zero; saturated unit weight smaller than the natural one; footing top level above the natural front ground level; in MSE, a corrosion allowance equal to or greater than the strip thickness. A base inclination entered in the wrong direction or greater than 15° in design mode.
Warning	An angle of internal friction entered at a value that gets clipped; zero undrained shear strength while “short-term undrained” is ticked; the profile ending above the underside of the footing; saturated unit weight not entered while water is present; a width entered for a non-strip load; passive resistance off while a base key is defined. Exceedance of the KGM stone wall chart range (h, H) or an embedment of less than 1.00 m in Figure 4.15; “Impervious” selected for dynamic permeability while granular selected fill is present; a conflict between the name and the soil class. The front ground line differing from the Df box by more than 5 cm; a counterfort end connection zone that does not fit the geometry; the active wedge cutting the excavation slope behind a narrow fill. In MSE, a corrosion allowance of 0, L/H below 0.5, and strip, line or point loads not being included in internal stability.
Info	A reminder that a point load is spread over an influence length; a surcharge very far from the wall; zero embedment depth; that only the static case will be solved while S_{DS} is zero; that layers without a modulus of elasticity and compressibility coefficient will be skipped in the settlement calculation. That in the chart reading H is computed from the 1:1 line and that a flat base is assumed instead of a stepped foundation in sound rock.

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10. Settings — The Ones That Change the Result

The retaining settings are grouped in twelve sub-tabs on the Retaining Structures tab of the single Settings window at the top. All of them travel in the main project file and are written in the assumptions section of the report; this is the place to look when comparing two reports produced with different settings.

Design code: the code the calculation follows is selected here. Only codes implemented in the program (Active) can be selected; codes not yet implemented appear grey with the note “Not available in this version.” The retaining calculations follow TBDY 2018 Chapter 16; KDYY and EN 1997-1 appear grey because they are not yet implemented in this module. The selector is on the General tab and the selection is written to the “Governing Code” line of the report.

Table 11. Setting groups

Group	Contents
General	Unit weight of water; form and coefficient of the minimum lateral design pressure and whether it is also applied in the crack zone; calculation grid spacing, permissible displacement table spacing, design code; whether the tension crack is considered and whether the crack is assumed water-filled; equivalent widths of line and point loads; distribution of the seismic thrust increment over the height.
Factors of safety	Overturning target and sliding partial factor for the static and earthquake cases; passive and bearing partial factors, whether passive resistance is included in stability and in overturning (both on by default; in overturning the passive resistance is counted at its full value), whether the soil weight over the toe is counted; base adhesion ratio.
Bearing capacity	Correction method (three options); switching the depth, ground-inclination and base-inclination factors on and off; maximum embedment ratio, water depth effect, net formulation of the base check, eccentricity limit under earthquake, base interface friction coefficient (table values or user-defined, within a limited range); scanning of the layers below the footing. Definition of N_γ (TBDY Eq. 16.8b — default — or the selected method's own equation).
Stone wall	Unit weight of the stone; design compressive strength of the masonry, inclusion of the soil over the steps in the weight.
Reinforced concrete	Unit weight of concrete; whether the section forces are computed with at-rest pressure; permitted bar diameters for wall, footing and buttress/load-relief slab. Whether the wall inertia $k_h \cdot W$ (balance, stone body, joints and gabion rows; default off) and the stem inertia in RC design (default off) are included; computing the section forces with the minimum pressure in a $\phi = 0$ layer; bar spacing as a multiple of 5 cm; cross-ties (stem, slab, footing; number and diameter); stem–footing joint (friction coefficient, additional dowel reinforcement, key and pour interval); single vertical lap; chair bars in the footing (diameter and number).
Anchor	The drill-hole diameter used in all anchor rows; the bond capacity is computed with this diameter. For the passive stone wall anchor: steel factor γs, bond factor γa, required Kranz FS and stone–mortar bond strength τ.
Well Foundation	Whether the earthquake (S_{DS}) analysis is performed for the caisson foundation; off by default. The embedment depth and H are derived from the lift geometry.
Gabion	Default box dimensions for new gabion walls and the wizard; inclusion of the soil over the steps in the weight; unit weight of the fill stone (default 2.60 t/m3) and fill porosity n (0.10–0.35, default 0.25). The box unit weight is taken as $\gamma_{stone} \cdot (1 - n)$.
Reinforced earth	Unit weight and angle of internal friction of the reinforced fill; pullout safety factor, working ratios of steel and geosynthetic reinforcement.
Overall stability	Static and earthquake target factors of safety — these are the code floor, and the analysis always takes the larger of the floor and the setting, i.e. the setting can only raise them; whether a buried surcharge is included like a surface load. Governing solver: Spencer (default) or TBDY 2018. Overall stability search density (Wall — fast, default, or Detailed — full search) and whether wedge / undermining surfaces are also searched with the Wall density (default off).
Drawing and drainage	Presence, diameters and spacings of the drainage pipe and weep holes; filter definition, reinforcement wastage allowance in the quantities and lean concrete thickness. These do not enter the calculation; they enter the drawing and the quantities.
Cost	Currency label and unit prices (concrete, reinforcement, formwork, stone, workmanship). An item left at zero does not enter the cost; if no price is entered, no cost is produced. Does not enter the calculation; enters the quantities and cost output.

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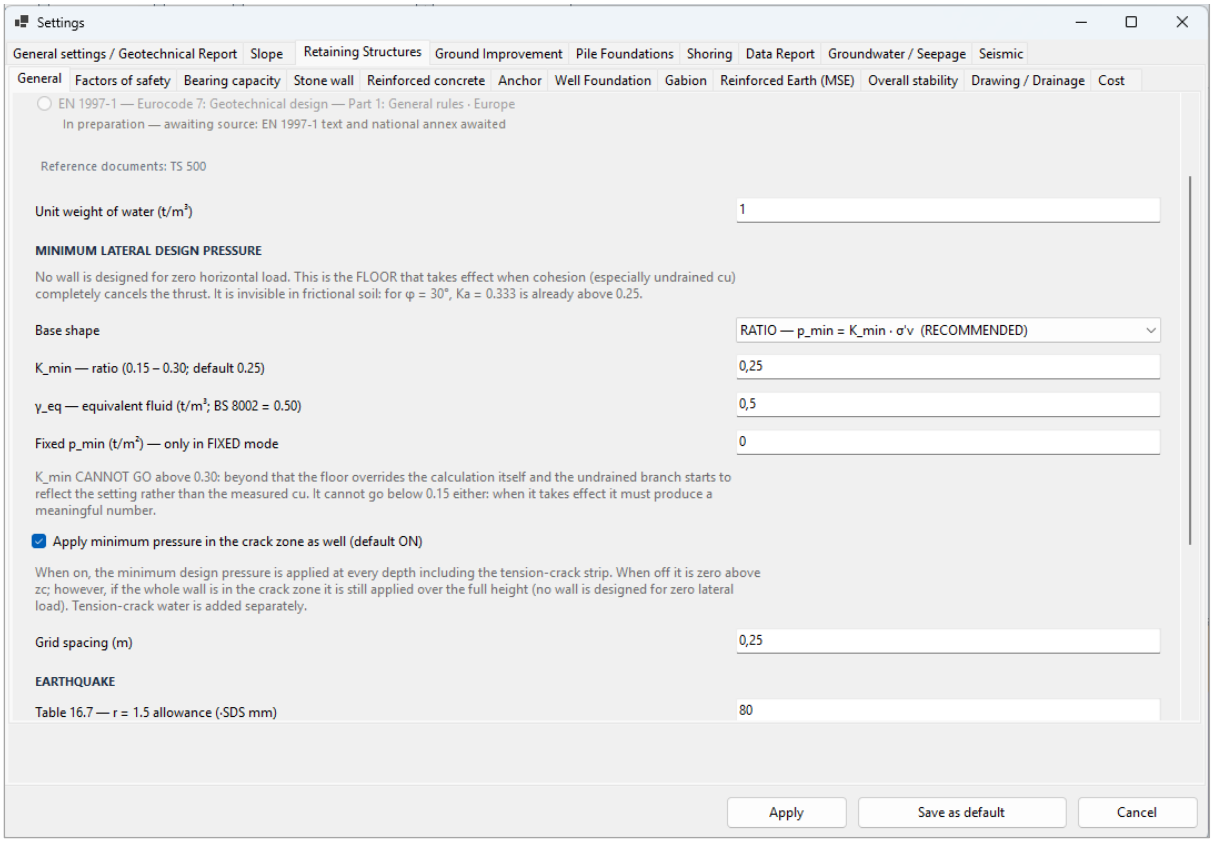


Figure 20. Settings window, Retaining Structures › General tab: design code and minimum lateral design pressure

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11. Verification

The calculations in this module have been compared number by number with published worked examples, hand calculations and the output of an independent commercial program. For global stability a comparison with PLAXIS 2D has also been made (11.1).

Table 12. Verification sources

Source	Scope and outcome
TBDY 2018 official worked example (Annex 16A)	Active and total pressure coefficients, passive coefficient, static and dynamic thrusts, horizontal demand, net vertical load, overturning and resisting moments and sliding resistance — all terms match within the rounding of the example itself.
Independent commercial program comparison	The static case of an RC wall was compared one to one; the pressure extends down to the underside of the footing and the results match.
Hand calculation comparisons	The relief-shelf model of the load-relief slab, the gabion row interface check and the stone joint scan have been verified one to one against hand calculations.
Internal consistency checks	The components of the pressure chart, summed down to the base, return to the thrust terms of the balance; the seismic passive coefficient stays below the static value; the total height of a body with an inclined base comes out exactly H.
KGM stone wall charts	Reading of the four charts, computation of H from the 1:1 line, the 4.19 polygons and the range warnings have been checked against hand calculations.

Scope of the verification

These comparisons show that the calculation is consistent with published examples and with its own rules. They do not show that the soil parameters of a site have been chosen correctly or that the model represents that wall; those are the engineer's responsibility.

11.1 Global stability: PLAXIS and inter-method comparison

Comparison section: stone wall, single layer (backfill, SM), H = 4 m, static case, target factor of safety 1.50. The PLAXIS 2D strength-reduction solution gave 1.56. In the PLAXIS displacement map the failure mechanism is wedge-shaped (polygonal): the wall and the fill block move together. In the program the governing solver is Spencer (three-point generator, 420 surfaces).

Table 13 D-01 example section: comparison against the PLAXIS value of 1.56

Method	FS	Difference to PLAXIS (%)	Status
PLAXIS 2D (reference)	1.560	—	Reference
Spencer (governing)	1.460	−6.4	Governing; on the safe side
TBDY 2018 (16.30)	1.440	−7.7	Information; separate circular search
Janbu corrected	1.292	−17.2	Information
Janbu simplified	1.224	−21.5	Information

The governing Spencer is the method closest to PLAXIS and is on the safe side by about 6%; the TBDY 16.30 value is also below PLAXIS. The Janbu methods are 17–22% lower: since Janbu ignores the inter-slice shear force, it is systematically low on a slip surface with a steep upper end. This difference is inherent to the method; the Janbu value does not govern, it is written for information only, and a warning is produced when the difference exceeds 10%. The comparison is for a single section; it has not been repeated with other sections or with a manually defined wedge surface, and the difference may be different for other sections. On the default example section Spencer gave 1.437 and TBDY 16.30 gave 1.343 (TBDY about 6.6% below Spencer).

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The table below compares the methods against Spencer on the same slip surface for a section similar to D-01 (three-point generator). This is not an independent reference but a measure of consistency between the methods. The values in Tables 13 and 14 were obtained with the Detailed (full search) density. With the default Wall density the factors of safety may differ by about 2%.

Table 14 Inter-method comparison (same surface; relative to Spencer)

Method	FS	Difference to Spencer (%)
Spencer	1.662	—
TBDY 2018 (16.30)	1.650	−0.7
Bishop	1.652	−0.6
Corps of Engineers	1.806	+8.7
Janbu corrected	1.476	−11.2
Janbu simplified	1.399	−15.8
Fellenius	1.358	−18.3

11.2 Known differences and limits

In the global stability search the slip surface cannot cut through the wall body or the base slab (7.3); this rule eliminates unrealistic surfaces and is shared by the Slope and Retaining modules. The calculations in this module have been checked against independent verification examples and hand calculations.

Known differences and limits:

- The Janbu methods are 17–22% lower than PLAXIS (above). They do not govern; the cause is the steepness of the upper end of the surface.
- The PLAXIS mechanism is wedge-shaped (polygonal). In the Retaining search, wedge surfaces are searched with the Detailed density or when the relevant box is checked (7.3). No comparison has been made with a manually defined wedge surface.
- The Spencer solution has no thrust-line check; only the slice-force limit, the m(α) threshold and the factor-of-safety band are checked.
- The PLAXIS comparison is for a single section; it has not been repeated with other sections.
- In a single-layer profile the base reference row and the main bearing check are not exactly equal on an inclined base (7.3).
- The PLAXIS export script has not been verified inside PLAXIS (12.3).

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12. Report, Drawing and Export

12.1 Word report

The report is produced from an editable Word template selected according to the wall type. The placeholders in the template are replaced with the computed values, table blocks are multiplied according to the number of rows, and figures are placed in their frames. The format of the report belongs to the user, the content to the program.

The report consists of nineteen sections, beginning with a summary page: general information, section geometry, soil profile, surcharges, earthquake parameters, pressure coefficients and thrusts, horizontal and vertical loads, overturning, sliding, bearing capacity and base pressures, settlement, global stability, Newmark, the type-specific check (joint sliding, row interface or internal stability), reinforced concrete design or body material requirements, quantities, input audit findings, assumptions and partial factors, conclusion and recommendations.

On the summary page, the overturning (M_r/M_d), sliding (R_d/H_d) and bearing utilisation ratios per load case are collected in a single table together with their required values and the verdict of every check. A per-layer table enters the pressure coefficients section: for every layer γ, ϕ′, c′, δ, ψ, the static and total active coefficients (K_{as}, K_{at}), $K_{ad} = K_{at} - K_{as}$, K_0 and the static/seismic K_p are written. The pressure-versus-depth table is given at 0.5 m intervals, with break points such as layer boundaries, groundwater and the rear ground surface added.

The global stability section shows the factors of safety of the static, $+k_v$ and $-k_v$ cases in a separate table. The reinforced concrete section contains the footing load diagram: on the base pressure diagram, the G_1 (slab self-weight) and G_2 (soil and surcharge over the footing) loads of the toe and heel and the forces at sections a_1 and a_2 are shown. The status of the optional sections is written as Checked (weak underlying layer, MSE internal stability), Computed (settlement), Analysed (global stability, Newmark) or Done (reinforced concrete design); a section that was not run shows Not done.

When the Word report is requested, the “Report contents” window opens first. Sections are chosen one by one in a single tree.

- The selection applies to all walls. A “Select differently per wall” option exists; default off.
- Mandatory sections are always included: Summary, 1, 2, 3 and 19.
- Some sections also skip their calculation when switched off, which speeds up the report: global stability, Newmark, settlement, underlying layer, reinforced concrete and MSE internal stability. Other sections are only omitted from the report.
- Section numbers close up when sections are removed.
- The selection is stored in the project file. DXF outputs are not affected.

The report does not compute overall stability on its own. Walls without a current overall stability result (never computed, input changed, or previous run failed) are listed before the report and a question is asked: Yes computes them now (in the background, can be cancelled); No writes without computing; Cancel produces no output. For a wall written without computing, the document states “Overall stability was not computed (run OVERALL STABILITY).” and the comparison table shows “—” instead of the factor of safety. The Word document is produced in the background with progress and a Cancel button; if cancelled, the partial file is deleted. The document contains a table of contents and lists of figures and tables.

Then, if there is missing or faulty input, a calculation that could not be solved, or report header information not yet entered, the shared report pre-check window opens. The findings are listed with severity (error or warning), section and description columns; the pre-check is not added to the report. “Continue anyway” produces the report, “Cancel” (default) aborts the operation.

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All walls can also be output in a single document; after a shared cover, a comparison summary and a shared assumptions section, this document appends each wall's own report. Where a figure cannot be drawn, a strip stating this is placed instead.

The report and drawing commands are grouped in the Report / Drawing menu at the top, under the Retaining Structures heading, as two separate items, Report and Drawing. In the section, force and reinforcement figures of the report, the counterfort/buttress and the load-relief slab are drawn with their dimensions, and the figures are produced from the same geometry as the DXF. The input table of the report includes the soil class (USCS) column.

The format of the report is changed in the “Report templates…” window at the end of the Report / Drawing menu. The window shows the Word templates shipped with the program in a single list with the columns Module, Template, In use and Default file. Retaining Structures has five rows: Reinforced concrete wall, Stone wall, Gabion wall, Reinforced soil (MSE) wall and Combined report cover / comparison. If a custom template has been chosen for a wall type, the Word report is produced with that template.

“Save a copy…” writes a copy of the default template to the chosen location; the copy is edited in Word for the company, and the placeholders (|…|) must be kept. “Add custom template…” copies the edited file into the template folder, checks it and selects it for that row: a file that cannot be opened is not added, and if some placeholders of the default template are missing a warning is given (those fields stay empty in the report; the report is still produced). “Choose custom template…” selects a custom template added earlier; “Back to default” removes the selection without deleting the file. “Back up templates…” writes the whole template folder to a single zip file; “Restore from backup…” unpacks that file and asks whether files already in the folder are to be overwritten. “Open template folder” opens the folder in Windows Explorer. Custom templates are stored under %LocalAppData%\GeoteknikPro Studio\Sablonlar; the program writes nothing to Documents or OneDrive automatically.

12.2 DXF drawing

Three basic sheets are produced for every wall: a dimension sheet (section, dimensioning, drainage and weep holes, soil layers), a reinforcement or detail sheet (section, reinforcement and quantity block) and an elevation sheet. Additional sheets depend on the wall: a slab reinforcement plan for a wall with a load-relief slab; a counterfort bar length sheet and a 3D isometric view showing the counterforts from the front and the back for a counterforted RC wall; stage, finished section and construction detail sheets for an MSE wall. The sheets are aligned at their bottom edge. If the wall length L is entered, the bar schedule is given for the whole wall and its heading states L. Every sheet is wrapped in a frame and title block; the title block states the concrete and reinforcement grade of the wall. The scale is always 1/25 and the paper is at least A0; if the drawing is large the paper grows, the scale does not change. All walls can also be output side by side in a single file.

The drawing is organised in layers: wall body and internal joints, hatching, soil and layers, fill, water, drainage, dimensions and levels, text, axis, reinforcement and bar marks, quantities, frame and title block, elevation, tie beam, caisson, anchor and Kranz; for MSE walls also the MSE_* layers and the MSE_METRAJ table.

In the drawing of an RC wall the counterfort/buttress (front and rear) is shown on both the dimension and the reinforcement sheet. The elevation sheet gives the elevation of a single wall segment (a representative piece): counterfort spacings, weep-hole grid and expansion joints; the total length and the number of segments are written as a note. The horizontal reinforcement layout is separate from the weep-hole drawing: it is drawn with the same elevation view and separately for every segment, at true length; the bars are split into commercial lengths and the laps are marked. On the reinforcement sheet the vertical bar layouts are placed to the right of the section, at the same levels as the section; the stem hatching is not drawn in the section, so the reinforcement stays legible. The wall top level line is drawn dashed and the front ground line runs up to the wall; the horizontal extensions of the sheet are clipped to the wall surroundings. For a stem of varying thickness the cross-tie length is written as “L = Lmin–Lmax (variable)” and the quantities take the mean length. The hooks of the load-relief

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slab U-bars turn inwards; the lap length is written together with its value in the form "$\ell_0 = 1.25 \times \ell_b$" (TS 500, 9.2.7); for a single lap the factor is 1.5. The 3D isometric sheet shows the concrete only (wall, footing, toe, heel and counterforts); no reinforcement is drawn and the view cannot be rotated.

12.3 PLAXIS 2D export

The model can be converted into a PLAXIS 2D command script. The wall body is exported as a region with a concrete material, as the finite-element counterpart of the rigid-block assumption; the layers are soil regions, and the layer touching the wall is traced along the wall outline so that the regions do not overlap. The flow consists of gravity loading, plastic calculation and strength-reduction phases.

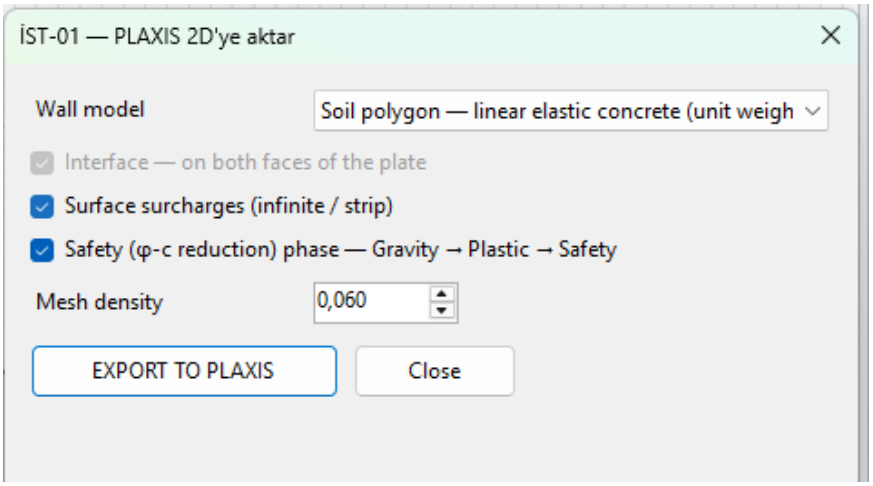


Figure 21. Export to PLAXIS 2D window: wall model, surcharge and stage options

The window has two tabs: the script to be pasted and a commented, read-only preview; the copy command always copies the script. The simplifications are stated explicitly: a single horizontal front level, use of only the upper material where the embedment enters a second layer, no separate modelling of the selected fill, and export of surface surcharges only. It is also stated explicitly that the script has not been verified inside PLAXIS.

12.4 Three-dimensional view

The three-dimensional view in the right pane shows the wall, the soil volume and the embedded elements; counterforts, tie beam and anchors are drawn translucent in front of the mass they lie in. The scene is rotated and zoomed with the mouse. The depth of the scene perpendicular to the section is an input but is purely visual; it does not enter the calculation.

12.5 Quantities and cost

The quantities are prepared with the values on the Drawing and drainage tab (reinforcement wastage allowance, lean concrete thickness, commercial bar length, expansion joint spacing, horizontal reinforcement lap). If the total wall length L is not entered, only per-metre-strip values are given; if L is entered, the total quantities are also built and the horizontal bars running along the wall are added as commercial-length bars with a lap at every splice.

The total wall length is entered in the "Total wall length L (m) — 0 = not entered" box on the Wall Parameters tab. In the Word report the quantities are in the "16. QUANTITY TAKE-OFF" section. If L is entered, the quantity column of the Total Quantities and Cost tables is for the whole wall and its heading states "(L = x m)". If L is not entered, the same column gives the 1 m strip value, the heading states "(per 1 m strip)", the units become "/m" and the table note begins with "WARNING — The total wall length (L) was not entered …"; the report pre-check also lists this as a warning.

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In the combined report, in which all walls are output in a single document, there is a “Grand Total Quantities and Cost” table: for every wall L, concrete, formwork, reinforcement, stone / basket fill, baskets and cost are written for the whole wall, and the last row is the GRAND TOTAL. The row of a wall without L is per 1 m strip (“/m”), is not included in the grand total and is named in the table note.

The quantities window on screen (Report › Quantities and cost table — ACTIVE WALL) shows, if L is entered, the total column first (bold) and the 1 m strip value beside it; in the cost table too the total amount comes first. If L is not entered, only the 1 m strip columns are shown and a red warning band appears at the top of the window. The reinforcement weight that the bar schedule gives for the whole wall may differ by about 1–2% from the reinforcement total in the quantity table because of the end bars.

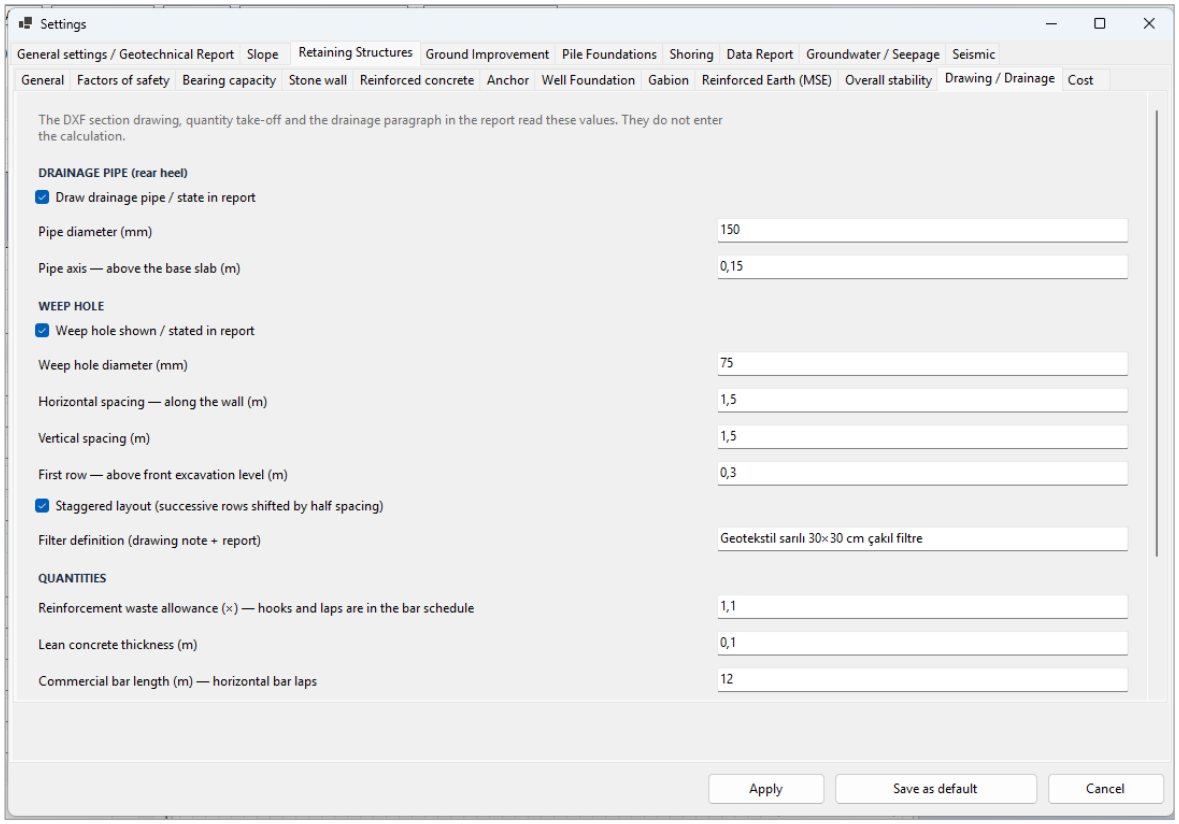


Figure 22. Settings window, Retaining Structures › Drawing / Drainage tab: drainage pipe, weep holes and quantity values

The cost is the unit prices multiplied by the quantities from the take-off (Settings › Cost). An item whose price is left at zero does not enter the cost; if no price is entered, no cost is produced. The reinforcement quantity enters the cost only if the reinforced concrete design has been performed; no reinforcement quantity is added by rough estimate. The per-metre-strip cost is always given, the total cost only if L is entered.

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13. Points to Watch

13.1 While building the model

- The H entered is the total height for every type. Mistaking H for the stem height means an error equal to the base slab thickness in reinforced concrete.
- The base width B is derived. To reach the B of the project section, adjust the projections and the stem dimensions.
- The DXF or point-table path updates the wall body; soil, water and load data are preserved.
- The wizard is a pre-dimensioning tool. The section it produces is a starting point; it must be re-solved together with the soil and load data.
- Selecting a horizontal tie beam switches on the reinforced concrete base slab automatically; the weight and base width of the wall change accordingly.
- In a KGM-type stone wall H is not entered; the program computes it from the 1:1 line. When the chart range is exceeded, the warnings in the input audit should be read.

13.2 While entering soil and loads

- Taking soils from the Geotechnical Report is a copy. If a parameter changes in the main report, the transfer must be repeated.
- The interface friction angle δ choice changes the result markedly and is per layer; leaving the default without thinking does not count as a decision.
- On a broken ground surface an equivalent slope is used. The “entered slope / effective slope” pair in the balance should be read; if the two differ, the ground surface shape is affecting the calculation.
- The lateral stress of strip, line and point loads is computed with a reflection factor of 1.0 (without the rigid-wall 2× reflection) and is capped at Ka·q or Ka·σv,max. This difference should be kept in mind when comparing with a program that uses the rigid-wall (NAVFAC 2×) assumption: such a program gives a markedly larger pressure from these loads.
- Water levels are measured from the local ground surface; because the rear and front surfaces are at different levels, the same number does not give the same water level on both sides.

13.3 While reading the results

- The governing case is not the one with the smallest factor of safety but the one with the narrowest margin relative to its own target.
- The global stability result is not refreshed automatically. When the input changes the result is removed from the section; the check must be re-run.
- Layers without a modulus of elasticity do not enter the settlement calculation at all. These layers do not give zero settlement — they are skipped, and this is reported.
- When r is chosen greater than one, check whether the Newmark check verifies this choice. An unverified r means the wall will displace more than accepted.
- If the input audit shows an error the results are unreliable; the status bar states this and it also goes into the report.
- In global stability the governing solver and the methods table should be read together. If there is an “Inter-method difference” warning, the section and the slip surface should be checked visually; the Janbu values do not govern.

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- In the earthquake case, for submerged granular fill the dynamic permeability choice determines whether a dynamic water thrust exists; the choice must be consistent with granular fill.

14. Code References

Table 15. Code references

Subject	Source	Counterpart in the program
Lateral earth pressure coefficients	TBDY 2018, 16.12	Active, total and passive coefficients; separately for every layer
Pseudo-static seismic coefficients	TBDY 2018, 16.12	Derived from S_{DS} and r; written in the header line
Permissible permanent displacement	TBDY 2018, Table 16.7	r choice and Newmark check
Horizontal sliding check	TBDY 2018, 16.9 – 16.11	Base resistance and a limited share of the passive resistance; drained and undrained branches
Base interface friction coefficient	TBDY 2018, Table 16.3	Selected in the settings; a user-defined value is clamped to a limited range
Bearing capacity	TBDY 2018, 16.8	Bearing capacity factors; shape, depth and inclination factors from the settings
Global stability	TBDY 2018, 16.13	Limit equilibrium surface search; governing solver Spencer (default) or TBDY 16.30; targets can only be raised above the code floor
Seismic permanent displacement	TBDY 2018, 16.22	Newmark check; two empirical relations
Reinforced concrete section design	TS 500 and TBDY 2018	Flexure and shear checks, minimum reinforcement ratio; load factor 1.6 for earth and water thrust in the static case
Anchorage and laps	TS 500, 9.2.5 – 9.2.7	Lap length $\ell_0 = \alpha_1 \cdot \ell_b$; 90° hook leg 12Φ, 135° hook tail at least 10Φ and 70 mm; 0.75 reduction for hooked anchorage
KGM stone wall charts	Highway Design Manual (Karayolu Tasarım El Kitabı), Figures 4.15, 4.18, 4.19-A and 4.19-B	KGM-type stone wall template
Dynamic water pressure	TBDY 2018, 16.12.3.2; Eq. 16.19–16.20	With the coefficient $0.4 \cdot S_{DS}$, without the r reduction; separate term

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15. Scope and Known Limits

Table 16. Scope and known limits

Subject	Status
DXF import scope	Stone wall body only; LINE and LWPOLYLINE only; binary DXF not supported; arc data not read.
Seepage solution	No flow net is solved; different water levels on the two sides are modelled as two independent hydrostatic distributions and a linear base uplift.
Deformation analysis	Wall displacement is evaluated with the Newmark estimate; no finite element solution is included.
Staged construction	The wall is solved for a single final condition; staged excavation is handled in the Excavation Support module.
Simplifications in global stability	Selected backfill is not modelled separately; line, point and buried surcharges are skipped. All are written to the diagnostics and are on the safe side.
PLAXIS script	The script has not been verified inside PLAXIS and this is stated explicitly; its simplifications are listed in the warning list.
Three-dimensional view	Visualisation only; the scene depth does not enter the calculation.
Stem inertia in reinforced concrete	The stem's own inertia is not included in the section forces by default; if the setting on the Settings › Reinforced concrete tab is switched on, it is added as a distributed load. The state is written in a note.
Probabilistic assessment	The design is made with deterministic values and partial factors.
Wedge surface generator in global stability	Wedge (two-block) and undermining surfaces are always searched with the Detailed search density; with the default Wall density only if the relevant box is checked. The other surfaces are generated by the three-point, entry–exit and centre-grid generators and, in a layered model, also by the weak-layer and composite generators.
Spencer thrust-line check	The slice-force limit, the m(α) threshold and the factor-of-safety band are checked; the thrust line is not checked separately.

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