GeoteknikPro

STUDIO — GROUND IMPROVEMENT

Version 3.0.1

USER GUIDE

and Calculation Methods Document

Jet Grouting · Deep Soil Mixing (DSM) · Stone Columns · Grouting
Plan and layout · Liquefaction and KG · Column capacity · Settlement · Quantities and cost

In accordance with the Turkish Building Earthquake Code (TBDY 2018)

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Contents

Contents 2
List of Figures 4
List of Tables 4
Symbols and Units 6
1. Introduction 7
1.1 What the module does 7
1.2 Scope 7
2. Screen and Workflow 7
3. Soil Profile and Method Parameters 9
3.1 Soil profile 9
3.2 Choosing the method 10
3.3 Method parameters 10
Jet grouting 10
Deep soil mixing (DSM) 11
Stone columns 11
Grouting 11
4. Five Ways of Building the Foundation Area 12
4.1 Building the area from DXF 12
4.2 Templates and building by coordinates 14
4.3 Free drawing 14
4.4 Edges: setback and extension 14
5. Layout 15
5.1 Layout types 18
5.2 Elimination rules 19
5.3 Manual editing 19
5.4 Footing projection and layout status information 20
6. Analysis 21
6.1 Area replacement ratio 21
6.2 Liquefaction and shear stress reduction 21
6.3 Single column capacity 22
6.4 Group effect and block failure 23
6.5 Composite ground and settlement 23
6.6 Calculations specific to stone columns 24
Bulging capacity 24
Priebe improvement factor 24
Drain effect 24
6.7 Target velocity profile for grouting 24
6.8 Post-liquefaction settlement 25
7. Checks 26

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8. Settings — What Changes the Result 27
9. Verification and Benchmarks 30
9.1 External benchmarks 30
9.2 What verification tells you 30
9.3 External benchmark comparison 30
9.5 Hand-calculation checks 31
9.5 Known differences and limitations 32
10. Quantities, Cost, Report and Drawing 33
10.1 Quantities 33
10.2 Cost 33
10.3 Report 34
10.4 Drawing 35
11. Points to Watch 38
11.1 In the plan and layout 38
11.2 In the calculation 38
12. Known Limitations and Out-of-Scope Topics 39
13. References 40

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List of Figures

Figure 1. 1 · Soil Profile tab: improvement method, parameters, soil table and SPT records 9
Figure 2. Choosing the improvement method: Jet Grouting, DSM (Deep Soil Mixing), Stone Column and Grouting 10
Figure 3. Soil Profile tab with stone columns selected: vibro replacement mode and drain and consolidation time parameters on the Construction sub-tab 11
Figure 4. 2 · Plan tab, Area and edges: hand-drawn foundation area and edge list 12
Figure 5. Drawing unit window opened after loading a DXF: the number of metres in one drawing unit is chosen and the program's unit estimate is shown 13
Figure 6. Foundation area built from DXF, edge list and typical section; square grid layout generated in the plan 13
Figure 7. 2 · Plan tab, Layout: foundation geometry, layout type and spacing 15
Figure 8. Improvement Plan — Design Wizard: choosing the reason for improvement 16
Figure 9. Improvement Plan — Design Wizard, 2 · Targets step: target settlement and target bearing capacity (final) 16
Figure 10. Improvement Plan — Design Wizard, 3 · System step: system, layout type, diameter and cost-optimum diameter scan 17
Figure 11. Improvement Plan — Design Wizard, 4 · Spacing Designs step: spacing solved for each criterion, a_r and number of elements 17
Figure 12. Improvement Plan — Design Wizard, 5 · Cost step: spacing, number of elements, constructed length and total cost for the candidate diameters 18
Figure 13. Staged grouting layout: primary, secondary and tertiary stage holes in the plan and typical section 19
Figure 14. 2 · Plan tab, Elements and view: single-element insertion, selection, moving and deletion commands, view options and the layout summary 20
Figure 15. 3 · Ground Improvement tab, KG Table: shear stress reduction coefficients at the SPT depths (Baez and Martin, Rayamajhi and the governing value) 22
Figure 16. Improvement Table: factors of safety before and after improvement at each SPT depth; quantity and cost breakdown below 22
Figure 17. Liquefaction Settlement table: volumetric strains and settlements before and after improvement 25
Figure 18. Diameter check warning opened in the centre of the screen after the analysis, and the findings on the Checks tab 26
Figure 19. Diameter check window: RISKY warning, suggestions and breakdown 27
Figure 20. Settings window, Safety and limits tab: design code, factors of safety, settlement limits and constants 28
Figure 21. Settings window, Liquefaction tab: choosing the shear stress reduction factor (KG) method 29
Figure 22. Settings window, Methods tab: choice of liquefaction method and composite behaviour settings . 29
Figure 23. Quantity take-off sub-table on the 3 · Ground Improvement tab: items, quantities, units and the unit cost per square metre of foundation 33
Figure 24. Settings window, Cost (TL) tab: unit prices by method and for common items 34
Figure 25. Report/Drawing menu: the Ground Improvement › Report… and Drawing… commands 35
Figure 26. Drawing sheet output: Jet grout layout plan (Ø60 cm, spacing 250 cm, 144 columns) — grid lines, dimension chain and column numbers (Turkish interface shown) 36
Figure 27. Drawing sheet output: typical section — foundation, columns and column spacings (Turkish interface shown) 37

List of Tables

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Table 1. Symbols used in the guide 6
Table 2. The three tabs 7
Table 3. Jet grouting parameters 10
Table 4. Comparison of the five ways 12
Table 5. Free-drawing commands 14
Table 6. Layout types 18
Table 7. Shear stress reduction methods 21
Table 8. Checks 26
Table 9. Settings groups 28
Table 10. External benchmark files 30
Table 11. External benchmark comparison 30
Table 12. Values checked by hand calculation 31
Table 13. Out-of-scope and limited topics 39

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Symbols and Units

Units convention

Inside the program every number is in SI units: metres, kilonewtons, kilopascals. The screen, however, shows the units customary on site: centimetres, megapascals, t/m², t/m³, bar, cm/min. The conversion is done in one single place. The reason is concrete: mixed units are the most expensive and the hardest-to-notice source of error in programs of this kind — t/m² and kilopascals differ by roughly a factor of ten, megapascals and kilopascals by a factor of a thousand, and the result looks reasonable even though it is wrong.

Table 1. Symbols used in the guide

Symbol	Description	Unit
D	Column (or borehole) diameter	m · cm
s	Layout spacing; in a triangular pattern, the side of the triangle	m · cm
a_r	Area replacement ratio — ratio of the column area to its tributary area	—
A_{trib}	Tributary area of one column ($S_x \cdot S_y$ for a square grid, $(\sqrt{3}/2)\cdot s^2$ for a triangular grid)	m²
G_r	Ratio of the column shear modulus to the soil shear modulus	—
K_G	Shear stress reduction coefficient	—
γ_r	Strain compatibility coefficient (Rayamajhi)	—
n	Stress concentration ratio (column / soil)	—
β	Settlement reduction factor, $1/(1+a_r(n-1))$	—
q_u	Unconfined compressive strength of the column material	MPa
η	Structural efficiency cap (applied to the column strength)	—
c_u	Undrained shear strength of the soil	t/m² · kPa
ϕ′, c′	Effective friction angle and cohesion	° · t/m²
E_s, E_c	Modulus of elasticity of the soil and of the column	MPa
K_{pc}	Passive pressure coefficient of the column material	—
n_0, n_1	Priebe basic improvement factor and improvement factor corrected for compressibility	—
FS	Factor of safety	—
BRN	DSM blade rotation number (revolutions/m)	1/m
IDI	Fines index; in sandy and gravelly soils the jet grout shaft friction is reduced by (1 − IDI)	%
V_s, V_{s1}	Shear wave velocity and stress-corrected velocity	m/s
ε_v	Post-liquefaction volumetric strain	%
U	Degree of consolidation	—

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1. Introduction

1.1 What the module does

The Ground Improvement module handles both the layout and the calculation for four improvement methods — jet grouting, deep soil mixing, stone columns and grouting — in one place. The user enters the soil profile and the method parameters, builds the foundation area in plan, places the columns and runs the analysis; the program calculates the liquefaction safety, column capacity, composite ground parameters, settlement and modulus of subgrade reaction, produces the quantities and cost, and generates the report and the drawing sheet.

What sets the module apart is that the plan side is taken as seriously as the calculation. In an improvement project the area replacement ratio depends on where the columns actually fall: the setback left to the neighbour, the margin kept from the road, a column moved by hand — every one of these changes a_r and therefore every result. This is why the program treats the plan as an input, not as a drawing.

1.2 Scope

- The load from the superstructure is taken as an input.
- Soil parameters are entered by hand or taken from the Geotechnical Report module; borehole and laboratory interpretation is done in that module.
- Settlement and capacity are calculated with closed-form and empirical methods.
- In grouting the object in the plan is a hole, not a column, and the improved volume is a sphere of influence; the acceptance criterion is not the quantity but the target velocity profile.
- For voids such as a lift shaft, a courtyard or an existing structure, the elements in that zone are selected and deleted.

2. Screen and Workflow

The program consists of a single window with three tabs; there is deliberately no forward/back wizard strip. You can move freely between the tabs, because in a real project the order is never linear: you return to the profile after the plan has been built, and you change the layout after the analysis.

Table 2. The three tabs

Tab	Content
1 · Soil Profile	On the left, the choice of improvement method and the method parameters (Material and Construction sub-tabs); on the right, the soil profile table, SPT records, groundwater and the pre-improvement values.
2 · Plan	On the left, the plan canvas and status bar, with the typical section to its right; on the right-hand side, a tool panel with three tabs: 1 · Area and edges, 2 · Layout, 3 · Elements and view.
3 · Ground Improvement	The button that runs the analysis, ten result tabs, the calculation and final soil results, and a detail section (columns, soil information, composite material, quantities).

The module's commands are collected in the single top ribbon of the main program, under the Ground Improvement menu: New Project (this module only), Edit (undo / redo), Quantities (table, Excel and CSV export) and Settings. In the Settings submenu, General settings… opens the settings window; Liquefaction and KG (stress reduction) method…, Settlement and subgrade reaction…, Column capacity…, Diameter check…, Construction and quality… and Drawing and report… open the same window directly at the corresponding tab (Liquefaction, Settlement, Column capacity, Diameter check, Construction and quality, Drawing and report) (see 8). The Report and Drawing commands are in the common Report / Drawing menu, and Help is in the common Help menu. The New Project command resets only this module's data; it does not touch the other modules of the main project.

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Saving and opening are done with the single project file (*.geos) of the main program. A new project does not open empty; it comes with three sample layers and a water level, so a first try can be made straight away.

After the analysis the feasibility checks run. These checks independently verify whether the chosen method is feasible on site; only a result found RISKY opens in a window in the centre of the screen, and the rest stays on the Checks tab. The aim is to prevent unnecessary warnings from hiding the necessary ones.

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3. Soil Profile and Method Parameters

3.1 Soil profile

The layers are defined in a table; for each layer you enter the thickness, soil type, unit weights, strength parameters, modulus of elasticity and — where defined — the consolidation parameters. The “Chain elevations” command joins the layers end to end and makes the profile continuous, so that no gaps or overlaps are left between them.

SPT records are kept in a separate panel. If SPT data have been entered, the liquefaction check runs row by row at the SPT depths; if there are none, it runs layer by layer. Groundwater is declared with a check box and its depth is entered; if no water is declared, all liquefaction rows are assumed saturated and this is written out explicitly as a warning.

The “previous bearing capacity” and “previous settlement” values define the pre-improvement condition and are needed to derive the final results. They are values that come from the Geotechnical Report module; they can also be entered by hand. Soil parameters can likewise be transferred from that module with a single command; the transfer is a copy, no live link is established.

The previous bearing capacity, previous settlement, previous immediate settlement, groundwater depth and manually entered E_s boxes are plain number boxes without spin arrows; the mouse wheel does not change the value in these boxes, so a value is not corrupted by accident while the page is being scrolled. “Previous immediate settlement” is used to calculate the modulus of subgrade reaction (k_s); if it is not entered, k_s is not calculated and no assumed value is substituted. The soil modulus of elasticity E_s can be taken from the weighted average of the layers (“Take from weighted average”) or entered by hand. The top level of the profile is entered in a separate box. The “γRv (bearing, for ks)” box in the same section is the resistance factor used in the modulus of subgrade reaction derived from the bearing capacity (default 1.40; see 6.5).

The “↓ Pull Data from GeoteknikRapor” button (shown in bold red) takes the soil parameters and the project identity information from the Geotechnical Report module. Since the transfer overwrites the values on the screen, confirmation is requested first; the identity information is refreshed from that module on every transfer. An SPT row cannot be added at a depth below the bottom of the profile.

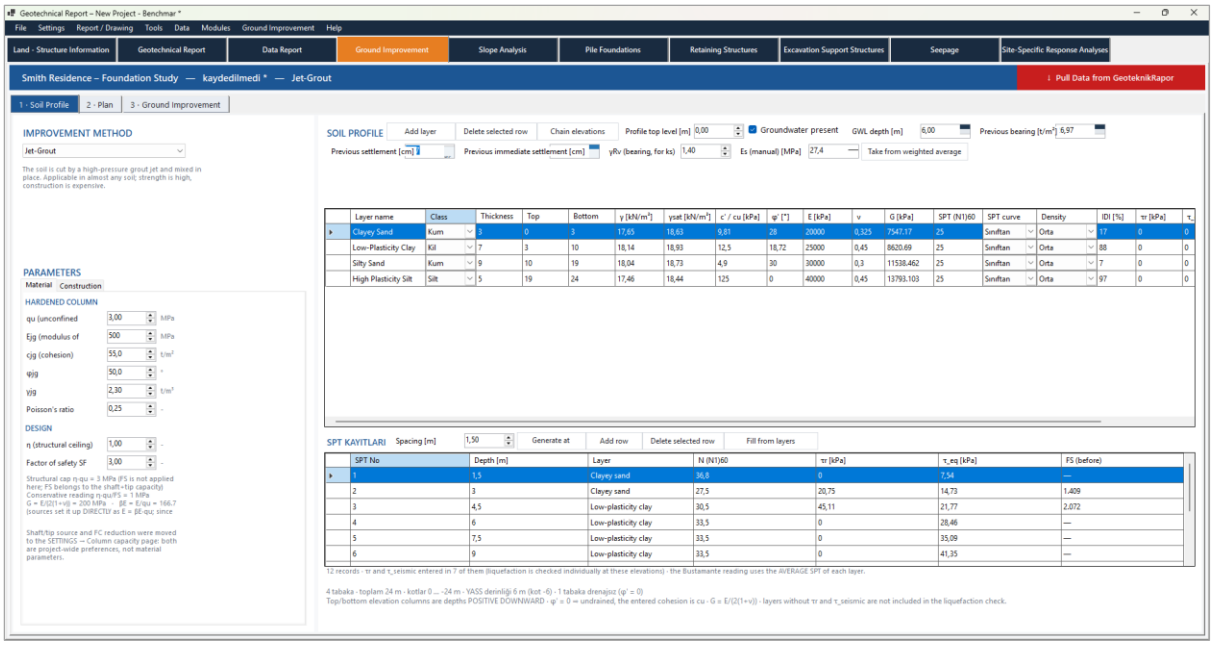


Figure 1. 1 · Soil Profile tab: improvement method, parameters, soil table and SPT records

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3.2 Choosing the method

There are four methods, and the choice affects the whole program: it determines which parameters are asked for, which layout types are offered in the plan, which calculations are performed and which feasibility check applies. When grouting is selected, the grouting type is also asked for: permeation, compaction or fracture grouting.

When the method is changed, the diameter is not carried over; the diameter last used with that method comes back. Carrying a jet grout diameter over to a stone column would produce wrong quantities that go unnoticed.

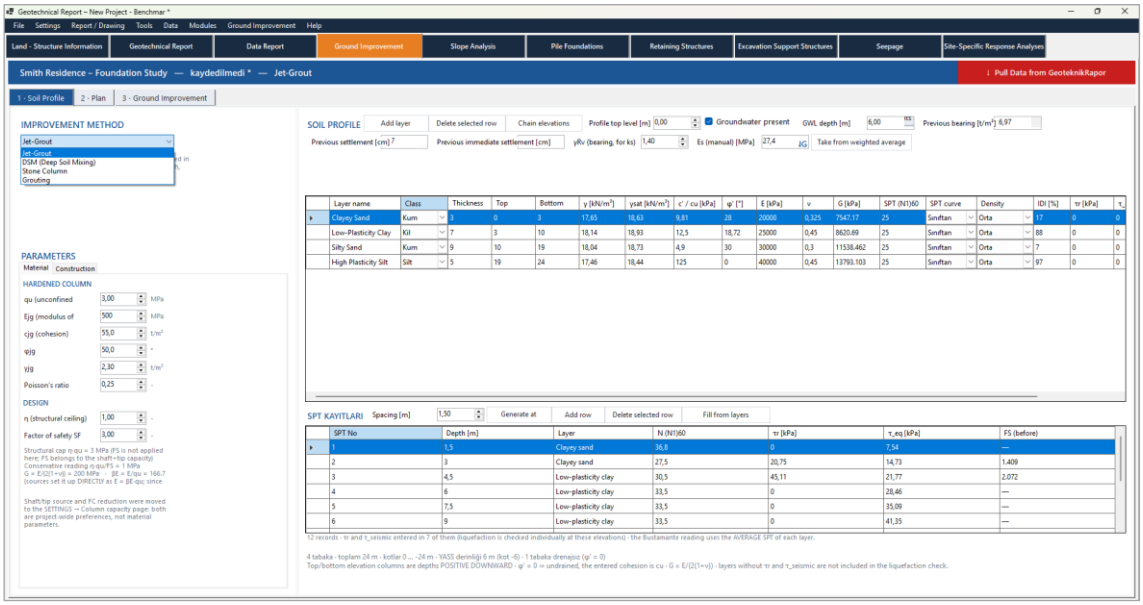


Figure 2. Choosing the improvement method: Jet Grouting, DSM (Deep Soil Mixing), Stone Column and Grouting

3.3 Method parameters

The parameters of each method are split into two sub-tabs: Material (properties of the hardened column or of the fill material) and Construction (the execution variables on site). The split is deliberate: material parameters enter the calculation, while construction parameters enter both the calculation and the quality control.

Jet grouting

Table 3. Jet grouting parameters

Group	Inputs
Hardened column	Unconfined compressive strength, modulus of elasticity, cohesion, angle of internal friction, unit weight and Poisson's ratio. In a new project the unconfined compressive strength defaults to 3 MPa.
Design	Structural efficiency cap and factor of safety. The values derived from these are also shown on screen: capped strength, design strength, shear modulus and modulus-to-strength ratio.
Jet system	Single fluid, double fluid or triple fluid; grout, air and water pressures, rod withdrawal rate, rotation speed, number and diameter of nozzles, water–cement ratio.
Quantities	Grout consumption factor and cement density.

For jet grouting, four sources can be selected for shaft friction and end bearing: the classical adhesion and friction relation, the Bustamante and Doix curves, a manually entered value, or Bustamante's SPT-based charts (the default). In sandy and gravelly soils a reduction is applied to the shaft friction; if the reduction exceeds a certain level, the program states that this soil is not a sand or a gravel and asks for it to be reclassified.

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Deep soil mixing (DSM)

The material parameters are the same items as for jet grouting. On the construction side you enter the wet or dry method, the soil stiffness, the number of blades, the injection pressure, the rotation speed, the torque, the mixing time, the penetration rate, whether mixing also takes place on withdrawal, the water–cement ratio, the mixing efficiency, the cement content and the minimum mixing energy.

From these values the blade rotation number and the mixing energy are derived and shown on screen together with the criterion. They are a quality criterion: insufficient mixing means that the strength measured in the laboratory cannot be achieved on site. An insufficient rotation number is also reported in the quick-results panel. The blade rotation number criterion is 360 rev/m (FHWA-HRT-13-046); for example, if a high penetration rate is chosen, the value drops below this criterion and a warning is given.

Stone columns

For the column material you enter the angle of internal friction, unit weight, modulus of elasticity, Poisson’s ratio and factor of safety; the passive pressure coefficient derived from these is shown on screen. For the Priebe calculation you select the Poisson’s ratio of the surrounding soil and whether the depth and compressibility corrections are switched on.

On the construction side you choose the dry or wet form of vibro replacement, or bottom feed, and enter the material and water consumption. A separate group defines the drainage function of the stone column: coefficient of consolidation, horizontal-to-vertical permeability ratio, smear zone diameter and permeability ratio, double drainage and — importantly — whether the drainage contribution is taken into account in the calculation. This last box is off by default.

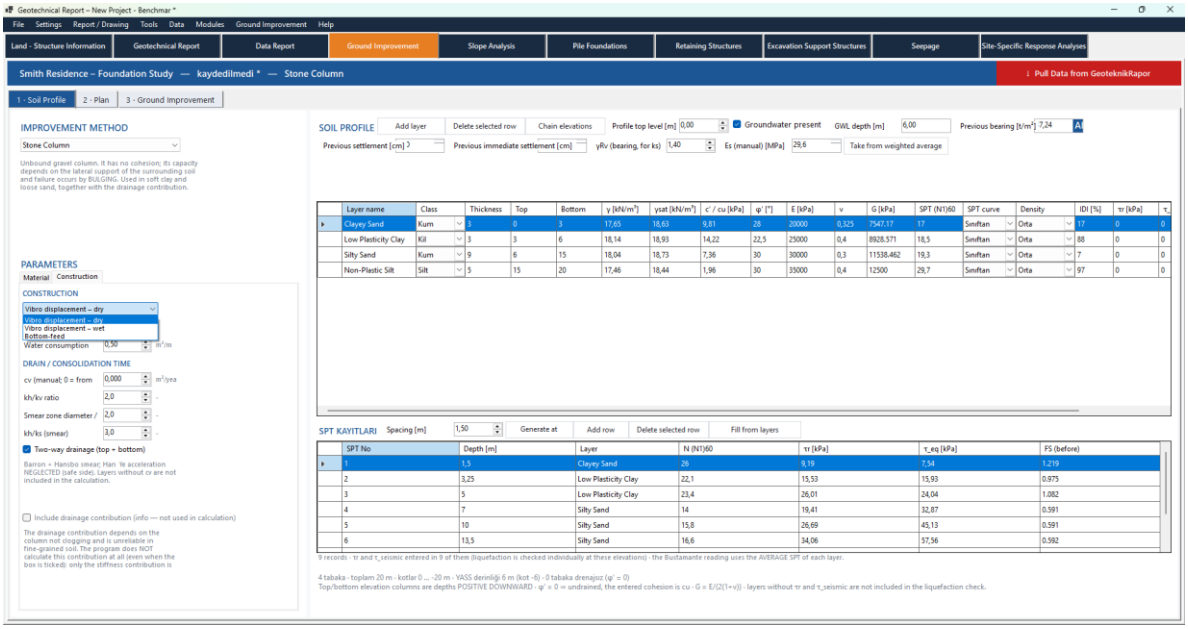


Figure 3. Soil Profile tab with stone columns selected: vibro replacement mode and drain and consolidation time parameters on the Construction sub-tab

Grouting

You enter the target strength, void ratio and filling efficiency; hole spacing, radius of influence and sleeve spacing; injection pressure, fracturing limit pressure, flow rate and water–cement ratio. A separate group feeds the suitability check: the grain sizes of the soil and of the grout and the percentage of coarse grains. In these fields zero means “not entered”, and that item is not checked.

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The last group is the site calibration: the take actually achieved in the first stage and the stage reduction coefficient. If no take is entered, the quantities are theoretical and are distributed between the stages in default proportions; once the take is entered, the second and third stages are derived from this measurement.

4. Five Ways of Building the Foundation Area

The foundation area is built in one of five ways: by selecting lines from a DXF, from a rectangle/square template, from a circular template, by typing in the corner coordinates, or by free drawing. Whatever the source, a single polygon travels through the program; keeping a separate “circular area” type would double every subsequent operation — offset, inside test, layout, quantities.

Table 4. Comparison of the five ways

Way	When to use it
Selection from DXF	When the foundation plan has been drawn in CAD — the most common way.
Rectangle / square template	Simple rectangular foundations; for a quick preliminary study.
Circular template	Circular foundations such as silos, towers and tanks.
Create by coordinates	When the corners are known as numbers; also for correcting an existing area numerically.
Free drawing	For drawing an irregular foundation directly when no CAD file is at hand.

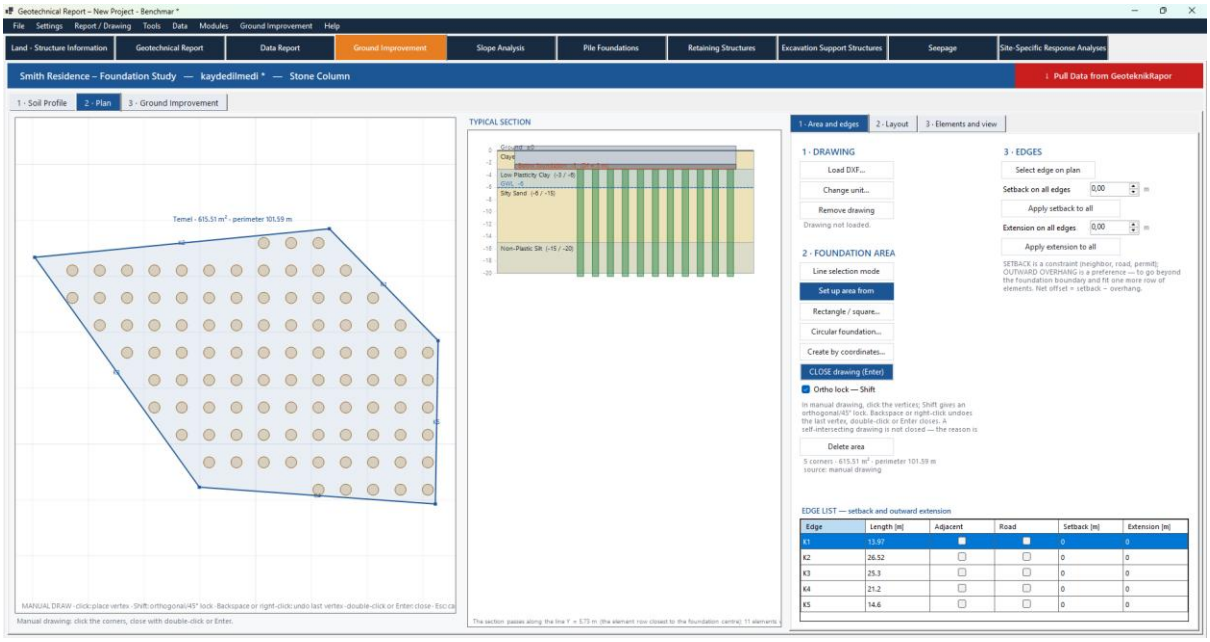


Figure 4. 2 · Plan tab, Area and edges: hand-drawn foundation area and edge list

4.1 Building the area from DXF

The entities read from a DXF are LINE, LWPOLYLINE and the older POLYLINE. Arcs, circles, splines and ellipses are skipped; the program reports how many were skipped and asks for them to be exploded in CAD. Binary DXF files are rejected and you are asked to save the file as ASCII.

The unit is estimated from the unit definition in the file header; if it is not recognised, metres are assumed. This estimate is not binding: a unit window opens and the user chooses. It can be corrected later with “Change Unit”; in that case only an area built from the drawing is scaled, a manually entered area is not.

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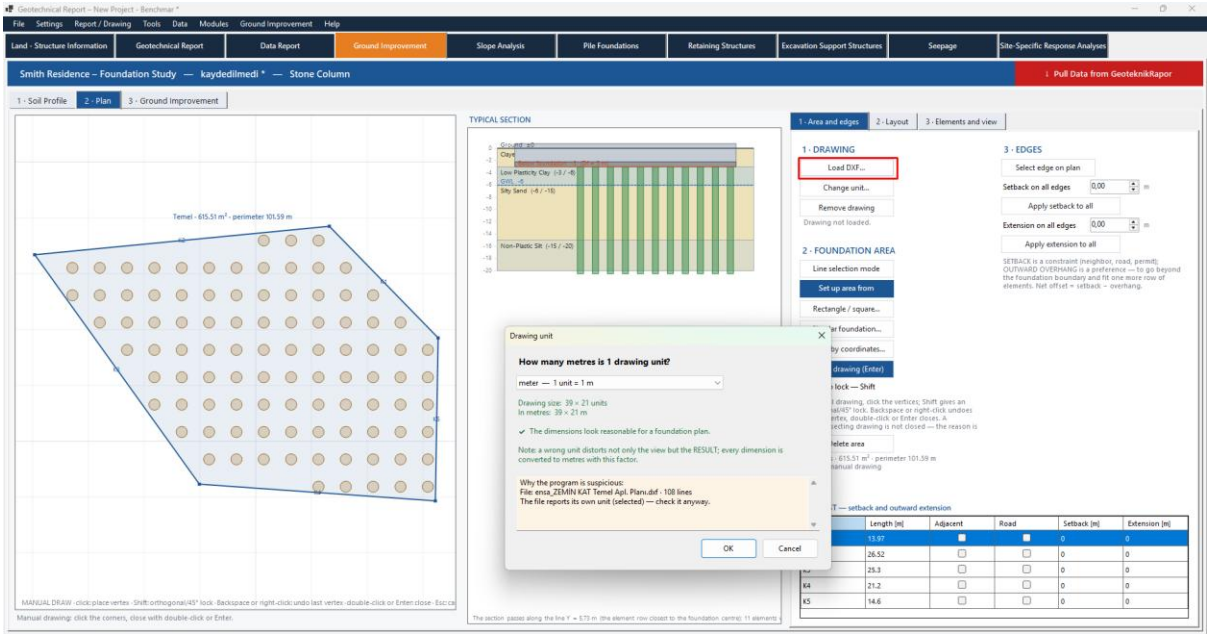


Figure 5. Drawing unit window opened after loading a DXF: the number of metres in one drawing unit is chosen and the program's unit estimate is shown

A wrong unit changes the area by a factor of ten thousand

Choosing metres instead of centimetres makes the area ten thousand times larger. Since the area replacement ratio is derived from this area, all results shift together. This is why the unit is always asked for; the estimate is not applied without confirmation.

When reading is complete, the program switches to line-selection mode. A single click on the foundation outline collects the whole chain of lines connected end to end; to add or remove a single line, click with the Ctrl key held down. The "Set up area from selection" command turns the closed chain into a polygon. If the chain does not close, the program says so and asks for the missing edges to be selected too or for the tolerance to be increased. When the area is rebuilt, the program tries to keep the previous edge settings.

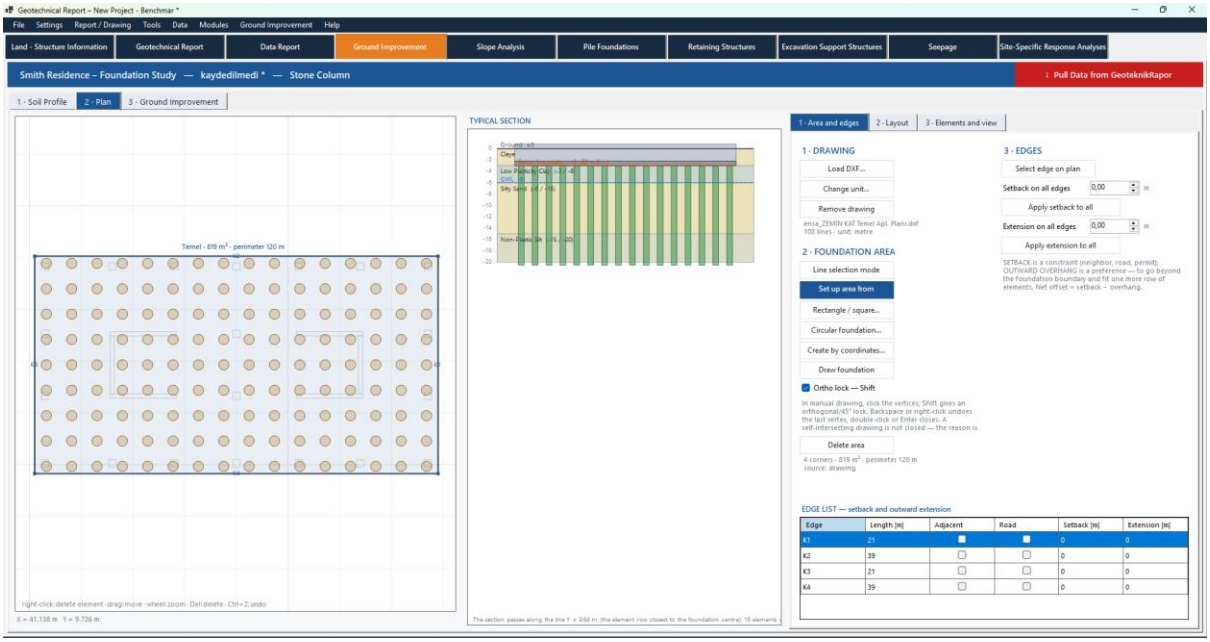


Figure 6. Foundation area built from DXF, edge list and typical section; square grid layout generated in the plan

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4.2 Templates and building by coordinates

In the rectangle template you enter the width and length; ticking a box makes it a square. A live preview shows the area and perimeter; the bottom-left corner sits on the origin. In the circular template you enter the diameter, and the circle is converted into a many-sided polygon whose area error stays below one per mille — because a single polygon type travels through the program.

When building by coordinates, the X and Y values of one corner are typed on each line. The text is checked as you type. If an area already exists, its corners are filled in; this is the way to edit an area numerically.

4.3 Free drawing

Free drawing is the plan counterpart of the hand-drawing tool in the slope module. If an area already exists, you are told that the drawing will replace it and asked for confirmation.

Table 5. Free-drawing commands

Command	Effect
Click	Places a corner.
Shift	Orthogonal and 45° lock (ortho). While ortho is on, grid snapping is rejected; only endpoint and corner snapping are accepted, because the two together would break the lock.
Backspace or right-click	Undoes the last corner and reports how many corners remain.
Double-click or Enter	Closes the drawing.
Esc	Cancels the drawing.

The snapping order is corner, line endpoint and grid. A live summary stays on screen: the number of corners, the perimeter and the area that would result if the drawing were closed. If the drawing intersects itself, this is shown in red.

Closing is refused for three reasons

Fewer than three corners; the drawing intersects itself; the corners do not enclose an area (the points lie on one straight line). The self-intersection check is made before the area check: for a self-intersecting area, the area value, the inside/outside test and the setback offset are meaningless, so this reason is reported first.

4.4 Edges: setback and extension

The setback distance is defined per edge. On an edge with adjoining buildings a distance is left to the neighbour, on an edge facing a road a different distance is left to the roadside, and on an internal edge none may be left at all. A single “edge margin” number cannot express this reality. In the edges table you enter, for each edge, whether it is adjoining, whether it faces a road, and the setback and extension distances.

Setback is a constraint, extension is a choice

Setback is a constraint: neighbour, road, permit. Extending outwards is a choice: going beyond the foundation boundary to fit one more row of elements. The net offset that defines the usable area is the setback minus the extension. If an extension is given on an adjoining edge or an edge facing a road, the program warns — extending beyond such an edge is usually not possible.

The usable area is found by offsetting the line carried by each edge inwards by its own net distance and intersecting consecutive lines. Offsetting the corners one by one would leave gaps or overlaps at acute angles. The result is shown in the plan as a dashed line.

There are cases in which the offset can fail, and all of them are reported by name: an edge of zero length; setbacks larger than a narrow part of the polygon (offset edges crossing one another, or a corner falling outside

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the original area); an extension that intersects itself. In such a case generation stops and the reason is reported. A warning is also given when the usable area shrinks to a very small fraction of the foundation area.

The offset is not a full “straight skeleton” offset (see 12).

5. Layout

The layout is generated from a rule. Typing in the number boxes changes only the draft; it reaches the project and the drawing only through the generate command, and while a change is pending a red line is shown on screen. This way the layout does not fall apart at every keystroke while a number is being corrected.

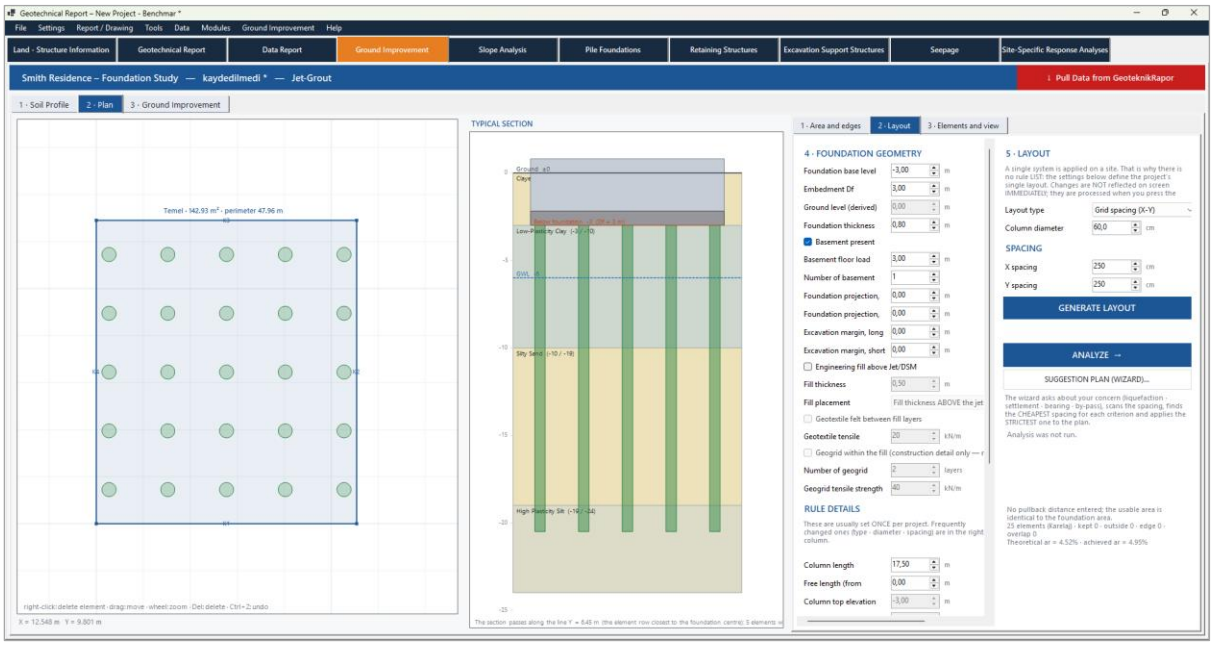


Figure 7. 2 · Plan tab, Layout: foundation geometry, layout type and spacing

The “SUGGESTION PLAN (WIZARD)…” button on the Layout tab opens the Improvement Plan — Design Wizard window. The wizard has five steps: Cause, Targets, System, Spacing Designs and Cost. The spacing is solved separately for each reason for improvement selected, and the most demanding criterion governs the plan; if the cost scan is selected, the candidate diameters are compared using the unit prices on the Settings › Cost (TL) tab. The chosen candidate is applied to the plan.

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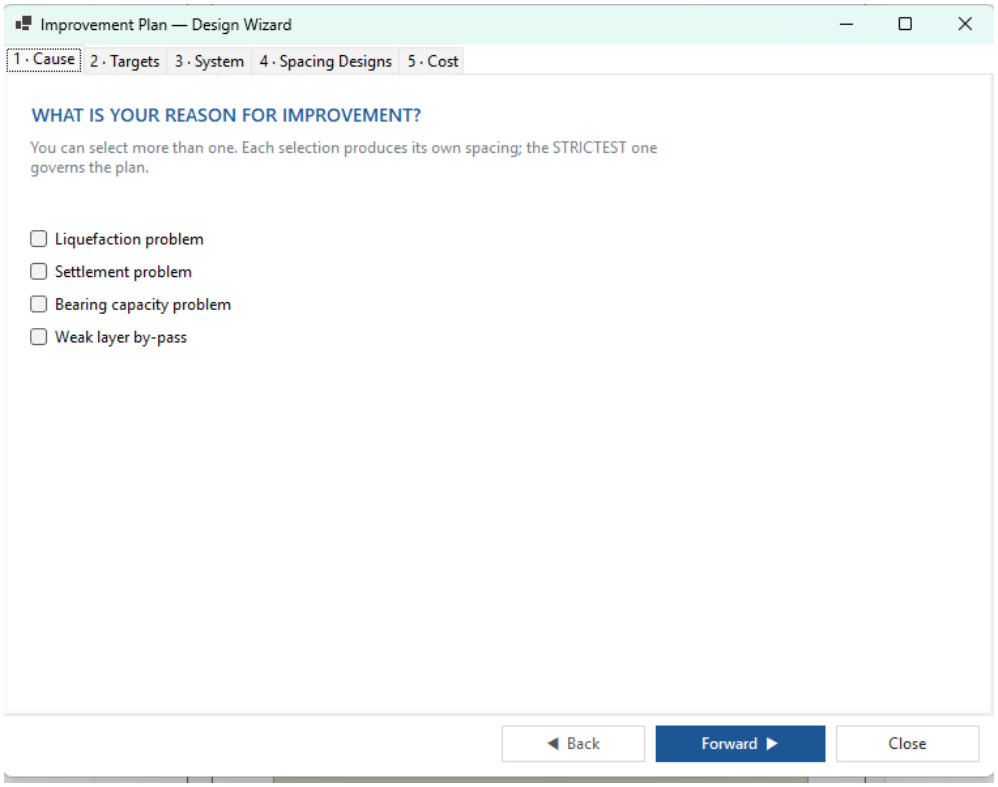


Figure 8. Improvement Plan — Design Wizard: choosing the reason for improvement

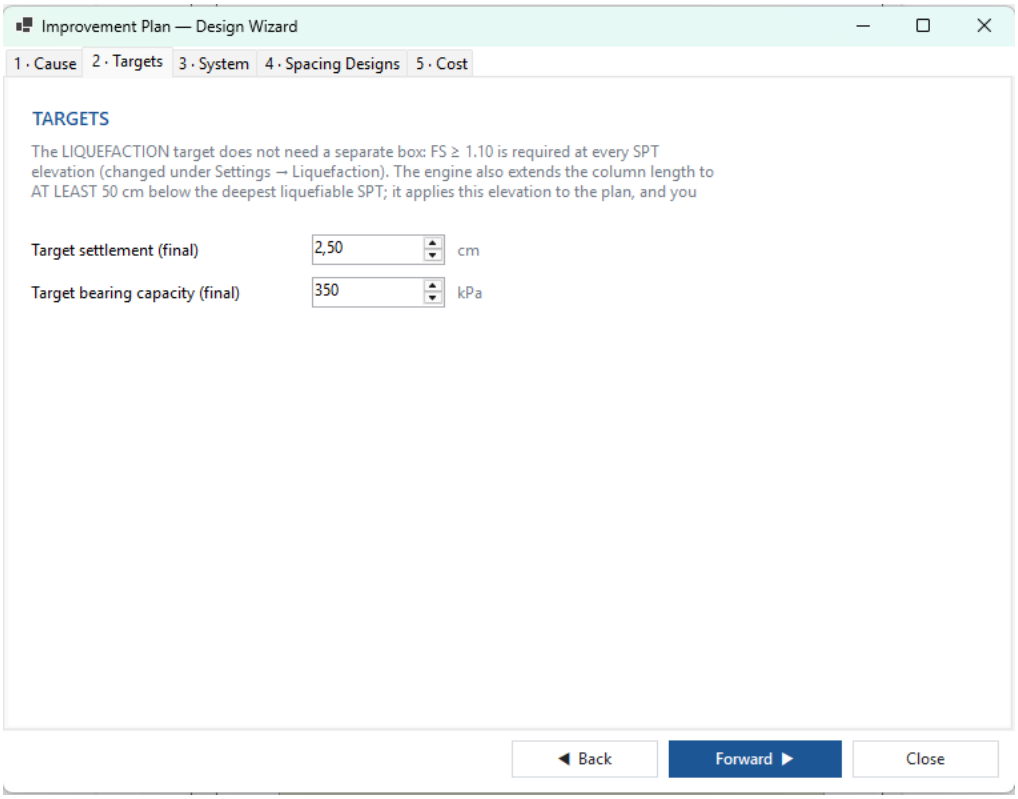


Figure 9. Improvement Plan — Design Wizard, 2 · Targets step: target settlement and target bearing capacity (final)

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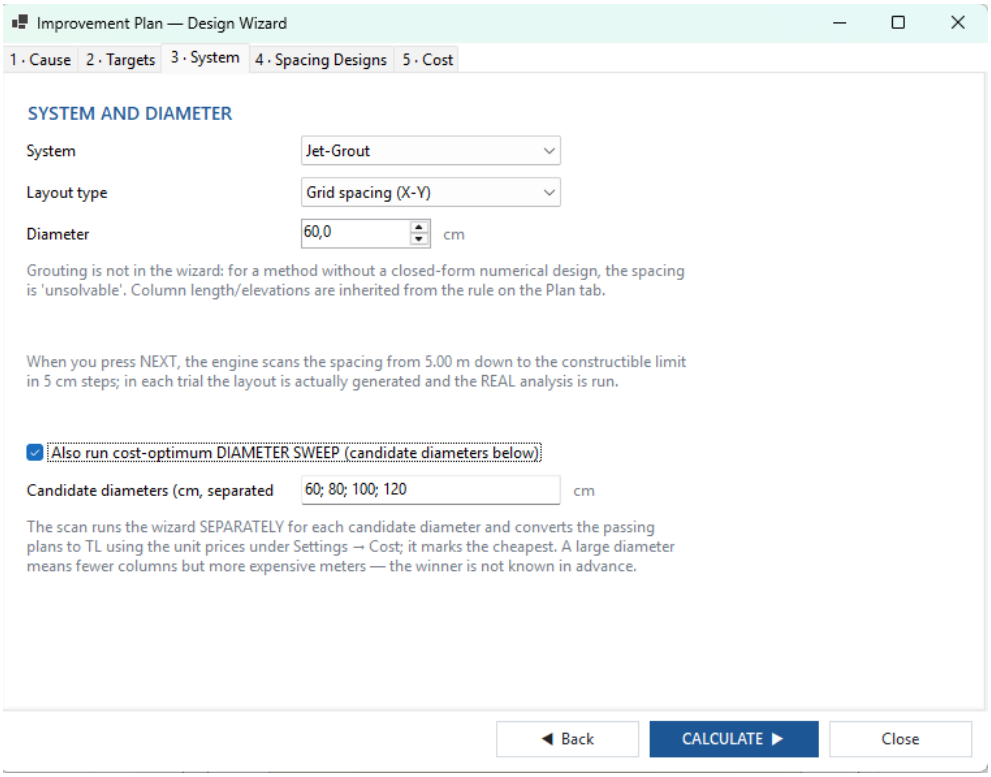


Figure 10. Improvement Plan — Design Wizard, 3 · System step: system, layout type, diameter and cost-optimum diameter scan

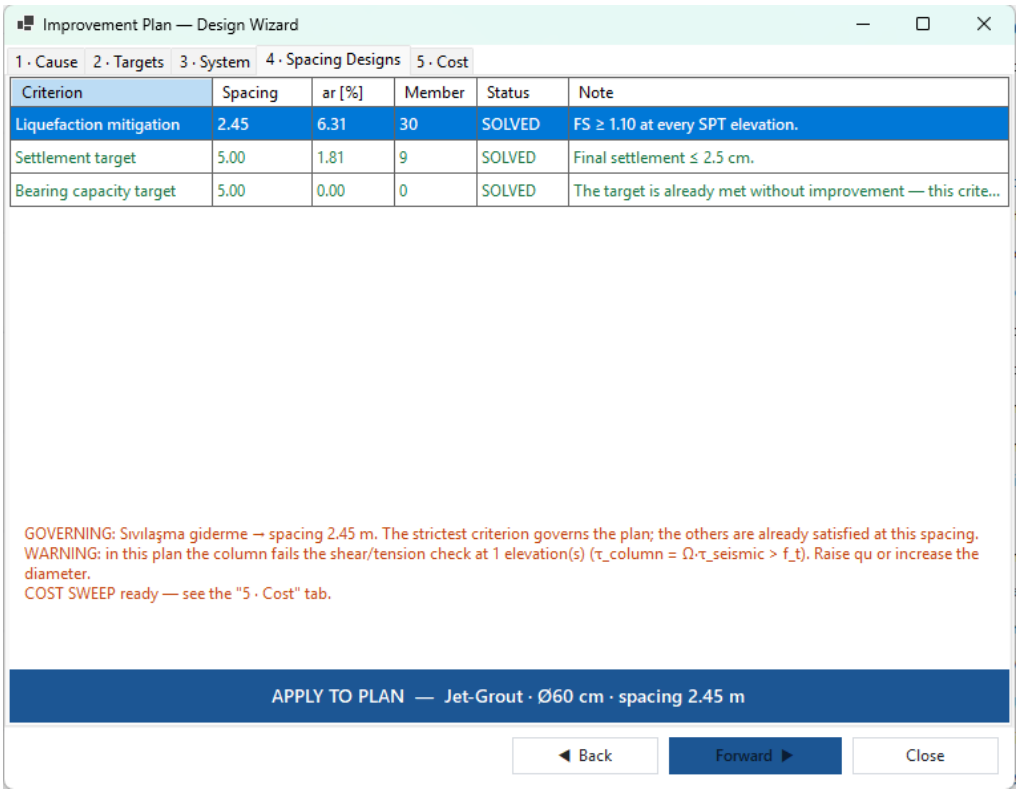


Figure 11. Improvement Plan — Design Wizard, 4 · Spacing Designs step: spacing solved for each criterion, a_r and number of elements

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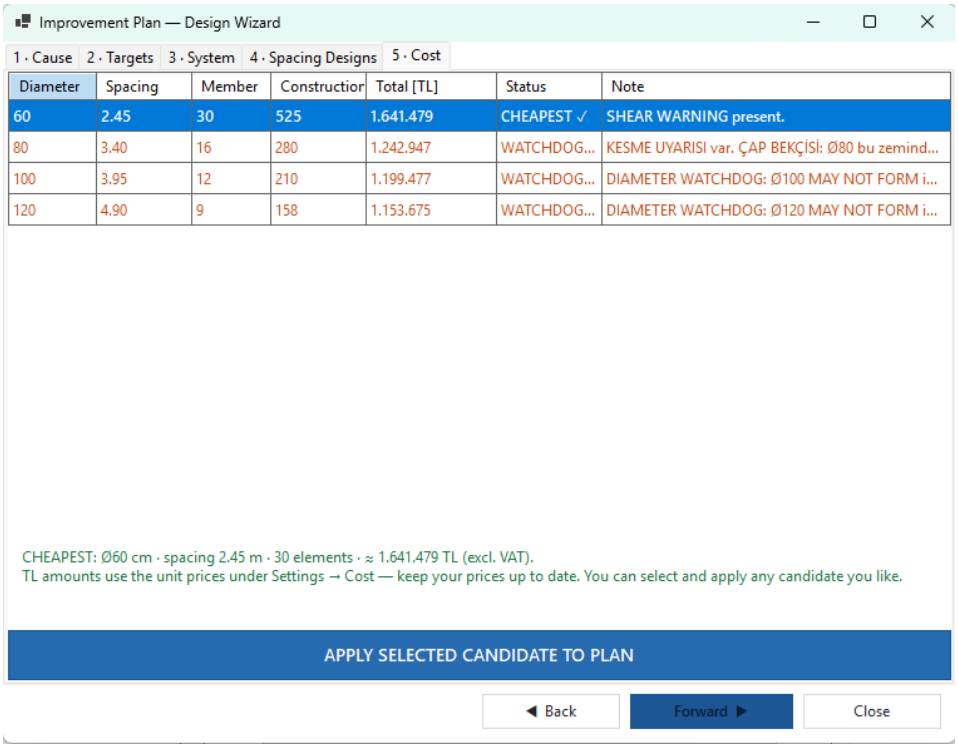


Figure 12. Improvement Plan — Design Wizard, 5 · Cost step: spacing, number of elements, constructed length and total cost for the candidate diameters

5.1 Layout types

Table 6. Layout types

Type	Definition and tributary area
Grid	The X and Y spacings are entered separately; the tributary area of a column is the product of the two spacings.
Triangular grid (equilateral)	The side of the triangle is entered; the row spacing is √3/2 times the side and consecutive rows are shifted by half a side. At the same spacing it gives a markedly higher area replacement ratio than the square grid.
Box — enclosing wall	The columns are lined up along the boundary of the usable area and a column is always placed at the corners; the overlap percentage is reported. The spacing is entered as a single value.
Staged grouting	The primary stage falls on the grid nodes, the secondary stage on the mid-points of the sides and the tertiary stage on the cell centres; the secondary and tertiary stages are switched on and off individually.

In the box layout the area replacement ratio belongs to the strip

In the enclosing wall layout the area replacement ratio belongs to the strip, not to the whole foundation. Unless an inner grid is taken into account, the composite ground formulas are not applied to this layout, and the program says so on screen; spreading the a_r of a wall over the foundation area would show an improvement that does not exist.

An optional inner grid can be added inside the box layout. On the Layout tab, “Inner grid (square grid / triangulation inside the box)” is ticked; the inner grid type (Grid or Triangular grid), the inner column diameter and the spacings are entered separately from the outer wall. Inner columns do not cut into the outer wall columns: they stay away from the boundary by at least the sum of the outer column radius and the inner column radius. Inner grid columns enter the construction and the quantities. For them to be included in the a_r, K_G, q_{final} and settlement calculations, tick the “Include INNER GRID columns in ar/FoS/settlement in box layout” box on the Settings › Liquefaction tab (off by default). When it is ticked, a_r is calculated from the unit cell of the inner grid and the rule of mixtures is applied.

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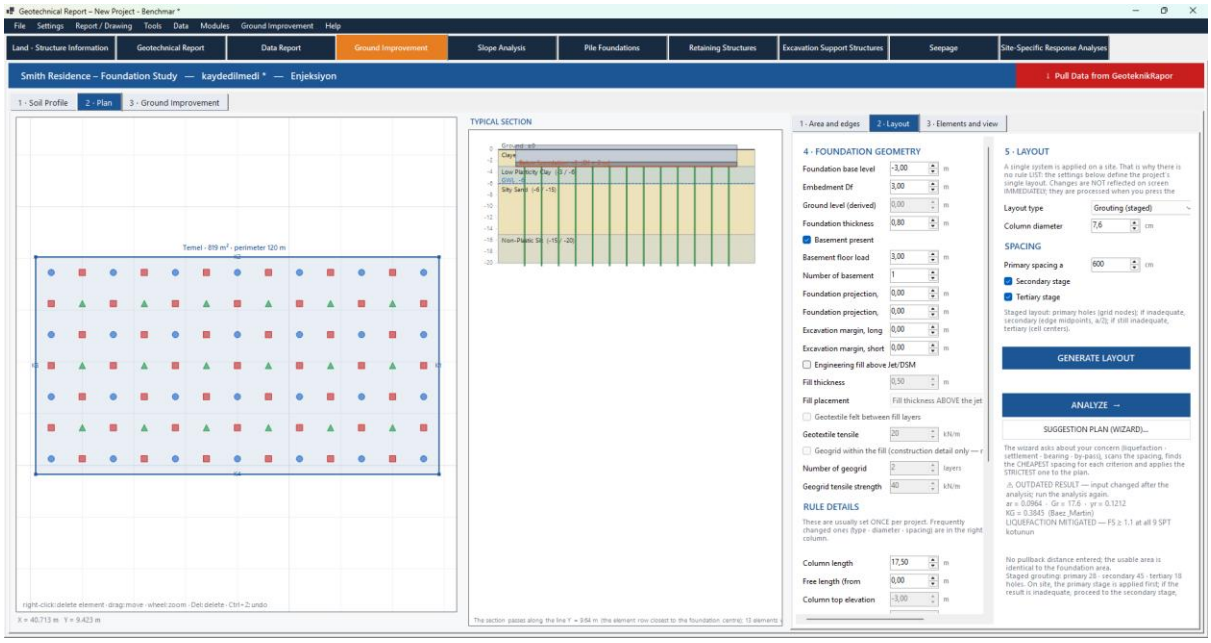


Figure 13. Staged grouting layout: primary, secondary and tertiary stage holes in the plan and typical section

The pattern can be set up parallel to the X–Y axes or to a selected foundation edge; an additional angle can also be given. The anchor of the pattern is selected as well: one of the four corners or the centre; the default anchor is the centre. In an anchored pattern the remainder strip always ends up opposite the chosen end — in other words, the user decides which edge comes out exact.

5.2 Elimination rules

Every candidate column generated passes through four filters: its centre must lie within the usable area; its distance to the boundary is measured from the outer face of the column and must exceed the radius; it must not be too close to a point deleted earlier; its centre-to-centre distance to protected elements must not be less than its diameter. At the end of generation the program reports how many elements were eliminated and for what reason, together with the theoretical and the achieved area replacement ratio.

If no element can be placed, the program says so and suggests reducing the spacing or the setback distances.

5.3 Manual editing

The generated layout can be edited by hand: dragging, arrow keys (with Shift for a large step), moving by coordinates, deleting and undoing. Overlap is checked at every move; if there is a violation the move is not applied and the reason is reported — with which element, how much overlap or how much clear spacing is left. With multiple selection, either all are moved or none.

A moved element is kept, a deleted one does not come back

An element moved by hand keeps its frozen position when the layout is regenerated; its diameter and level continue to come from the rule, and no new element is placed within one diameter of a protected element. A deleted position, on the other hand, is written to the rule's list of forbidden points: even if the layout is regenerated, that spot is never filled again. The "Forget deleted ones" command clears this memory.

The numbers are refreshed after every deletion and move and remain continuous; the order is top to bottom, then left to right. The selection is tracked by object identity, not by number, so the selection does not slip even when the numbers change.

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The column diameter, the length and the empty length to be left below the foundation are also entered in this panel; the column top and bottom levels and the empty drilling depth are derived from these and shown read-only. In a new project the empty length defaults to 0, i.e. the column top sits at the foundation base level.

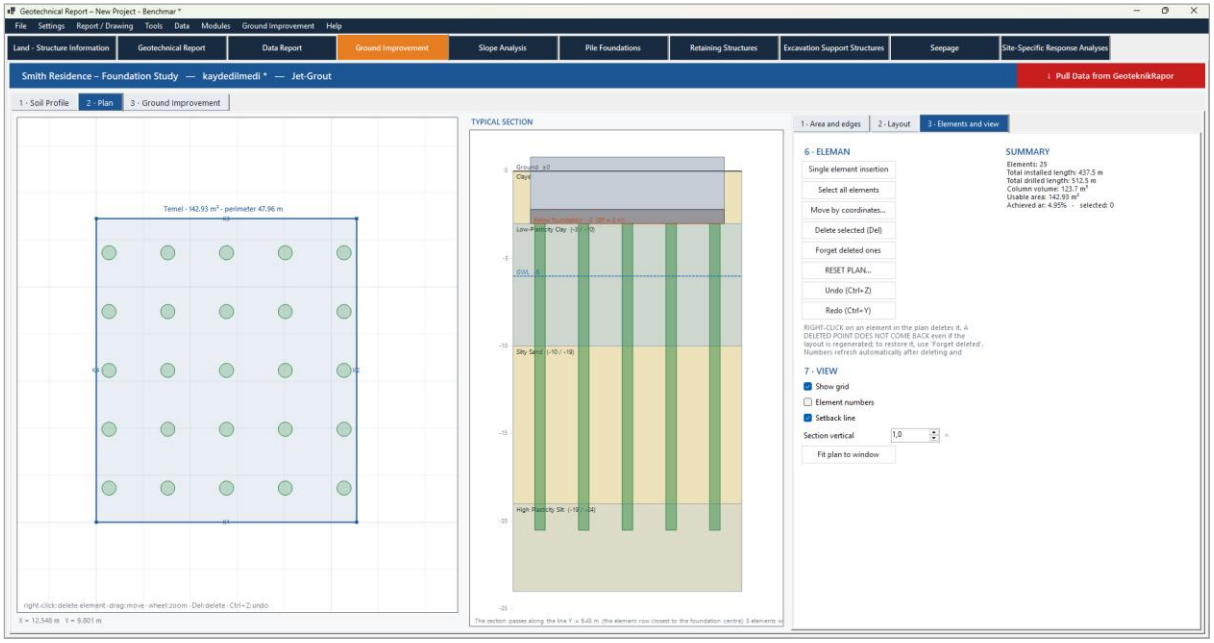


Figure 14. 2 · Plan tab, Elements and view: single-element insertion, selection, moving and deletion commands, view options and the layout summary

5.4 Footing projection and layout status information

The tool panel has three tabs: 1 · Area and edges (drawing, foundation area and edges), 2 · Layout (foundation geometry, rule details, generation of the layout and the Improvement Plan wizard) and 3 · Elements and view.

In the foundation geometry a footing projection can be defined for the basement outline: entered separately for the left and right sides in the section and for the long and short sides in the plan. The footing projection is for display only; it is drawn in the plan and section and does not enter any calculation. The empty drilling length above the columns is not drawn in the section.

The number of “manually placed” elements shown on the Plan tab is screen information only and does not enter the calculation. If a generated element is later moved, it counts as manual. If the rule or the pattern differs from the last generation, the screen shows the warning “Changes pending, not yet generated”; the GENERATE LAYOUT command rebuilds the layout according to the rule.

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6. Analysis

The analysis runs with a single command and the results are spread over ten tabs: shear stress reduction table, improvement table, liquefaction settlement, jet and DSM shaft friction tables, stone column drain time, grouting target velocity profile, column stresses, settlement table and checks. In addition there are the summary calculation results, the final post-improvement soil values and the detail sections.

6.1 Area replacement ratio

The starting point of every improvement calculation is the area replacement ratio: the ratio of the column area to the tributary area assigned to that column. The tributary area comes from the layout type. In the analysis the definition of the ratio can be selected in the settings — relative to the foundation area, to the grid cell or to the usable area — and whether the denominator is the remaining soil or the total area is also a choice. This choice directly changes the result and is stated in the report. The default denominator is the TOTAL area; the remaining-soil denominator is non-standard, increases the area replacement ratio and reduces the shear stress reduction coefficient on the unsafe side. When a project file saved with the remaining-soil denominator is opened, the program does not alter the saved choice, but gives a warning so that the definition can be checked consciously.

6.2 Liquefaction and shear stress reduction

During an earthquake, rigid columns take up part of the shear stress and relieve the soil between them. This effect is expressed by a reduction coefficient calculated from the ratio of the shear moduli of column and soil and from the area replacement ratio; the post-improvement factor of safety is found by multiplying the earthquake stress by this coefficient.

Table 7. Shear stress reduction methods

Method	Assumption and source
Baez and Martin	Assumes that the column and the soil undergo the same shear strain (strain compatible). It was derived for stone columns and for a narrow band of modulus ratios; outside this band the program warns.
Rayamajhi et al.	Assumes that the strains are not compatible and introduces a compatibility coefficient; for rigid columns it gives a markedly smaller — i.e. more conservative — reduction.
Intermediate value	Interpolation between the two methods with a coefficient.
Both	Both are calculated and the conservative one governs. This is the default.

The liquefaction check runs row by row, and for each row the factors of safety before and after improvement are given together. Some rows are excluded from the decision and the reason is stated: rows above the foundation base level because they will be removed by excavation, and rows above the groundwater level because they are not saturated. These rows remain on screen but do not enter the counters, the decision or the liquefaction settlement. Rows considered non-liquefiable (non-liquefiable soil class, fine-grained soil with a plasticity index of 12 or more, clay and rock) are also excluded from the decision; they are marked on screen as “non-liquefiable (TBDY 16.6.3) · NOT GOVERNING” and do not enter the counters, the decision or the liquefaction settlement. A liquefiable layer lying outside the improvement zone enters the “before” column and stays the same in the “after” column; it is not shown as if it had benefited from the improvement.

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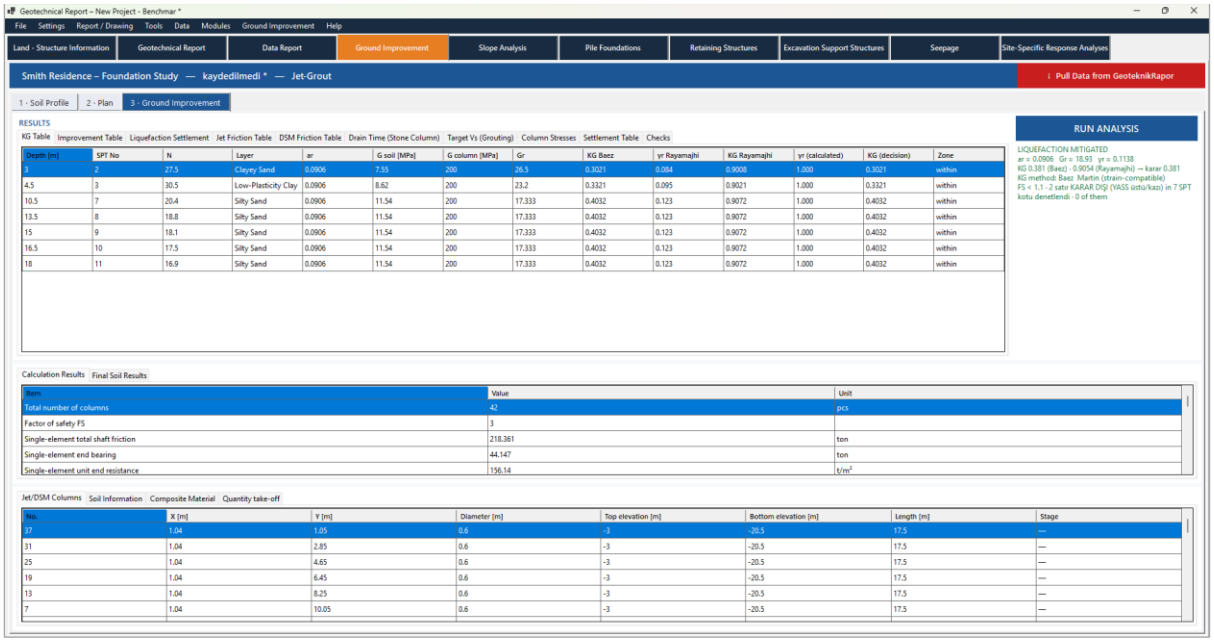


Figure 15. 3 · Ground Improvement tab, KG Table: shear stress reduction coefficients at the SPT depths (Baez and Martin, Rayamajhi and the governing value)

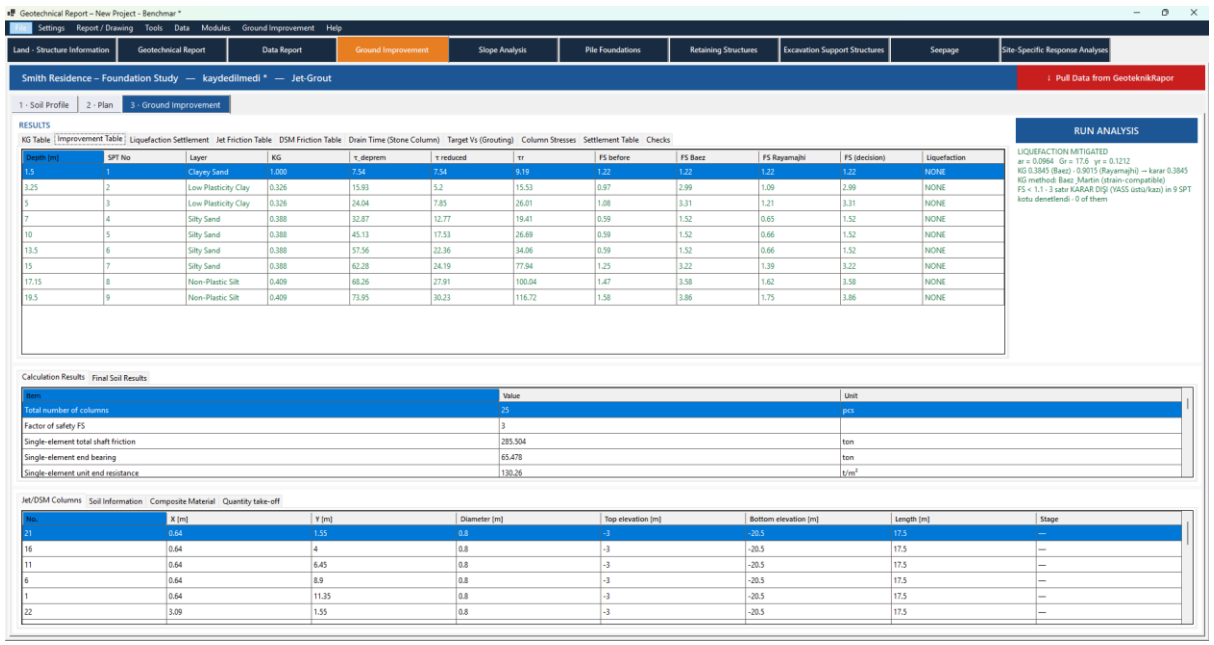


Figure 16. Improvement Table: factors of safety before and after improvement at each SPT depth; quantity and cost breakdown below

This chain is not run for grouting. The acceptance criterion for grouting is not a reduction coefficient but the target velocity profile (see 6.7).

6.3 Single column capacity

The column capacity is calculated in a pile-like way: the shaft friction is summed layer by layer, the end bearing is added and the total is divided by the factor of safety. The vertical effective stress is frozen at a critical depth; this depth is a multiple of the diameter that depends on the density of the soil. The cohesion factor for end bearing is smaller than the one used for piles; the reason is the difference in stiffness.

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There are four options for the bearing capacity factor, and the last three reduce algebraically to the same expression. For jet grouting the shaft friction and end bearing are read from the SPT-based charts of Bustamante and Doix; in sandy and gravelly soils a reduction is applied and an upper limit is set for the shaft friction.

Two branches, the smaller governs

The column capacity is limited along two separate paths: the geotechnical branch (shaft plus end bearing, divided by the factor of safety) and the structural branch (design strength of the column material times the cross-sectional area). The design value is the smaller of the two, and which one governs is stated on screen. For stone columns this branch does not govern; there the failure mode is bulging, and a warning note is issued.

This calculation does not include negative skin friction, the group effect or settlement-dependent mobilisation; the group effect is a separate step.

6.4 Group effect and block failure

For rigid columns the group efficiency is taken as the smaller of two criteria: the classical geometric relation and the AASHTO (2020) criterion. The smaller one is adopted in order to stay on the safe side. At close spacing the AASHTO criterion usually governs (efficiency 0.65 for s/D = 2.5); as the spacing opens up the classical relation governs and the efficiency approaches one (0.91 for s/D = 7). Which criterion governs is written in the note line. The report also states that the smaller (governing) of the two values is used.

Block failure is also checked: the envelope formed by the column centres is taken as one mass, and the soil-on-soil sliding around its perimeter and the end bearing at its base are calculated. The result is the smaller of the single capacities multiplied by the efficiency and the block capacity. For stone columns the group step is not applied and the reason is stated in the checks: there, the unit-cell approach already represents the group behaviour itself. The total bearing capacity shown on screen is the value reduced by the group efficiency and is the same as in the report.

6.5 Composite ground and settlement

The composite parameters are obtained with the rule of mixtures: unit weight, cohesion and modulus of elasticity are weighted by the area ratio; the friction angle is combined with a relation that takes the stress concentration into account.

The limit of the rule of mixtures is shown on screen

The rule of mixtures is a parallel-spring assumption. When the modulus ratio of column to soil becomes very large, the composite modulus comes out larger than it really is. The program shows this ratio in a column and colours it red above a certain value; this keeps the limit of the assumption visible.

Settlement is solved in a two-layer approach. First the load is spread with depth — with the classical spread ratio or with the elastic solution; which one is used is a setting. Then the depth of influence is found: the depth at which the stress increase drops to a certain fraction of the overburden stress, limited by a cap value. The raw compression of each layer is calculated from this distribution, and the previous total settlement entered by the user is distributed according to it — so that the value measured or calculated before improvement is respected.

Only the contributions within the improvement zone are reduced by a reduction factor; the layers below the zone remain unchanged. The factor depends on the stress concentration ratio; this ratio starts from the elastic modulus ratio and is clipped by the real capacity of the column — a column cannot take a load it is unable to carry.

Two second opinions are offered: the equivalent pier approach (column and soil together as a single equivalent modulus) and the equivalent raft approach (assuming that the load descends to a virtual raft at a certain fraction of the column length, together with the elastic shortening of the columns). In the equivalent raft approach, if

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the soil profile ends below the virtual raft, the calculation is not performed and the reason is reported; no assumed half-space is added.

Which settlement approach is used in the governing row is selected on the Settings → Settlement tab: simple ratio (s = previous settlement × E_s / $E_{composite}$; the default), the two-layer approach or the equivalent raft. Whichever is selected, all three views are calculated and written side by side; the choice only determines the governing row. For stone columns the governing row also follows this choice: in the two-layer approach the settlement of the improvement zone is divided by the stress concentration ratio and the settlement below the zone is added; in the simple ratio approach the total settlement is reduced by this ratio and the case is reported with a CAUTION note.

The outputs also include subgrade reaction values: the spring constant of a column, the modulus of subgrade reaction of the soil between the columns and a single average value. The T coefficient table used for the modulus of subgrade reaction is shared with the Geotechnical Report module (Bowles, Foundation Analysis and Design) and is read from the immediate settlement; if the previous immediate settlement has not been entered, T and k_s are not calculated. The settlement limit check applies only to the total settlement; differential settlement and angular distortion are not checked. In the relation for the modulus of subgrade reaction derived from the bearing capacity, the resistance factor γRv entered on the Soil Profile tab ("γRv (bearing, for ks)", default 1.40) is used, not the column factor of safety FS; the formula printed in the report uses this factor as well.

6.6 Calculations specific to stone columns

Bulging capacity

The failure mode of a stone column is bulging, not shear: the column expands sideways under a load exceeding the lateral support provided by the surrounding soil. The capacity is scanned over a depth of several diameters from the column top, and the smallest value governs — the weakest point is the shallowest point, because the overburden stress is lowest there. The lateral confining stress comes from cavity expansion theory in the undrained case and from passive pressure in the drained case.

A widely used shortcut relation is calculated as well, and the result is the smaller of the applicable values.

Priebe improvement factor

Priebe's method gives the ratio of the settlement of the untreated ground to that of the improved ground as a factor. The program calculates the basic factor and applies the compressibility correction — if selected. The depth factor is not applied in this version, and this is stated explicitly.

Drain effect

A stone column is also a vertical drain. Radial consolidation is calculated with a classical solution that also accounts for the smear zone and is combined with vertical consolidation; the result is given as the ratio of the time to reach a given degree of consolidation to that before improvement — i.e. the speed-up. The additional acceleration due to the column stiffness (Han and Ye, 2001) is deliberately neglected (safe side); a layer with no coefficient of consolidation entered is not taken into account; the clogging reservation is written as a note. This contribution is off by default, and switching it on is the user's declaration.

6.7 Target velocity profile for grouting

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The acceptance criterion is performance, not quantity

In grouting it is not possible to tell from the quantities how much improvement has been achieved. The program therefore does the opposite: at every depth it solves for the shear wave velocity that would provide the required factor of safety and gives this as a target profile. If the velocity profile measured on site after grouting lies above this curve, liquefaction has been eliminated. The acceptance criterion is thus moved from the input (quantities) to the output (performance); for grouting the program does not claim a quantity, it gives a target.

The resistance curve used has an upper limit, and the curve steepens as it approaches this limit. If the required velocity runs up against this limit, no realistic site measurement can demonstrate safety; that row is marked CANNOT BE SHOWN and the report does not hide it — it states that at that depth the adequacy of grouting cannot be proven by velocity and that the method must be changed.

6.8 Post-liquefaction settlement

In liquefying layers the volumetric strain is calculated from the corrected blow count and the factor of safety with a closed-form relation and summed over the layer thicknesses. The same relation is applied separately before and after improvement; the only difference is the factor of safety. In rows where the blow count is below the calibration range of the relation, the value is clipped to the limit and this is reported. In layers outside the improvement zone the settlement does not change.

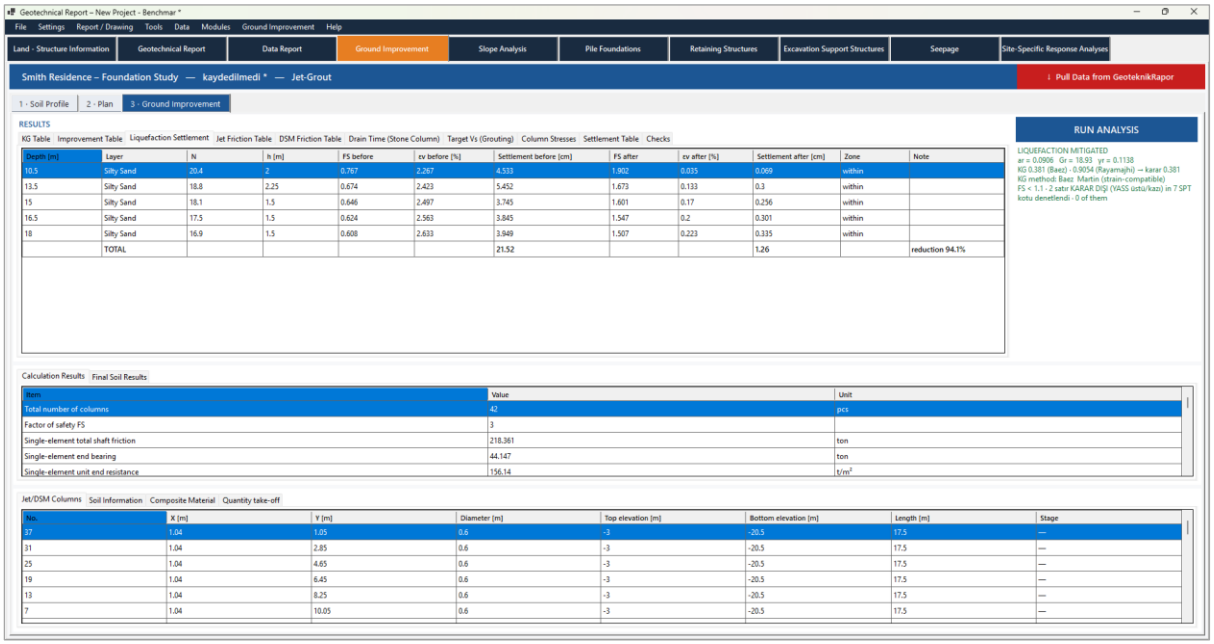


Figure 17. Liquefaction Settlement table: volumetric strains and settlements before and after improvement

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7. Checks

The Checks tab reports by name every assumption made in the analysis and every calculation that was not applied: missing parameters, values outside the calibration range, calculations not applied and the reasons for them. If a calculation is not applied, the reason why it was not applied is written out.

Table 8. Checks

Check	What it checks
Diameter check	For jet grouting, checks whether the selected diameter can really be achieved on site with the construction parameters entered and the soil type. Entering a diameter does not produce it.
DSM check	Checks whether the blade rotation number and the mixing energy meet the criterion; insufficient mixing means that the laboratory strength cannot be achieved on site.
Grouting suitability check	From the grain sizes of the soil and the grout and the percentage of coarse grains, checks whether the selected grouting type is feasible in that soil. An item that has not been entered is not checked.

Check findings have three levels, and only a RISKY finding opens in the centre of the screen after the analysis. The rest stays on the Checks tab and goes into the report.

The report ends with a result verdict that is cross-checked against the tables: if any row of the liquefaction, column capacity or settlement tables reads NOT SATISFIED, or a check could not be carried out, the overall verdict cannot read “suitable”. The comparison of the improved bearing capacity qt(improved) with the foundation base pressure is a warning only; it is written in the Checks tab and in the report but does not change the verdict and does not stop the process. The general principle of the program applies: it warns, it does not stop you.

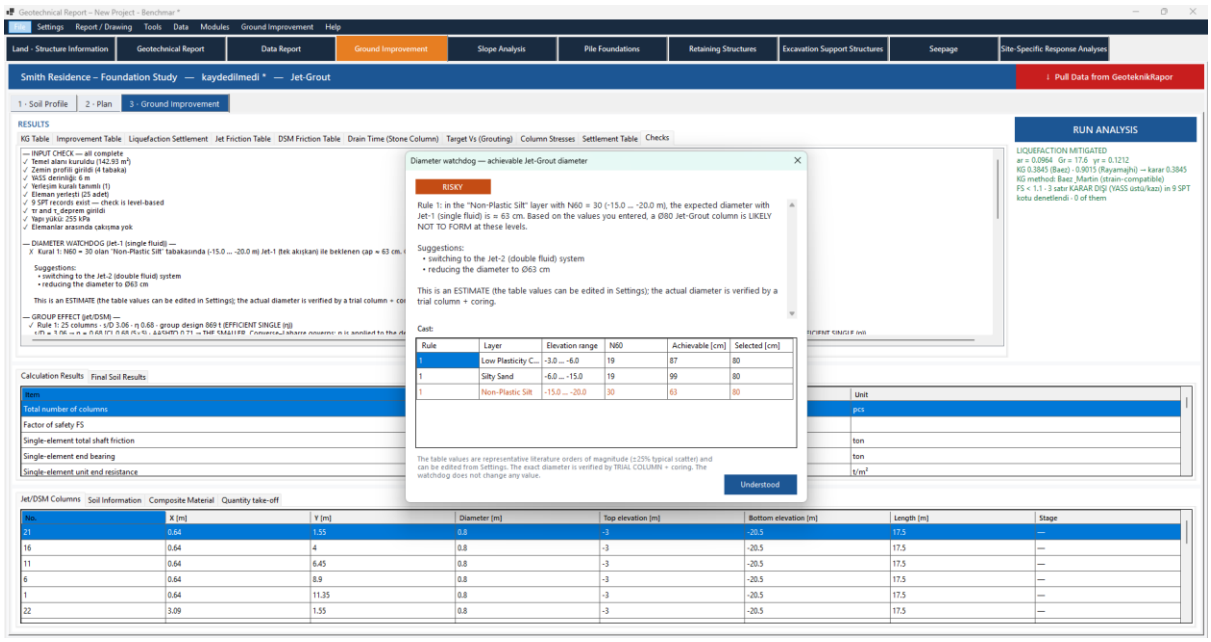


Figure 18. Diameter check warning opened in the centre of the screen after the analysis, and the findings on the Checks tab

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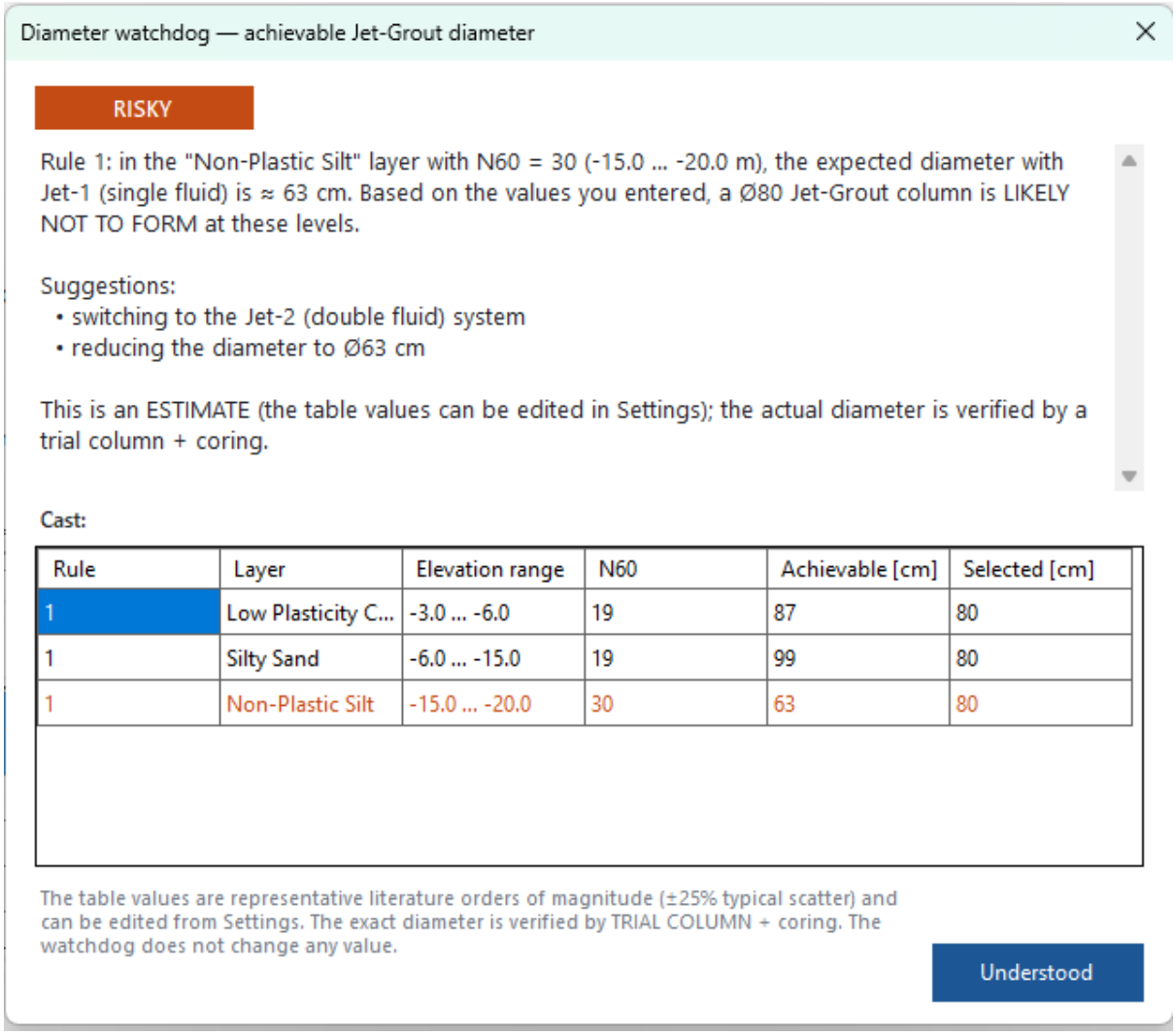


Figure 19. Diameter check window: RISKY warning, suggestions and breakdown

8. Settings — What Changes the Result

The settings are collected in a single window with ten tabs: Safety and limits, Seismic, Liquefaction, Settlement, Methods, Column capacity, Diameter check, Construction and quality, Cost (TL), and Drawing and report. The settings are stored in the main project file and shown in the report. In the main program these settings open under the Ground Improvement tab of the common Settings window. There are two ready-made calculation profiles — two clusters close to market practice and to the literature respectively — and you can select one and then change individual items.

Design code: the code according to which the calculation is made is set with the “Design code” selector on the Settings › Safety and limits tab and is stored with the project. Only codes implemented in the program (Active) can be selected; the others (e.g. FHWA GEC-7 and EN 1997-1) appear greyed out with the note “Not available in this version.” The selection is for information and is not used in the calculation. It is written to the report if the |tasarim_yonetmeligi| field is placed in the report template; the standard template does not contain this field.

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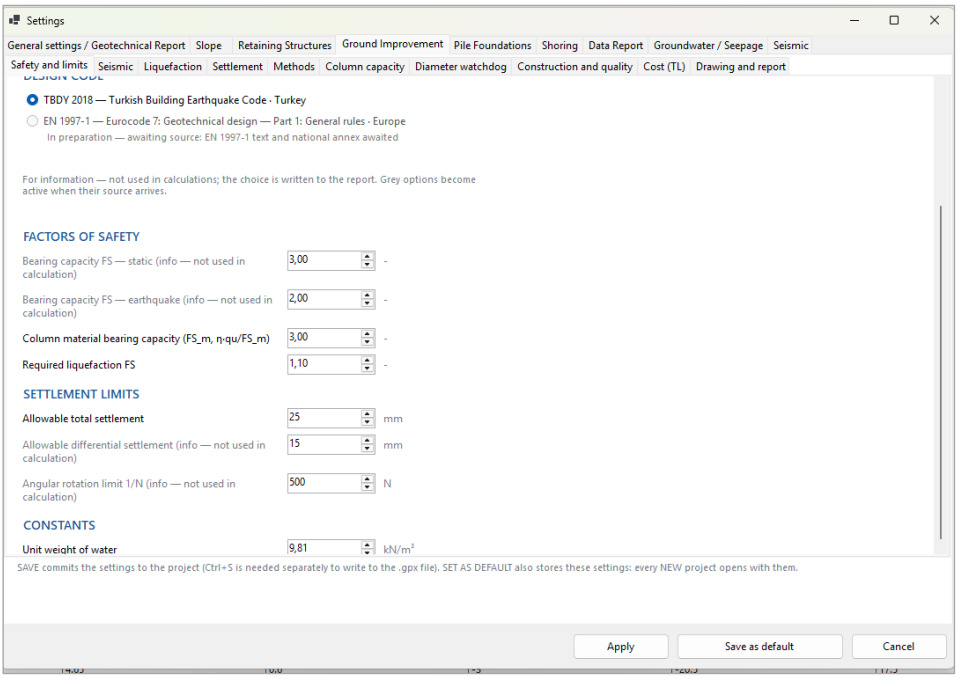


Figure 20. Settings window, Safety and limits tab: design code, factors of safety, settlement limits and constants

Table 9. Settings groups

Group	Contents
Safety and limits	Calculation profile, design code (for information), bearing capacity factors of safety (static and seismic; for information), column material factor of safety, factor of safety required against liquefaction, allowable total settlement, allowable differential settlement and angular distortion limit (for information), unit weight of water.
Seismic	Whether the earthquake effect is taken into account, S_{DS}, S_{D1} (for information), PGA, earthquake magnitude.
Liquefaction	Shear stress reduction method (Baez and Martin, Rayamajhi, both, or an intermediate-value coefficient), target V_s multiplier for grouting, definition and denominator of the area replacement ratio, inclusion of the inner grid in the box layout, structural check of the column (tensile strength / q_u ratio; default 0.25), factor of safety required against liquefaction.
Settlement	Settlement approach of the governing row, stress distribution method, depth-of-influence ratio and cap, limiting the stress concentration ratio by the column capacity, equivalent pier shape factor, settlement T coefficient table (shared with Geotechnical Report).
Methods	Choice of liquefaction method, bearing capacity method and subgrade modulus (for information); composite behaviour: whether shear stress reduction is applied, stress concentration ratio and its limits.
Column capacity	Jet grout shaft and tip source, IDI reduction, end bearing, critical depth, Bustamante SPT charts and tip coefficient.
Diameter check	Whether the check is on, jet diameter calibration coefficient, auto-calibration from a trial column, table of achievable diameters by SPT blow count.
Construction and quality	Quantity items (waste percentage), quality control: trial column and coring ratios, deviation limits.
Cost (TL)	Unit prices for jet grouting, DSM, stone columns and common items.
Drawing and report	Element numbers continuous across the whole layout, plan and section scales (chosen from the standard series), soil pattern scale, the REPORT UNITS and BEHAVIOR groups (marking the result ‘stale’ when input changes, running the analysis automatically when the project opens). The report sections and the template are chosen in the Create Report window (see 10.3).

On every tab the “Revert to defaults” button resets only that tab to its default values. In the bottom strip of the main program’s Settings window, Apply writes the settings into the project; Save as default also stores these settings so that every new project opens with them; Cancel discards the changes. When the window is opened from the Settings submenu of the Ground Improvement menu, it opens on its own and the same actions are

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carried out by SAVE, SAVE + SET AS DEFAULT and Cancel. Some settings are for information only and carry “(info — not used in calculation)” in their labels. The resistance and earthquake shear stress values used in the liquefaction check come from the Geotechnical Report module, not from a method selected in this module. Settings stored as default are kept in the user profile, in the file %LocalAppData%\GeoteknikPro Studio\Ayarlar\ZeminIyilestirme.varsayilan.json; the program does not write to the Documents folder. The report and the drawing sheet are written only to the location chosen in the Save window.

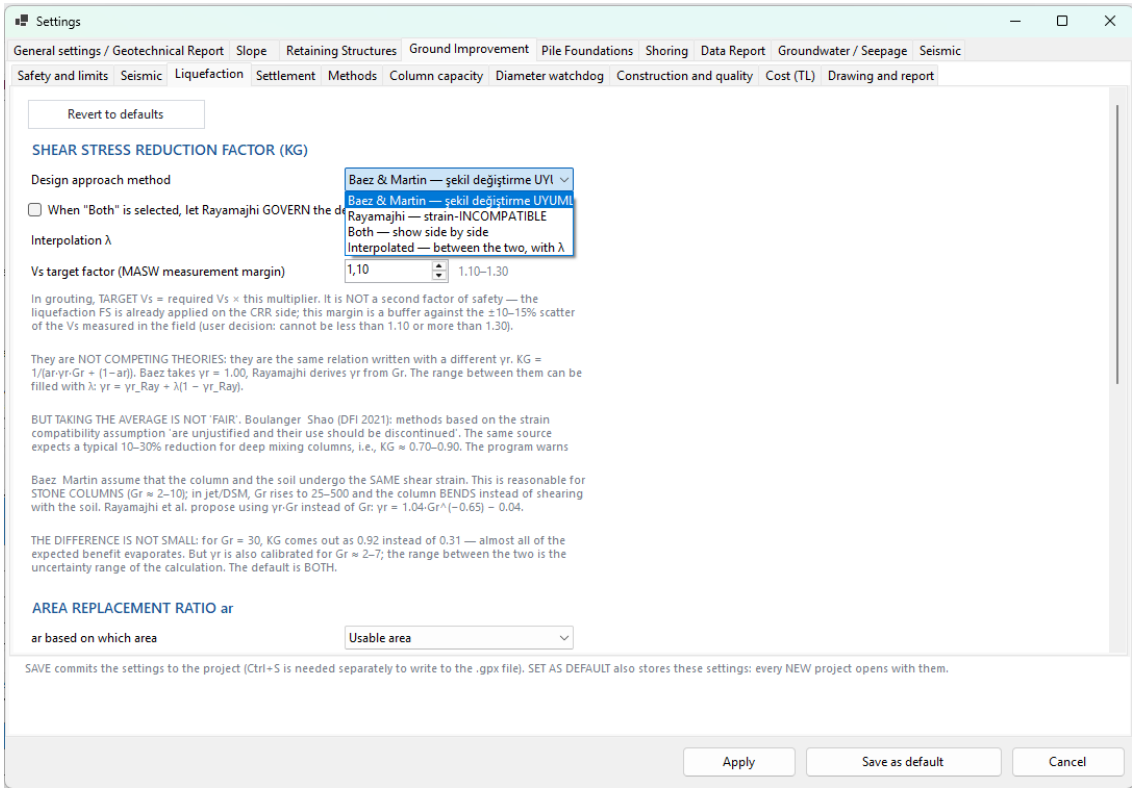


Figure 21. Settings window, Liquefaction tab: choosing the shear stress reduction factor (KG) method

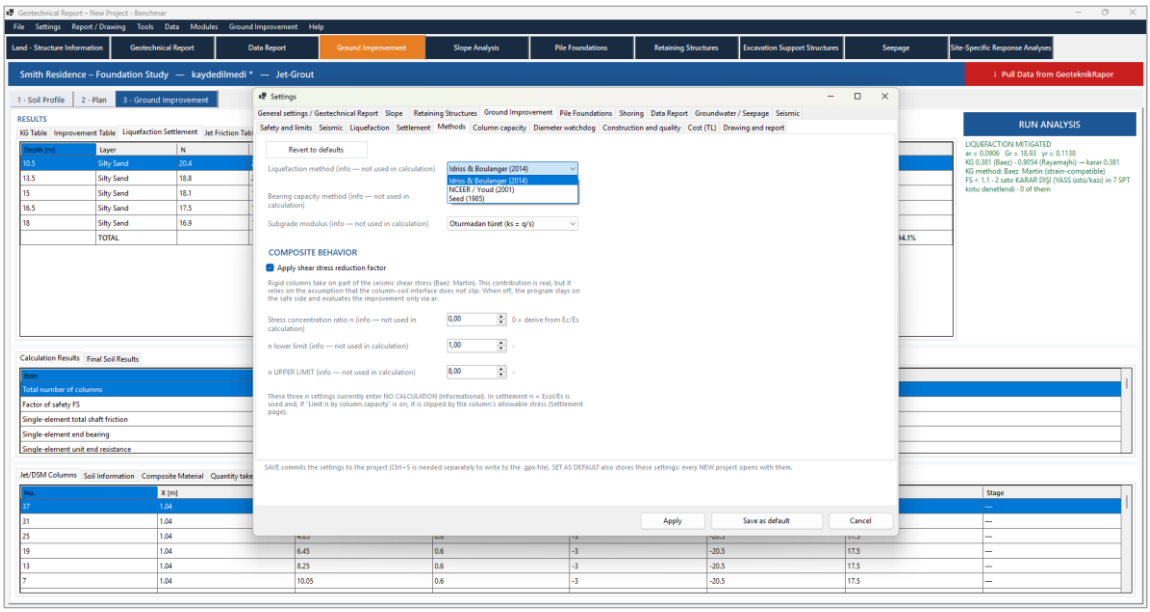


Figure 22. Settings window, Methods tab: choice of liquefaction method and composite behaviour settings

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9. Verification and Benchmarks

The calculations in this module have been checked against independent verification examples and hand calculations. The literature comparisons are given in 9.3 and the hand-calculation checks in 9.4.

9.1 External benchmarks

How the external benchmarks are compared

Each benchmark is a sample project prepared in the program's own file format: the program opens the file, runs the analysis and compares the result with the literature value. These files are not loaded from the user interface and are not part of the installation package. The comparisons are repeated with every release.

Table 10. External benchmark files

Benchmark	Calculation checked and reference
Stone column bulging capacity	A published field load test. The program stays about one fifth below the ultimate stress measured in the field — on the safe side, because it is based on the weakest (shallowest) point of the bulging zone. The acceptance band is the published range.
Priebe improvement factor	Compared with the value read from the method's own chart; the program stays within the chart band.
Post-liquefaction volumetric strain	Compared with the value read from the published chart.
Shear stress reduction	The two methods are calculated together for the same geometry: the strain-incompatible method lies within the reduction band reported in the literature, the strain-compatible method lies outside it. This is the reason for the decision to make the conservative method the default.
Radial consolidation	The radial consolidation coefficient including smear effects is compared with a hand calculation, and the speed-up with the expected order of magnitude.

The tolerance philosophy is explicit: values read from charts are compared against a band, closed-form relations to hand-calculation accuracy. In field tests, success means that the program stays on the safe side, not that it matches exactly.

The verification examples also check that the number of columns and the area replacement ratio do not change when the layout rule is run again.

9.2 What verification tells you

The verification examples show that the calculations reproduce the literature values and that the program follows its own rules. They do not show that the soil parameters of a site have been chosen correctly, that the works have been built as designed, or that the selected method is suitable for that soil; these are the responsibility of the engineer and of site supervision.

9.3 External benchmark comparison

Table 12 gives the results of the external benchmark comparisons. The reference column shows the published field value, the band read from a chart or the hand calculation; the program column shows the value produced by the program with the same input. Where a band is given, the difference is stated as whether the value lies within the band; where a point value is given, as a percentage difference.

Table 11. External benchmark comparison

Example	Reference value	Program value	Difference	Status
Stone column bulging capacity — Hughes and Withers (1974)	Field ≈ 25·c_u; acceptance band 18–26·c_u;	q_{ult} = 380 kPa = 20.0·c_u	≈ −20% relative to the field value (safe side);	Within band

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Example	Reference value	Program value	Difference	Status
	theoretical relation 385 kPa		−1.3% relative to the theoretical relation	
Priebe improvement factor (1995); a_r = 0.25, ϕ_c = 40°	n_0 chart band 2.5–2.7	n_0 = 2.57	Within band; −1.2% relative to the band centre (2.6)	Consistent
Post-liquefaction volumetric strain — Ishihara and Yoshimine (1992); D_r ≈ 50%	Chart band 3–4.5%	ε_v = 3.74%	Within band; −0.3% relative to the band centre (3.75%)	Consistent
Strain compatibility coefficient γ_r — Rayamajhi et al. (2014)	0.1929 (literature, hand calculation)	0.1928	−0.05%	Consistent
Shear stress reduction coefficient K_G, Rayamajhi method — Boulanger and Shao (2021) band	Band 0.70–0.90; hand calculation 0.843	0.8434	Within band; +0.05% relative to the hand calculation	Consistent
K_G, Baez and Martin method (same geometry)	Same band 0.70–0.90	0.357	Outside the band	Expected result (see 9.5)
Radial consolidation factor F — Barron (1948), Hansbo (1981)	F = 1.4517 (hand calculation)	F = 1.452	+0.02%	Consistent
Consolidation speed-up (without columns / with columns)	Expected band 15–30 times	22.3 times (t_{90}: 4.24 years → 0.190 years)	Within band	Consistent

None of these comparisons was made against a finite element program (e.g. PLAXIS); finite element analysis is also outside the scope of the module (see 1.2).

9.5 Hand-calculation checks

In the checks in Table 13 the program value matched the hand calculation within the tolerance.

Table 12. Values checked by hand calculation

Check	Hand calculation (reference)	Status
Andrus and Stokoe (2000): CRR (V_{s1} = 150 m/s)	0.0796 (program 0.07955; difference −0.06%)	Consistent
Stress reduction coefficient r_d (6 m and 12 m)	0.9541 and 0.8536	Consistent
Inverse solution from CRR: V_{s1}	CRR 0.05 → 122.2; 0.10 → 163.41; 0.20 → 193.56 m/s	Consistent
Group efficiency, s/D = 2.5	0.65 = min(classical 0.7578; AASHTO 0.65); AASHTO governs	Consistent
Group efficiency, s/D = 5	0.8743 (classical), smaller than AASHTO 0.90; classical governs	Consistent
Group efficiency, s/D = 7	0.9097 (classical governs; AASHTO 1.00)	Consistent
Block failure: envelope and perimeter friction	Perimeter 10.513 m; area 7.703 m^2; perimeter friction 4205 kN	Consistent
DSM blade rotation number	4·1/0.01 × 2 = 800 rev/m (criterion 360); 160 with fast penetration (warning); 80 if mixing on withdrawal is off	Consistent
Grouting: grout and cement quantity	100·10·0.35·0.75 = 262.5 m^3; cement 198.5 t; with site calibration 4 + 1.5 + 0.75 = 6.25 m^3	Consistent
Equivalent raft	Level −6.667 m; q = 100·100/7.84 = 1275.5 kPa	Consistent

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9.5 Known differences and limitations

- Hughes and Withers: the program stays about one fifth below the value measured in the field. This is a deliberate safe-side choice, because the weakest (shallowest) point of the bulging zone is taken as the basis, and the value lies within the acceptance band.
- The Baez and Martin method lies outside the band for the same geometry; this difference is not an error, but the reason why the two methods are shown together and the Rayamajhi method governs.
- Since the Priebe depth factor is not applied, the Priebe comparison has been made without the depth factor.
- The source of the Kσ and Gr coefficients used in the shear stress reduction has not yet been confirmed; use results that depend on these coefficients with caution.

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10. Quantities, Cost, Report and Drawing

10.1 Quantities

The quantities are a direct result of the layout and involve no engineering assumption: the number of columns, the total column length, the empty drilling, the column volume and the volume including waste follow from the geometry. Material items are added according to the method: cement, water and grout for jet grouting and deep mixing; loose and compacted gravel for stone columns; grout stage by stage for grouting. The site control quantities — number of trial columns, number of cores and number of PIT (integrity) tests, the last taken as 2 % of the columns and at least one — are calculated in a single place, so the report and the drawing sheet print the same numbers.

For grouting, the stage quantities are theoretical if no site calibration has been entered, and are distributed between the stages in default proportions; once the take achieved in the first stage is entered, the second and third stages are derived from this measurement and the quantities are reported as calibrated.

The quantity table can be exported to Excel and CSV.

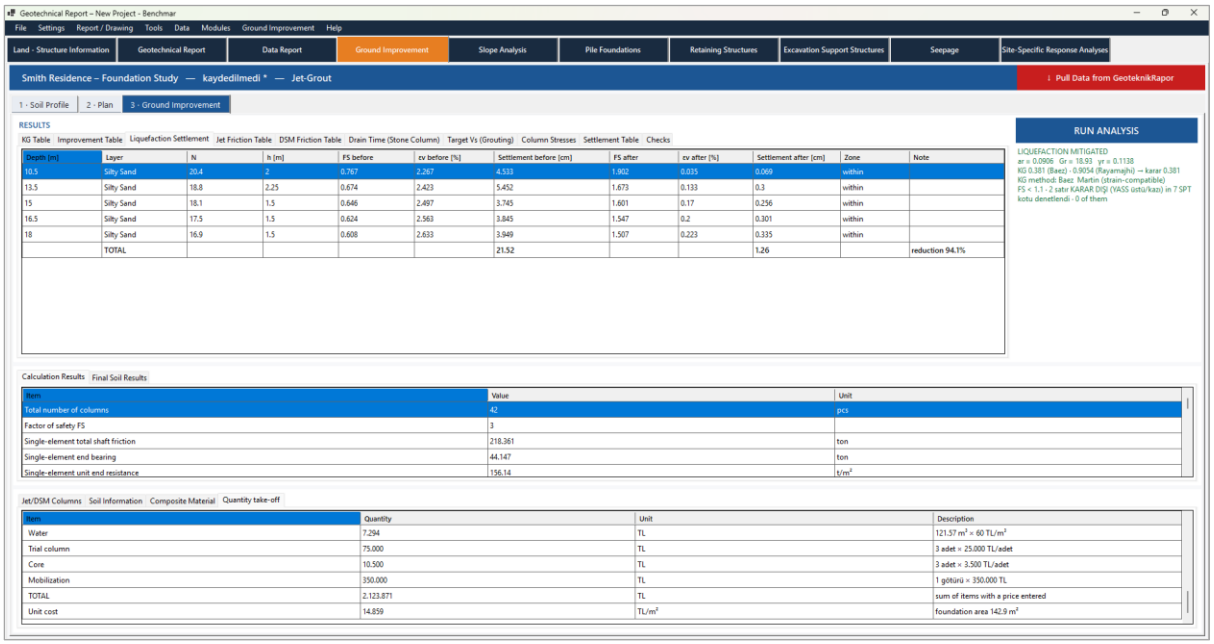


Figure 23. Quantity take-off sub-table on the 3 · Ground Improvement tab: items, quantities, units and the unit cost per square metre of foundation

10.2 Cost

The unit prices are entered in the settings: construction per method, empty drilling, cement, water, gravel, trial column, coring and mobilisation. From these a cost summary is produced and — using the daily production capacity and the number of rigs — a duration estimate. The cost section is switched on in the report by default.

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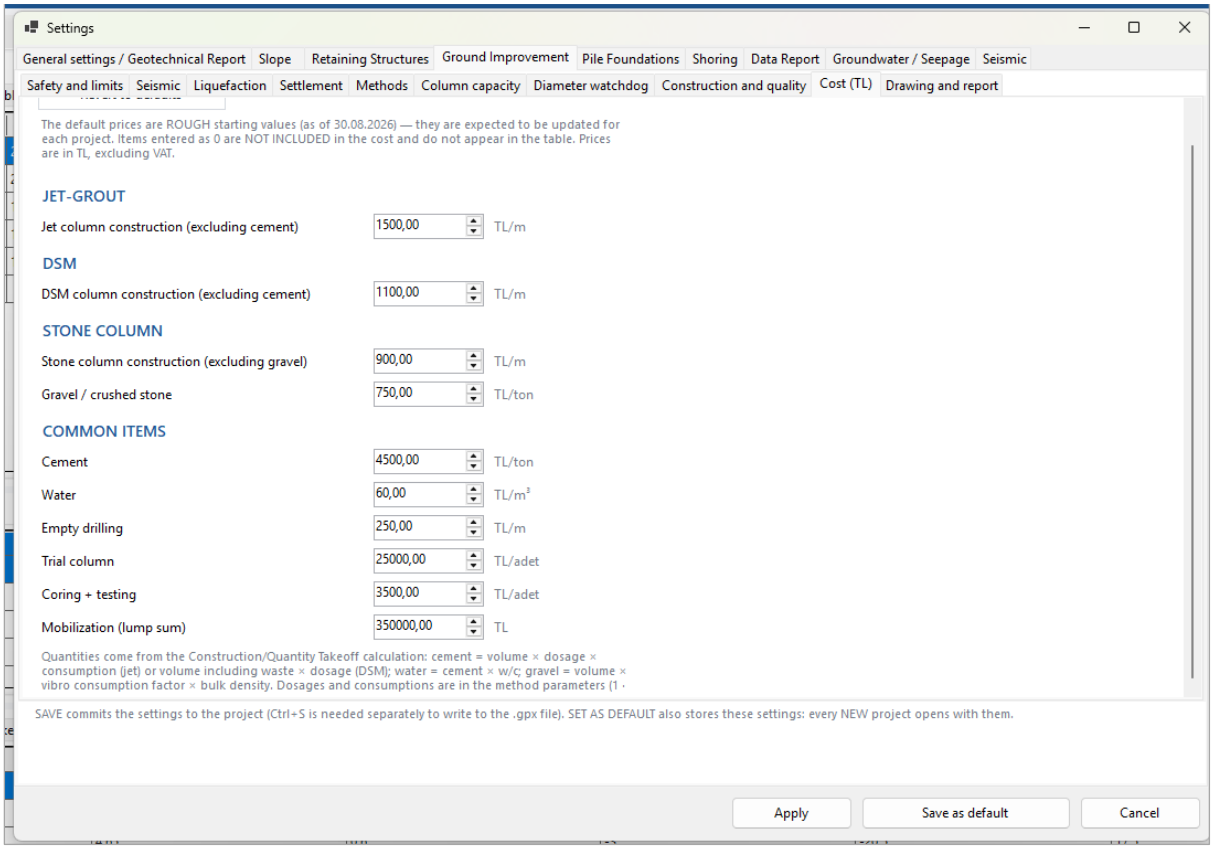


Figure 24. Settings window, Cost (TL) tab: unit prices by method and for common items

10.3 Report

The report is produced from an editable Word template selected according to the method; the placeholders in the template are replaced with the calculated values, and the tables grow with the number of rows. The template is selected in the TEMPLATE field (Browse…) of the Create Report window. When the window opens, this field is filled in the following order: a template path stored in the project that does not carry the name of the program's default template and still exists; otherwise the custom template selected for the method in the Report / Drawing › Report templates… window; otherwise the current default template of the installation. The program's own default template is always taken from the current installation copy. Individual report sections are switched off in the REPORT SECTIONS list of the same window, and this selection is stored with the project.

The "Report templates…" window at the end of the Report / Drawing menu shows the Word templates shipped with the program in a single list with the columns Module, Template, In use and Default file. Ground Improvement has four rows: Jet grouting, Deep soil mixing (DSM), Stone column and Grouting.

"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 method: 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.

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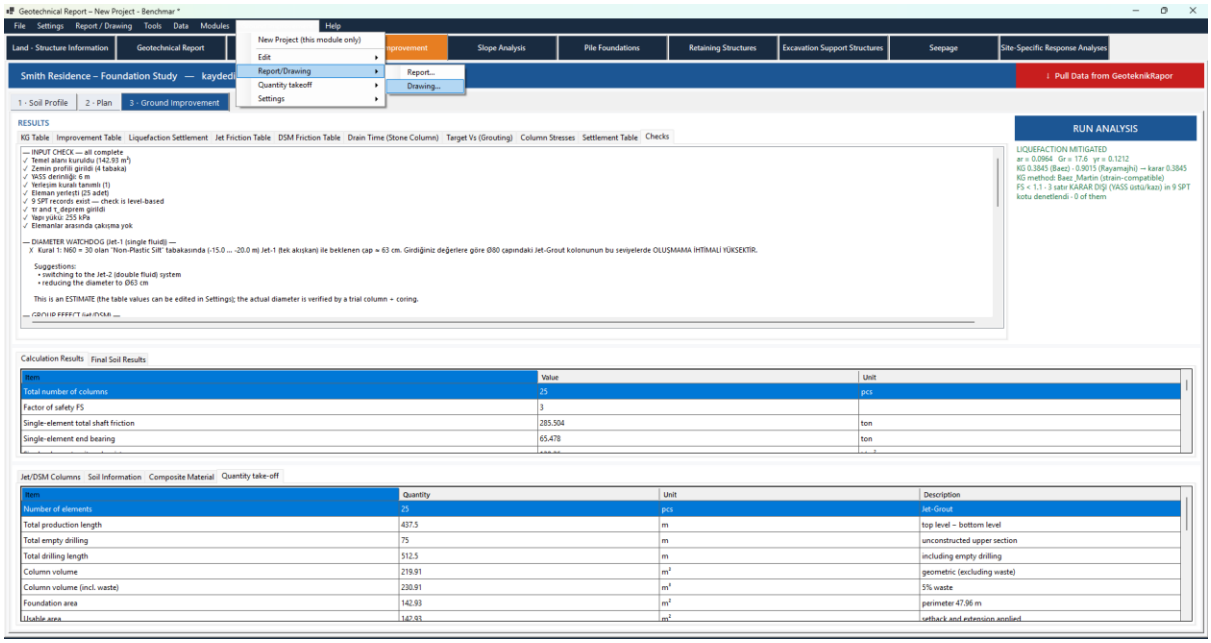


Figure 25. Report/Drawing menu: the Ground Improvement › Report… and Drawing… commands

In all human-readable row tables of the report the vertical axis is positive depth — downwards from the surface. Levels are used only for the geometry: column top and bottom level, section and DXF. This is a presentation choice only; in the project file the geometry is stored in terms of levels.

The report begins with a table of contents, a list of figures and a list of tables; these are built as fields in Word and are updated when the document is opened. At the end there are the references (only those cited in the text) and the symbols and units table. Subscripted symbols are printed with true subscripts in the fixed text as well; a_r, A_{jet}, A_{kol}, G_{kol}, G_s, G_r and K_G are among them. The document asks Word to update all fields when it is opened, so the lists and the figure and table numbers are current without F9; F9 is needed only if the fields do not appear updated. The fill properties, the fill check section of the report and the fill note on the drawing are produced only when engineered fill above the columns has been selected; without fill they are left out.

The cover carries no figure caption; the cover photograph is the current cover photograph of the Geotechnical Report module. In the plan image the columns are labelled with numbers (e.g. J001); the construction sections are drawn with the columns, and the section line snaps to the nearest column row. The cost section is switched on in the report by default. The consistency of the report with the calculated values is checked automatically by the program (SPT numbering, DSM blade rotation number, coring percentage, factors of safety before and after, capacity summary).

10.4 Drawing

The drawing sheet produces the plan and the typical section together with a frame and a title block. The layers are separate: foundation, usable area (dashed), columns and column hatching, column numbers, grouting stages, grid lines and grid labels, dimension chain, soil layers and their hatching (the common soil section layers ZEMIN-TARAMA, ZEMIN-SINIR, ZEMIN-SU, ZEMIN-YAZI and ZEMIN-KOT; the hatching density changes with “Soil pattern scale” on the Settings › Drawing and report tab), walls, fill, notes, text, title block and frame. Column numbers are written with the method letter and switch to three digits when the number of columns exceeds one hundred.

Level labels are placed to the right of the typical section: foundation top, foundation bottom, fill bottom, column top, column bottom and ground. The levels are relative to the foundation bottom; the foundation bottom reads ±0.00 and the levels below it are written with a minus sign. Levels that fall at the same elevation are merged into a single line, and the labels do not overlap. The notes, the layer labels and the typical section use the same

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level system, and the datum (foundation bottom ±0.00) is written on the sheet. The execution standard in the title block follows the method: TS EN 12716 for jet grouting, TS EN 14679 for deep soil mixing, TS EN 14731 for stone columns and TS EN 12715 for grouting.

If an outward extension has been given, the dimension chains, the grid bubbles and the typical section are moved beyond the extended columns; texts do not overlap. When the general notes are very long, the quantity table moves below the notes. The scale is always standard: the sheet grows when necessary, the scale is not reduced, and no note about the paper or about the drawing not fitting is written on the drawing.

If fill is selected, the engineered fill above the jet columns is shown on a separate layer in the typical section. If the fill lies above the jet columns, the jet head ends at the base of the fill and does not enter it. The fill description is written to the left of the section with a single two-line label; the geotextile and geogrid information is on the second line. When geosynthetic reinforcement is selected, the layer lines and an explanatory note are added to the drawing. This is a drawing detail; the contribution of the reinforcement does not enter the calculation, and this is also stated on the drawing.

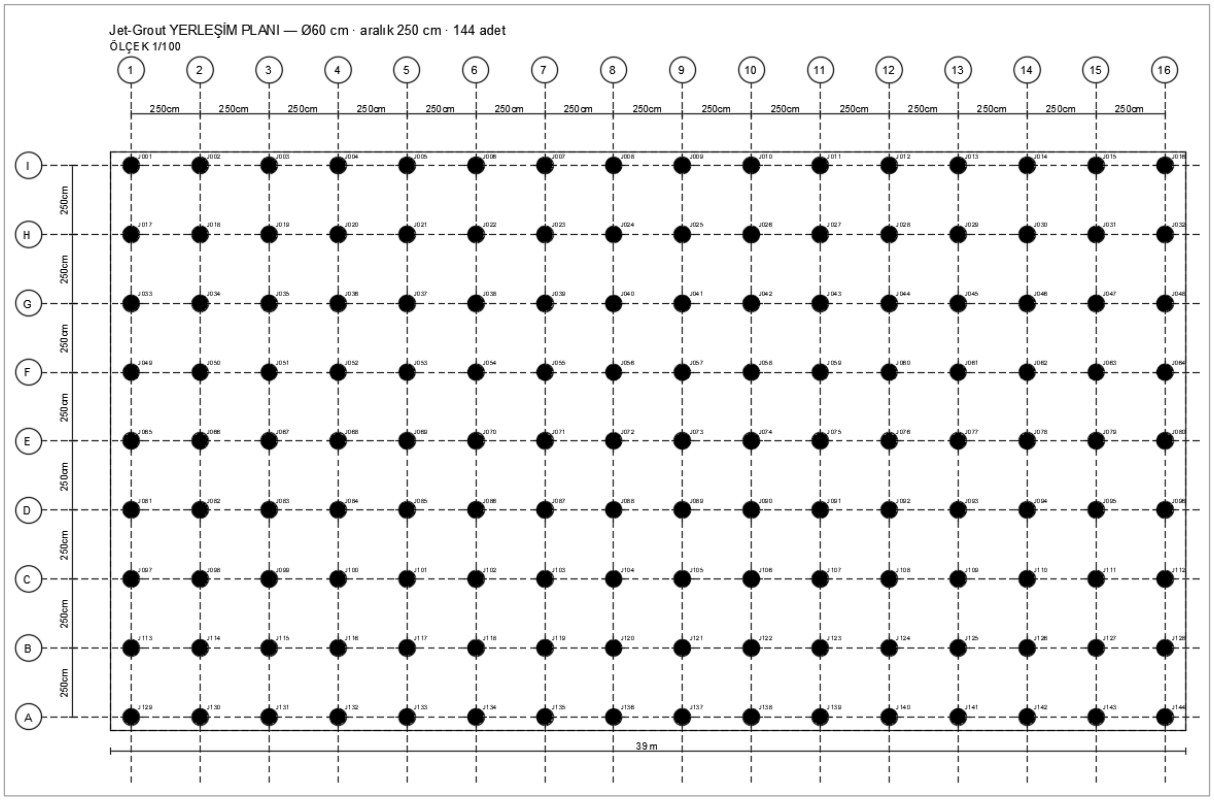


Figure 26. Drawing sheet output: Jet grout layout plan (Ø60 cm, spacing 250 cm, 144 columns) — grid lines, dimension chain and column numbers (Turkish interface shown)

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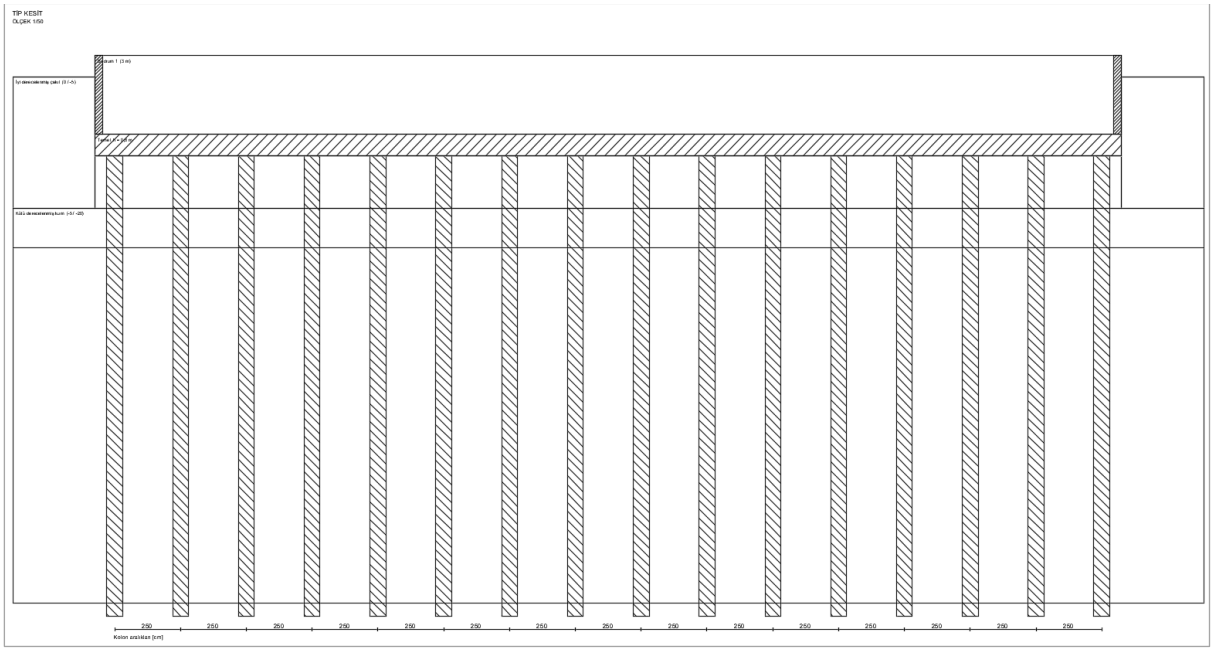


Figure 27. Drawing sheet output: typical section — foundation, columns and column spacings (Turkish interface shown)

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11. Points to Watch

11.1 In the plan and layout

- Choosing the wrong DXF unit changes the area by up to a factor of ten thousand and shifts all results together. The unit window is not a step to be skipped.
- The setback distances determine the usable area, and the usable area determines the area replacement ratio. Giving one edge an extra half metre of setback can change the liquefaction result.
- At the same spacing a triangular pattern gives a markedly higher area replacement ratio than a square grid. Comparing the two patterns at the same spacing is misleading.
- In the enclosing wall layout, the composite ground formulas are not applied (unless the inner grid is taken into account); the area replacement ratio of that layout belongs to the strip.
- An element moved by hand is kept, while a deleted position is never filled again. Regenerating the layout does not undo either of these decisions; use the relevant command to undo them.
- The theoretical and the achieved area replacement ratio may differ; the achieved ratio is what enters the calculation, and both are written in the generation note.

11.2 In the calculation

- The definition of the area replacement ratio is selected in the settings and directly changes the result. When comparing two reports, first make sure that this definition is the same.
- For shear stress reduction the two methods give markedly different results for the same geometry. The default selects the conservative one; changing the method is a deliberate decision.
- If no groundwater is declared, all rows are assumed saturated. This is on the safe side but may not reflect reality; the water level should be entered.
- The composite modulus of elasticity comes out larger than it really is as the modulus ratio of column to soil increases. When the ratio column in the table turns red, the result must be read with this in mind.
- For stone columns the governing failure mode is bulging; the pile-like shaft–tip table does not decide there.
- The drain contribution is off by default. Switching it on declares that the stone column will act as a vertical drain; the clogging reservation must be kept in mind.
- For grouting the program does not claim any quantity. Acceptance means that the velocity profile measured on site lies above the target curve; this measurement must be planned.
- When a feasibility check says RISKY, it is saying that even if the calculated numbers are correct, the construction cannot produce those numbers on site. Entering a diameter does not produce the diameter; entering a strength does not produce the strength.

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12. Known Limitations and Out-of-Scope Topics

Table 13. Out-of-scope and limited topics

Topic	Status
DXF entity types	Only LINE, LWPOLYLINE and POLYLINE are read; arcs, circles, splines and ellipses are skipped and their number is reported. Binary DXF is not supported.
Hole (island) in the foundation area	Cannot be defined. For a lift shaft, courtyard or existing structure, the elements in that zone are selected and deleted.
Offset algorithm	It is not a full “straight skeleton” offset. If the setback distance is larger than a narrow part of the polygon the edges cross each other; the program detects this, treats it as invalid and says so.
Grouting layout	Does not work with column logic; the object in the plan is a hole and the improved volume is a sphere of influence. A staged pattern is offered, but the composite formulas are not applied.
Priebe depth factor	Not applied in this version.
Stiffness contribution to drain acceleration	Deliberately neglected (safe side); the clogging reservation is written in a note.
Geosynthetic reinforcement	A drawing detail only; its contribution does not enter the calculation.
Negative skin friction	Not included in the column capacity calculation.
Finite element analysis	Out of scope.
Differential settlement and angular distortion	Not checked; the settlement limit check applies only to the total settlement. The related settings are for information only.
Footing projection	Display only; drawn in the plan and section, it does not enter the calculation.
Choice of liquefaction method	The choice is for information only; the resistance and earthquake shear stress values come from the Geotechnical Report module.

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