GeoteknikPro

STUDIO — SITE-SPECIFIC RESPONSE ANALYSES

USER GUIDE

and Calculation Methods Document

Ground motion record editing · Scaling to a target spectrum and spectral matching ·
One-dimensional site response: equivalent linear and nonlinear · Pore water pressure generation

In accordance with the Turkish Building Earthquake Code (TBDY 2018), Chapter 2, Chapter 16 and Appendix 16C

Version 3.0.1

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Contents

Contents 2
List of Figures 5
List of Tables 6
Symbols and Units 7
1. Introduction 8
1.1 What the module does 8
1.2 Why a single program 8
2. Program Workflow 9
2.1 The mandatory order of the workflow 9
2.2 Persistent record library 10
3. Ground Motion Editing 10
3.1 Importing a record 10
3.2 Processing a record: baseline, filter, taper 11
Baseline correction 11
Butterworth filter 12
Taper and order of operations 12
3.3 Processing quality and automatic suggestion 13
3.4 Velocity and displacement 13
3.5 Response spectrum 13
3.6 Strong ground motion parameters 14
3.7 Frequency content 15
3.8 Velocity pulse recognition 15
3.9 Output of this section 16
4. Ground Motion Scaling 17
4.1 Reading the source records 17
4.2 Defining the target spectrum 17
Code spectrum 17
Damping other than five per cent 18
Target spectrum from a file 18
4.3 Analysis dimension: planar and spatial 19
4.4 Matching and the check band 20
4.5 Automatic suite selection 20
4.6 Amplitude scaling 21
Manual scale factor 21
4.7 Spectral matching: wavelet scaling 21
4.8 Mean spectrum compliance and the common β 23
4.9 Outputs of this section 24
5. Soil Profile and Calculation Model 25
5.1 Main soil layers 25

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

5.2 Groundwater and bedrock 26
5.3 Shear wave velocity profile 26
5.4 Taking the profile from the main program 27
5.5 Generating the calculation sub-layers 27
6. Dynamic Curves and Curve Calibration 29
6.1 Reference curve library 29
6.2 Calibration of the backbone curve 29
6.3 Damping: non-Masing correction 30
6.4 What the user sees, and the gate of calibration 30
7. Record Selection and Analysis 31
7.1 Record library and input motion type 31
7.2 Equivalent linear solution 32
7.3 Nonlinear solution 33
7.4 Pore water pressure generation 33
7.5 Output depths 35
8. Results, Design Spectrum and Checks 35
8.1 Result views 35
8.2 Building the site-specific design spectrum 37
8.3 TBDY §16.5.2 applicability checks 38
8.4 Pile kinematic displacement demand 38
9. Verification and Comparisons 40
9.1 Three levels of comparison 40
9.2 Record processing quantities 40
9.3 Site response solution 40
Comparison 1 — DeepSoil, Benchmark 1: 40 m sand profile 40
Comparison 2 — DeepSoil, Benchmark 2: 30 m clay / sand / clay profile 42
Comparison 3 — RSSeismic, Benchmark 3: 20 m three-layer profile, total and effective stress 44
Comparison 4 — Constitutive model 46
Closed-form solution 46
9.4 The Run benchmarks window 46
10. Outputs, Project File and Bridges 48
10.1 Selective export 48
10.2 Project file 49
10.3 Bridge to the Pile Foundations module 49
10.4 Bridge to the main program 50
10.5 Currency of the results 50
10.6 PLAXIS 2D site response script 50
11. Points to Watch 51
12. Scope and Limitations 51
13. References 52

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Codes and standards 52
Record processing and ground motion measures 52
Scaling and spectral matching 52
Dynamic soil properties and one-dimensional response 52
Pore water pressure generation 52

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

List of Figures

Figure 1. 1.1 Data and Records tab: loaded ground motion, acceleration–time plot and spectral view 11
Figure 2. 1.2 Record Processing tab: baseline, Butterworth filter and taper; raw and processed velocity–time 13
Figure 3. 1.3 Motion Parameters tab: amplitude, duration and energy parameters, Arias intensity 15
Figure 4. 1.5 Pulse Recognition tab: pulse extraction and the $S_d \times S_v$ spectrum 16
Figure 5. Multiple Ground Motion Record Loading window 17
Figure 6. Target Spectrum Definition window: TBDY 2018 parameters and target spectrum 19
Figure 7. 2 · Ground Motion Scaling: spectra and acceleration time histories after wavelet scaling 22
Figure 8. Wavelet Scaling Settings window 23
Figure 9. Mean Spectra tab: TBDY mean check and final β 24
Figure 10. Ground Motion Parameters tab and export buttons 25
Figure 11. 3.1 Soil Profile and Settings tab: analysis definition and main soil layers 26
Figure 12. V_s – Depth Profile tab: control points and profile 27
Figure 13. 3.2 Profile Creation tab: sub-layer table 28
Figure 14. Profile Plots: V_s, G_{max}, f_{max}, damping and stresses along the sub-layers 28
Figure 15. Curve Fitting tab: target and calibrated curves for G/G_{max}, damping and shear strength 30
Figure 16. 3.3 Record Selection tab: record library and input motion definition 32
Figure 17. The physical difference between the two base boundary conditions: Rock Outcrop (elastic half-space) and Within (rigid base) (Turkish interface shown) 32
Figure 18. 3.4 Analysis tab: nonlinear solution settings and analysis summary 33
Figure 19. GMP / EPWP tab: pore water pressure model and layer-by-layer settings 34
Figure 20. Results, GMP / EPWP — depth distribution of the maximum r_u 35
Figure 21. 3.5 Results, Response Spectrum: input and surface motion 36
Figure 22. Depth Profiles: PGA, PGV, PGD, γ_{max}, maximum stress, G/G_{max}, damping and degraded V_s 36
Figure 23. Stress-Strain tab: hysteresis loops of the selected sub-layer 37
Figure 24. Design Spectrum tab: surface spectra of the records, mean and program design spectrum 38
Figure 25. Pile Displacement Demand tab: records, TBDY mean and diagnostic envelope (Turkish interface shown) 39
Figure 26. Benchmark 1 — comparison of surface response spectra (Turkish interface shown) 42
Figure 27. Benchmark 2 — comparison of surface response spectra (Turkish interface shown) 43
Figure 28. Depth profile of maximum shear strain for both benchmarks; the depth of the peak is the same in both programs (Turkish interface shown) 44
Figure 29. Benchmark 2 — depth profiles of mobilised stress ratio and maximum acceleration (Turkish interface shown) 44
Figure 30. Export Table of Contents window 49

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

List of Tables

Table 1. Symbols used in the guide 7
Table 2. Preconditions for the analysis 9
Table 3. Record reading modes 10
Table 4. Import fields and their default values 10
Table 5. Filter settings and their defaults 12
Table 6. Response spectrum solvers 14
Table 7. Groups of motion parameters 14
Table 8. The two period bands 20
Table 9. Automatic suite selection settings and their defaults 20
Table 10. Spectral matching settings and their defaults 22
Table 11. Outputs of the scaling section 24
Table 12. V_s input modes 26
Table 13. Reference dynamic curve families 29
Table 14. Input motion type 31
Table 15. Pore water pressure solution modes 34
Table 16. Result headings 35
Table 17. Verification levels 40
Table 18. Benchmark 1 — general profile and analysis parameters 41
Table 19. Benchmark 1 — soil layer definitions (identical in both programs) 41
Table 20. Benchmark 1 — input verification results 41
Table 21. Benchmark 1 — comparison of peak values 41
Table 22. Benchmark 1 — depth profiles and spectrum statistics (34 points) 41
Table 23. Benchmark 2 — general profile and analysis parameters 42
Table 24. Benchmark 2 — soil layer definitions (identical in both programs) 42
Table 25. Benchmark 2 — comparison of peak values 43
Table 26. Benchmark 2 — depth profiles and spectrum statistics (29 points) 43
Table 27. Results of Comparison 3 45
Table 28. Benchmark 3 — model 45
Table 29. Benchmark 3, Analysis A — total stress results 45
Table 30. Benchmark 3, Analysis B — pore water pressure on, ChiChi 46
Table 31. Site analysis outputs 48

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Symbols and Units

Table 1. Symbols used in the guide

Symbol	Description	Unit
Δt	Time step of the record	s
PGA, PGV, PGD	Peak ground acceleration, velocity and displacement	g · cm/s · cm
$S_a(T)$	Spectral acceleration	g
T_n	Fundamental period of the structure	s
α	Amplitude scale factor	—
β	Mean spectrum compliance factor	—
V_s	Shear wave velocity	m/s
G_{max}, G/G_{max}	Small-strain shear modulus and modulus reduction ratio	kPa · —
ξ, D	Damping ratio	%
γ, γ_{max}	Shear strain and its maximum	%
τ, τ_{max}	Shear stress and shear strength	kPa
f_{max}	Maximum frequency a sub-layer can transmit, $V_s/(4H)$	Hz
$\theta_1 \ldots \theta_5$	Backbone curve fitting parameters	—
r_u	Pore water pressure ratio, $\Delta u/\sigma'_{v0}$	—
δ_G, $\delta\tau$	Stiffness and strength degradation factors due to pore water pressure	—
σ'_{v0}, p'_{m0}	Initial vertical and mean effective stress	kPa
S_{DS}, S_{D1}	Short-period and 1 s design spectral acceleration coefficients	—
$u_{ff}(z)$	Free-field displacement envelope	m
Arias	Arias intensity	m/s
$D_{5\text{-}95}$	Significant duration	s

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

1. Introduction

1.1 What the module does

The Site-Specific Response Analyses module runs the whole chain from the raw state of an earthquake record to the site-specific design spectrum within a single program: reading and correcting the records, scaling them to a target spectrum or matching them spectrally, and solving these records in a one-dimensional soil column to obtain the surface motion, the depth profiles and the design quantities.

1.2 Why a single program

The work of three separate programs, in a single main project file

In common practice this chain is run with three separate pieces of software: one corrects the record, one matches it to the target spectrum, one solves the soil column. At every hand-over the file format, the units, the time step and which state of the record it is have to be re-established — and every hand-over is an opportunity for the wrong state of a record to enter the next step. In this module all three are numbered tabs of the same window: they share the same record store, the same spectrum solver, the same report writer and the same main project file.

The practical consequences are concrete. The final records produced in the scaling section are transferred to the site analysis with a single button and in memory; no file is written and read in between, so neither the units nor the time step are reinterpreted. The spectrum is calculated with the same solver and the same period grid on all three tabs; a spectral acceleration shown on one is not a different number on another. The report and the Excel output gather the whole chain in a single document.

The record editing results on the first tab are not passed to the second tab automatically; the screen states this explicitly. The reason is that the set of records going into scaling does not have to be the same as the records tried out during editing; which records go into the suite is a separate decision.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

2. Program Workflow

The program consists of three numbered tabs, and the numbers are the workflow itself. The diagram below shows the path a record follows from its raw state to the design quantities, and the bridges between the two modules.

INPUT — raw earthquake records

Text file or standard record formats · unit g, m/s² or cm/s² · Δt

Decimal and column separators are resolved from the file or given by hand

▼ import

1 · GROUND MOTION EDITING

1.1 Data and records — 1.2 Record processing — 1.3 Motion parameters

1.4 Frequency content — 1.5 Pulse recognition

Baseline correction · filtering · response spectrum · Arias, duration, number of cycles

▼ records are selected again on the second tab

2 · GROUND MOTION SCALING

Step 1 source records — Step 2 target spectrum — Step 2B analysis dimension

Step 3 scaling / matching — Step 4 export

Automatic suite selection (11 records) · amplitude scaling · wavelet-based spectral matching · mean spectrum check and common β

▼ "Get from Scaling" — one button, in memory, no file

3 · SITE-SPECIFIC RESPONSE ANALYSIS

3.1 Soil profile and settings → 3.2 Sub-layers and curve fitting → 3.3 Record selection

3.4 Solution settings and output depths → 3.5 Results (sixteen views)

Equivalent linear or nonlinear solution · optional pore water pressure generation

▼ results

OUTPUTS AND BRIDGES

Site-specific design spectrum (S_{DS}, S_{D1}) · Word report · Excel workbook · PNG

Free-field displacement envelope $u_{ff}(z)$ → Pile Foundations module (via file)

Soil profile ← Geotechnical Report module (when running embedded)

2.1 The mandatory order of the workflow

On the third tab the analysis does not start until four conditions are met, and every refusal takes the user directly to the sub-tab where the missing item is.

Table 2. Preconditions for the analysis

Condition	Reason
The calculation model must have been built	The main soil layers are user input; the calculation sub-layers are the program's own discretisation, and there is no solution mesh until this generation has been run explicitly.
Curve fitting must be complete	The constitutive behaviour of a sub-layer whose backbone curve has not been fitted is undefined. The program states as a number how many of the sub-layers are complete.
For the equivalent linear solution, every sub-layer must have a valid reference curve	In a layer without modulus reduction and damping curves the iteration has nothing to hold on to.
At least one record must be ticked	A solution without input is meaningless.

While the analysis is running the input tabs are locked; when it finishes the screen switches to the results automatically.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

2.2 Persistent record library

3. Ground Motion Editing

This section describes the program's first numbered tab. Its purpose is single: to turn the raw acceleration record at hand into engineering data that calculations can be performed on, and to show in numbers what that record is. The section has five sub-tabs: data and records, record processing, motion parameters, frequency content and velocity pulse recognition.

3.1 Importing a record

The add-record button opens a definition window. In this window you first select the file, then define the data structure of the file, and finally check the lines to be read on a preview. The program can guess the format of the file; it shows its guess to the user and asks for confirmation.

The extensions that can be read are txt, at2, acc, dat and csv. Four reading modes are offered for the data structure.

Table 3. Record reading modes

Mode	What it expects
1 — Acceleration Only	A single column of acceleration values; time is generated from the Δt entered.
2 — Time / Acceleration Columns	Two columns. Δt is derived from the median of the intervals in the time column; if the intervals are not uniform a warning is given.
3 — Multiple Acceleration Series (PEER / AT2)	The classical PEER layout with several acceleration values per line.
4 — Automatic Diagnostics	The default mode. The program resolves the layout from the file itself and writes the format it has resolved to the console.

The numerical fields and their defaults are given below. All of them apply at the moment of reading; they cannot be changed after the record has been loaded — the record is loaded again instead.

Table 4. Import fields and their default values

Field	Default	Description
Time step Δt (s)	0.005	If a PEER / AT2 header is present, it is read from there and the field fills itself.
Number of lines to skip	0	For skipping header lines.
Last row to read	Automatic	When Automatic is ticked, the file is read to the end.
Time column / Acceleration column	1 / 2	Meaningful only in the two-column mode.
Acceleration unit	g	g, m/s^2 and cm/s^2 are accepted; the internal calculation is always in SI units.
Multiplier	1	The user's own factor, separate from the unit conversion.
Decimal separator / Column separator	Automatic	When Automatic is selected, the decision is made once for the whole file, not line by line.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Information read and not read from the record

Only two quantities are read from the file header: the number of samples (NPTS) and the time step (DT).

The station name, earthquake name, magnitude, source distance and component direction are not read; the record name is derived from the file name.

PGA is not read; it is calculated from the record itself. A difference between a PGA written in the file and the calculated PGA is the first sign that the unit of the record has been defined wrongly.

If the NPTS in the header does not match the number of samples read, the program stops and asks whether to continue; the default answer is no.

The preview offers two views. In the first, the first lines of the file are shown, each labelled SKIP, READ or AFTER, so you can check by eye which line is taken as data. In the second, the series read is shown both as a table and as a plot, together with the number of points read and the calculated PGA.

The same window contains a validation record button. This button loads a reference record embedded in the program and writes the published quantities for that record and the quantities calculated by the program side by side in the console. Its purpose is to let the user see that the installation works correctly without putting their own data at risk.



Figure 1. 1.1 Data and Records tab: loaded ground motion, acceleration–time plot and spectral view

3.2 Processing a record: baseline, filter, taper

The following sentence is written at the top of the processing tab: the raw record is preserved, the operations are applied to a separate data array. This way the raw record is never lost in any operation. The raw series and the processed series are kept separately in memory; in the plots they can be drawn together, one dashed red and the other solid dark blue.

Baseline correction

Baseline correction is the subtraction from the record of a polynomial determined by least squares. The four options correspond to polynomial degrees from zero to three: removal of the mean, linear correction (the default), second degree and third degree. The time axis is normalised during this calculation; this is for numerical stability with higher-degree polynomials and does not change the result.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Butterworth filter

Table 5. Filter settings and their defaults

Setting	Default	Options / range
Filter type	Band-pass	High-pass, Low-pass, Band-pass
Lower cut-off frequency	0.1 Hz	0.001 – 1000 Hz
Upper cut-off frequency	25 Hz	0.001 – 1000 Hz
Order	2	2 – 10, in steps of two
Phase	Zero Phase / Acausal	Causal or Zero Phase

The choice of phase matters more than it seems. With the causal option the record is filtered once, in the forward direction; the amplitude response belongs to the chosen order, but the filter introduces a phase shift into the record. With the zero-phase (acausal) option the record is filtered forwards, reversed, filtered again and reversed back; the phase shift disappears, but in return the amplitude response is squared. The result is that the effective order doubles and there is an attenuation of about 6 dB at the cut-off frequency. The program does not leave this to guesswork: it writes the effective order and the attenuation at the cut-off into the processing history.

The cut-off frequencies are clipped so that they stay below the Nyquist frequency. Since a cut-off frequency above Nyquist would mean filtering a band that does not exist, the values are pulled back to this limit.

Taper and order of operations

The cosine taper is meaningful only together with the filter and is on by default; the default ratio is five per cent at each end of the record. Before the taper is applied, the DC component of the record is removed unconditionally and the value removed is written to the processing history, because applying a taper to a non-zero mean creates an artificial step at the ends.

When baseline correction and filtering are selected together, the order in which they are applied is left to the user; the default order is filter, then baseline. The two orders give different results, and the order used by the program is written in the processing history and in the report.

What the “Undo” button does

This button does not unwind a stack of operations step by step. It returns to the raw record; in other words, it gives the same result as “Revert to Original”. A half-undone record is a record with an uncertain history.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

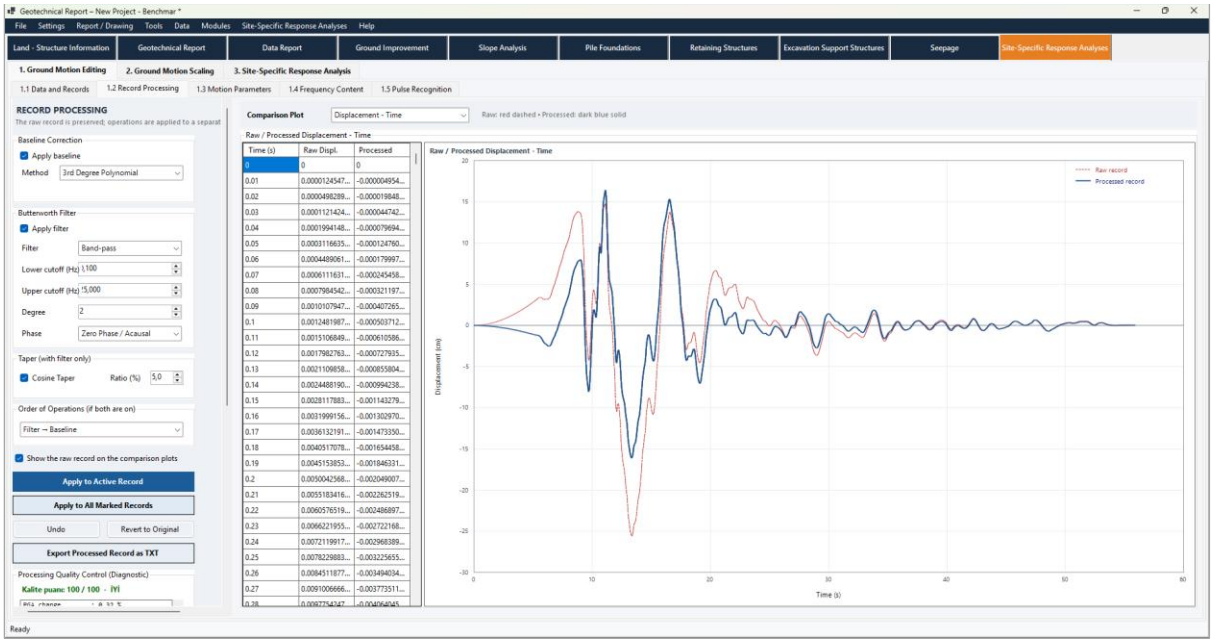


Figure 2. 1.2 Record Processing tab: baseline, Butterworth filter and taper; raw and processed velocity–time

3.3 Processing quality and automatic suggestion

The program measures with five diagnostics whether the processing has corrupted the record and gives a score out of one hundred: the change in peak acceleration, the change in Arias intensity, the residual velocity at the end of the record, the residual displacement at the end of the record, and the ratio of the mean acceleration to PGA. Eighty and above is good, above sixty requires checking, and below sixty must be investigated.

This score is not a code compliance check

The score only measures how much the processing has altered the record. A high score does not mean that the record is suitable for the project, and a low score does not by itself invalidate the record. The decision rests with the engineer of record.

The automatic processing recommendation is a separate button and has two steps: first it creates the recommendation, then, if desired, it fills in the settings. The processing is applied with the user's approval: processing a record is an engineering decision, not a program default.

3.4 Velocity and displacement

Velocity and displacement are obtained by integrating the acceleration once and twice with the successive trapezoidal rule; the initial velocity and displacement are taken as zero. The operation is carried out separately for the raw series and the processed series, so that the effect of processing on the residual velocity and residual displacement can be seen directly. The internal units are metres and metres per second; the screen shows centimetres and centimetres per second.

3.5 Response spectrum

The response spectrum of the record is calculated with one of three numerical solvers. All three calculate the same quantity, the maximum relative displacement of a single-degree-of-freedom system; pseudo-velocity and pseudo-acceleration are derived from this displacement through the angular frequency.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Table 6. Response spectrum solvers

Solver	Character
Duhamel Integration	Numerical integration of the exact solution. The slowest, and conceptually the most direct, route.
Newmark Beta (default)	Average acceleration assumption. It is unconditionally stable and is the solver engineering practice is used to.
Frequency-Domain	The solution is set up in the frequency domain. Fast for long records.

The damping ratio is entered by the user; the default is five per cent. The period grid consists of three zones with 1262 points in total: zero period is kept as a separate point, where the spectral acceleration is set equal to the peak ground acceleration; between 0.010 and 0.100 s the step is 0.0005 s, between 0.105 and 1.000 s it is 0.005 s, and between 1.010 and 10.000 s it is 0.010 s. The single-degree-of-freedom system is solved anew at every period; the plot is not an interpolation of a sparse grid.

There is a separate button that compares the three solvers. It runs all three for the same record and writes the maximum and root-mean-square differences, as percentages, for spectral acceleration, velocity and displacement to the console. The same quantity coming out the same along all three routes is proof that it is the record speaking, not the solver.

3.6 Strong ground motion parameters

The third sub-tab describes the record not by a single number but by about fifty quantities collected under three headings. When the comparison option is on, each quantity is shown in three columns at once: raw record, processed record and the percentage difference between them; this makes it possible to read at a glance which property of the record the processing has changed and by how much.

Table 7. Groups of motion parameters

Group	Main quantities included
Amplitude parameters	PGA, PGV, PGD; positive and negative peak accelerations; ratio of peak velocity to peak acceleration; root-mean-square values of acceleration, velocity and displacement; third and fifth sustained maximum values.
Time and duration parameters	Total duration; times at which 5, 50, 75 and 95 per cent of the Arias energy are reached; significant durations $D_{5\text{-}75}$ and $D_{5\text{-}95}$; bracketed and uniform durations based on threshold exceedance; Bommer and Martínez-Pereira effective duration.
Energy, cycles and frequency summary	Arias intensity; cumulative absolute velocity and its standardised form; specific energy density; characteristic intensity; maximum incremental velocity; damage index; impulsivity index; A95 parameter; effective design acceleration; velocity spectrum intensity; Housner intensity (both with its original twenty per cent damping definition and with five per cent); average spectral acceleration; effective number of cycles; predominant frequency, predominant period and mean period.

The threshold definitions are left to the user: the bracketed duration threshold can be entered either as a percentage of the peak acceleration or as an absolute value in g, the default being five per cent; the exponent in the effective number of cycles can also be entered, its default being three. When the definition of a quantity changes, its value changes too; this is why the thresholds are written in the report.

The effective number of cycles is derived from the cycle distribution obtained by rainflow counting, and this distribution is shown in a separate table with amplitude, range, count, weight and contribution columns. The build-up of Arias intensity over time is also plotted as a separate curve; this curve shows where the significant duration comes from.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

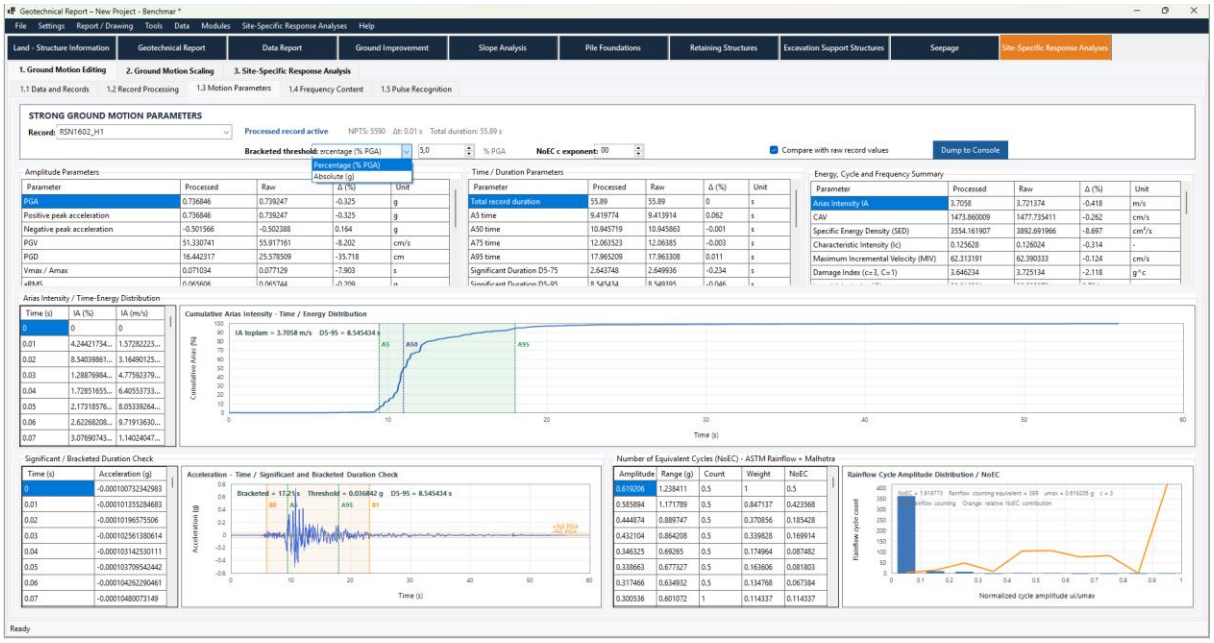


Figure 3. 1.3 Motion Parameters tab: amplitude, duration and energy parameters, Arias intensity

3.7 Frequency content

The fourth sub-tab gives the frequency content of the record in one of four representations: Fourier amplitude spectrum, power spectral amplitude, engineering power spectral density and phase spectrum. The transform is performed on the original length of the record; there is no zero padding, because zero padding invisibly changes the scale of the amplitude spectrum. No data are produced above the Nyquist frequency.

Konno-Ohmachi smoothing is optional and off by default; the default bandwidth coefficient is forty. The smoothing is applied only to the display and the console; the record itself and the quantities derived from it remain unchanged.

3.8 Velocity pulse recognition

The fifth sub-tab looks for the velocity pulse that governs near-fault records. Two methods are offered: the cross-correlation-based approach of Kardoutsou et al. (2017) and the wavelet-transform-based approach of Baker (2007). The result is a pulse indicator value and a classification based on it: above 0.65 pulse-like, below 0.55 not pulse-like, in between ambiguous.

This analysis does not run automatically; the user starts it. The following sentence is also written on the screen: not every record has to be pulse-like; the absence of a pulse is a valid result.

On the Pulse Recognition tab the pulse plots are at the top and the parameter table is a short strip at the bottom. If the record does not meet the pulse-like criterion, the extraction is still drawn; in that case the pulse curve appears faint and dashed, its marker reads “Candidate pulse (criterion not met)”, and the marker on the Sd × Sv plot reads “Candidate Tp”.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.



Figure 4. 1.5 Pulse Recognition tab: pulse extraction and the $S_d \times S_v$ spectrum

3.9 Output of this section

A single file comes out of the Ground Motion Editing section: a text export of the processed record. The file has two columns, the first being time in seconds and the second the processed acceleration in g. The Word and Excel outputs are taken from the scaling and site analysis sections.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

4. Ground Motion Scaling

The second numbered tab makes the records at hand compatible with a target spectrum. There are two separate ways of doing this, and they are not the same thing: multiplying the whole record by a single factor (amplitude scaling), and changing the frequency content of the record so that it fits the target (spectral matching, wavelet scaling). The first preserves the character of the record and approaches the target only on average; the second fits the target very closely and, in return, changes the original frequency content of the record.

This section is independent of the first tab

The records in the Ground Motion Editing section are not transferred to this section automatically. The records to be scaled are read again here. At first sight this looks like extra work; the reason is that the engineer of record should knowingly decide which processing steps the record to be scaled has gone through.

4.1 Reading the source records

Records can be added one at a time or in bulk. In bulk loading the data structure defined is applied jointly to all selected files; bulk loading is therefore meant for suites of records coming from the same source in the same format. The fields and their defaults are the same as on the first tab. The extensions that can be read here are limited to txt, at2 and dat.

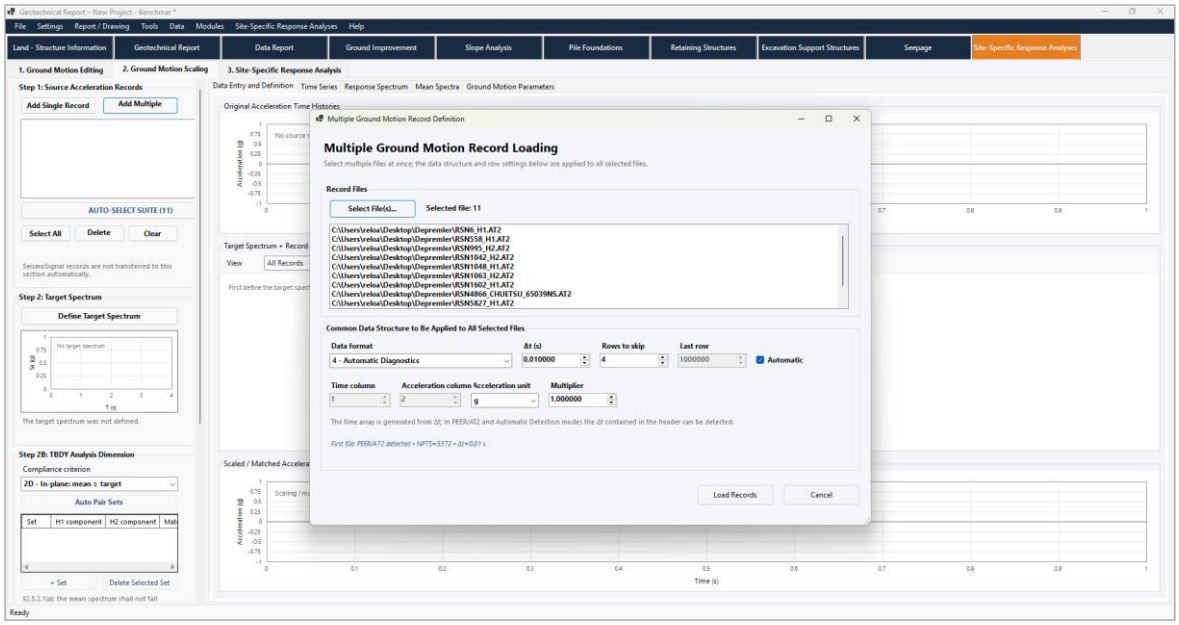


Figure 5. Multiple Ground Motion Record Loading window

4.2 Defining the target spectrum

The target spectrum can come from two sources: the code spectrum, or a spectrum loaded from a text file.

Code spectrum

The code offered is the Turkish Building Earthquake Code 2018 (TBDY 2018). The quantities entered are the short-period map spectral acceleration coefficient S_S, S_1 for a period of one second, and the site class; the defaults are 1.000, 0.300 and ZD respectively. From these the program reads the local site coefficients F_s and F_1 from the code tables by linear interpolation, calculates the design spectral acceleration coefficients S_{DS} and S_{D1},

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

and derives the corner periods TA and TB; the long-period corner TL is six seconds. These fields are read-only: keeping two separate input fields for the same quantity means, sooner or later, two numbers that do not agree.

S_S and S_1 are entered by hand

No coordinates are entered; the coefficients are not taken from the earthquake hazard map. S_S and S_1 are entered by the engineer of record and are written in the report as entered values.

The spectrum relation has the four-branch form given in the code: a branch rising linearly up to TA, a plateau between TA and TB, a branch inversely proportional to the period between TB and TL, and a branch inversely proportional to the square of the period after TL. The spectrum is generated from zero to ten seconds in steps of one hundredth of a second; TA and TB are also added to the grid at their exact values, because a corner point that does not coincide with the grid means missing the top of the plateau.

Damping other than five per cent

The damping ratio can be chosen for the target spectrum; the default is five per cent. When a damping other than five per cent is chosen, the spectrum ordinates are multiplied by the damping correction factor given in Eurocode 8 Part 1. At this point the program writes an explicit warning: this factor is not a TBDY provision; since the code's compliance criterion is defined for five per cent damping, an analysis made with a different damping cannot be presented as a statement of code compliance. The correction is applied only to the spectrum ordinates; S_{DS}, S_{D1}, F_s and F_1 keep their raw values, and the effective plateau value is written separately.

Site class ZF

When ZF is selected, no code spectrum is generated; the coefficient fields are left empty and the following warning is given: for site class ZF, TBDY 2018 requires a site-specific site response analysis. This is the program referring to its own work: for ZF the target spectrum is the output of the third tab of this module, not its input.

Target spectrum from a file

The target can also be loaded from a text file. Two layouts are accepted: the classical two-column layout with a period and spectral acceleration pair on each line, and a two-line layout with all periods on the first line and the corresponding accelerations on the second. Negative and non-finite values are discarded, the points are sorted by period and at least two valid points are required. The source of the target is written in the report together with the file name.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

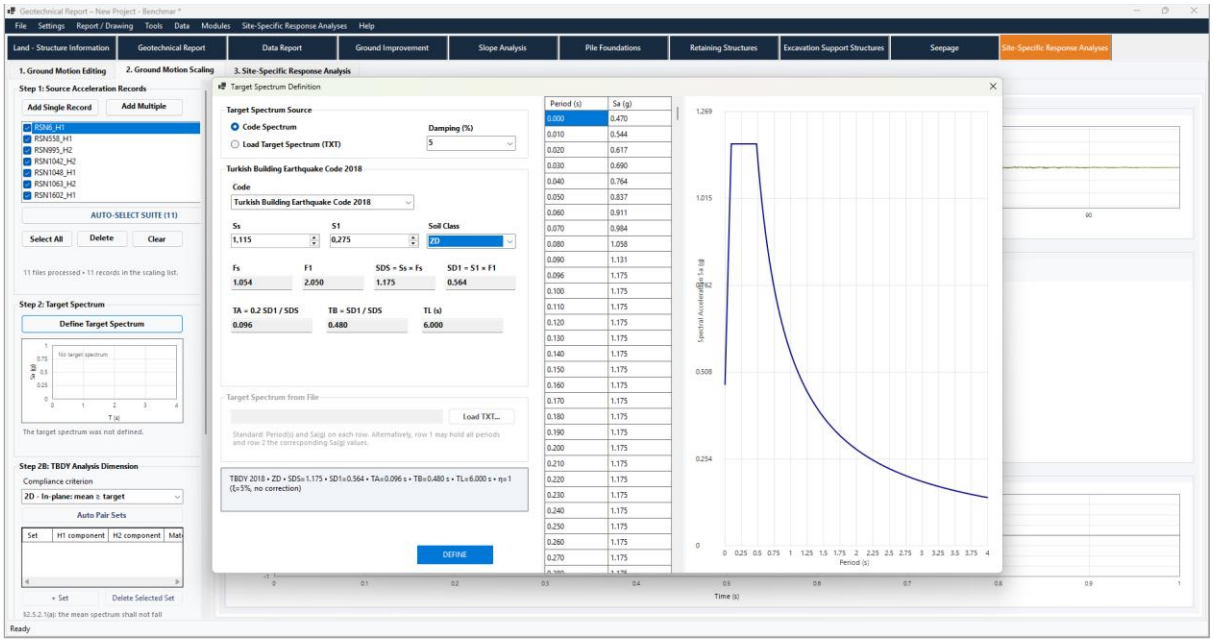


Figure 6. Target Spectrum Definition window: TBDY 2018 parameters and target spectrum

4.3 Analysis dimension: planar and spatial

The compliance criterion is one of two options. If the analysis is planar (2D), the mean spectrum of the scaled records shall not fall below the target within the check band. If it is spatial (3D), the records are divided into sets of horizontal components, the square root of the sum of the squares of the spectra of the two components of each set is taken, and the mean of these combined spectra shall not fall below 1.3 times the target.

The sets can be paired automatically. The program looks at the direction identifier in the file name — angles in degrees, north-east letters, H1 and H2, X and Y, L and T, and so on — and pairs them if it finds exactly two candidates with different identifiers sharing the same stem. If it cannot, it lists the unpaired ones; the components can also be selected by hand.

Spectral matching cannot be selected when working in three-dimensional space

The 3D compliance criterion and wavelet scaling cannot be selected together; the program prevents this and states the reason. The reason has two parts. First: the square root of the sum of the squares is never the spectrum of a time series, so it is not a target that can be fitted by matching. Second: the 1.3 factor is the allowance for scatter in simple scaling; applying this allowance once more to a matched record that already fits the target very closely would be double counting.

The combined spectrum of a paired set is shown for diagnostic purposes; no statement of compliance based on the 1.3 criterion is given for these pairs.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

4.4 Matching and the check band

The fundamental period of the structure T_n is entered by hand. The program has two separate period bands, which are independent of each other.

Table 8. The two period bands

Band	Default	Function
Matching / scaling band	0.2 T_n – 1.5 T_n	The band in which the scale factor or the wavelet additions are calculated. In amplitude scaling it is derived automatically from T_n; in spectral matching it can be changed by hand, and once changed it is not overwritten.
Check band	0.2 T_n – 1.5 T_n	The band in which mean spectrum compliance is tested. It is independent of the matching band and is entered separately.

The reason for this distinction is that fitting a record to the target over a wide band and checking compliance over a narrow band are different decisions, and both must be written in the report. The matching grid has a step of one hundredth of a second; the ends of the band at their exact values and the corner points of the target spectrum are added to the grid as well. The band must lie within the period limits of the target spectrum; if it does not, a warning is given. When the fundamental period of the structure T_n is changed, the existing scaling results are not deleted at every keystroke; when you leave the field, the program asks if the value has changed.

4.5 Automatic suite selection

The user can load any number of records (for two-dimensional work) or pairs of horizontal components (for spatial work) into the scaling tab. The ‘AUTO-SELECT SUITE (11)’ button below the record list in the first step does not run until a target spectrum has been defined and T_n has been entered; it reports the missing input with a warning. The window scales every candidate in the same band and with the same least-squares factor as in amplitude scaling; for a record with a value entered in the manual α list, that value is used.

The suite is selected so as to minimise the common β. β is found as the inverse of the smallest value within the band of the ratio of the scaled suite mean to the target (with a factor of 1.0 for two-dimensional work and 1.3 for spatial work); in other words, the weakest point of the mean spectrum relative to the target is raised as far as possible. Not all possible suites are tried; an exact solution is sought by the branch-and-bound method. For up to thirty records the exact solution is found in about one second. When the number of records reaches fifty or more and the solution cannot be proven optimal within the time limit, the best suite found so far is given and this is reported explicitly.

Table 9. Automatic suite selection settings and their defaults

Setting	Default	Meaning
Number of records in the suite K	11	Initial value set according to the TBDY 2018 requirement of at least eleven records; it can be changed.
Maximum from the same earthquake	3	The maximum number of records by which one earthquake may be represented in the suite. It can be switched off; the earthquake identity can be corrected in the window.
α range	0.5 – 2.0	A record whose scale factor lies outside this range does not become a candidate. It can be switched off.
Exceedance cap	Off (1.6 if switched on)	The upper limit, within the band, of the ratio of the suite mean after applying β to $c \cdot S_{ae}$; prevents the selection of records that greatly exceed the target.
Secondary criterion: β difference	1%	Among the suites whose β lies within this ratio of the best β, the one with the smallest mean spectral misfit (MSE) is selected.
Time limit	10 s	If the time runs out, the best suite found so far is given and it is reported that it could not be proven optimal.
Alternative suites shown	5	In addition to the selected suite, the best alternatives ranked by β.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

The earthquake identity is taken from the second line of the PEER .AT2 header or, if not found there, guessed from the file name; the ‘Earthquake’ column in the window can be edited. Since record metadata (magnitude, distance, V_{s30}) are not kept, the records cannot be filtered by these quantities.

The window shows the selected suite and the five best alternatives (β, mean MSE, distribution over earthquakes) in a table and a plot; the plot shows the scaled spectra of the suite, the mean and $c \cdot S_{ae}$ together. ‘Apply selection’ only changes the ticks in the scaling list; records not selected are not deleted. Scaling and the TBDY mean check are then run as usual. The selection criterion is written as a paragraph to the console, the documentation and the Word report; if the ticks have been changed by hand after the selection, the report states this explicitly. When the method is spectral matching, the selected suite can be used as a pre-selection; the selection criterion is still based on amplitude scaling.

4.6 Amplitude scaling

In amplitude scaling the whole record is multiplied by a single factor. The factor is calculated in closed form as the value that minimises the sum of the squares of the differences between the record spectrum and the target spectrum within the matching band. For this calculation the record spectrum is recalculated with the damping of the target spectrum, using the Newmark-β solver; a spectrum drawn on screen with another damping is not used.

For each record the relative errors in the band are given as three readings: root-mean-square error, mean absolute error and maximum absolute error, all as percentages. Giving all three instead of a single fit number is deliberate, because a fit that looks good on average may be very poor at a single period.

The reasonable range of the scale factor

If the calculated factor falls below 0.25 or rises above 4, the program writes an explicit warning to the console and marks that record as out of range. The record is not rejected; the analysis continues. The reason is that a record scaled by a very large factor no longer represents the earthquake in which it was measured but that factor; whether this is acceptable is the decision of the engineer of record, not of the program.

Manual scale factor

The list opened with the “Manual α List (Amplitude Scaling)...” command under Settings allows a factor and a justification to be entered per record. The rules are as follows: a zero or negative factor is rejected; a factor outside the range 0.25 to 4 is accepted but annotated, and even when a factor is entered by hand the program still carries out its own calculation. Both numbers and the percentage difference between them are written to the report, and the name of the method changes to indicate manual entry. The justification field is transferred to the report verbatim.

4.7 Spectral matching: wavelet scaling

In spectral matching, wavelets that bring the response at the selected periods closer to the target are added to the record in the time domain, and the process is repeated until it converges. Two algorithms are offered: Al Atik and Abrahamson (2010) and Hancock et al. (2006). Both work in the time domain; the difference between them is the shape and the support scale of the wavelet added.

The expert settings are kept not on the main screen but in the “Wavelet Scaling Settings...” window under Settings; on the main screen only the limits of the matching band are changed. Numbers that should not be changed in everyday use being on the everyday screen means that, sooner or later, they will be changed by mistake. The module settings are in the Settings submenu of the Site-Specific Response Analyses menu in the top ribbon. The Seismic tab in the single Settings window of the main program does not open a separate settings

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

page: it states that this module has no single-page settings and offers the commands of the same submenu (“Wavelet Scaling Settings...”, “Manual α List (Amplitude Scaling)...”, “Design code...”) as buttons.

Table 10. Spectral matching settings and their defaults

Setting	Default	Meaning
Algorithm	Al Atik & Abrahamson (2010)	Wavelet shape and support scale. The other option is Hancock et al. (2006).
Misfit tolerance	10.00% (maximum) / 5.00% (mean)	The maximum and mean relative difference allowed in the band; these two are the convergence criterion. The mean criterion is entered in the ‘Mean deviation tolerance’ field.
Target multiplier	1.000	Shifts the target by a factor. A value other than one changes the target itself and is written in the report.
Maximum iterations	30	If convergence is not achieved the process stops at this number and is reported as ‘Out of tolerance’.
Maximum wavelets / additional wavelets	40 / 20	The number of control periods to be corrected in one iteration, and the pool of additional wavelets.
Dynamic initial padding	On	Adding a zero-acceleration segment to the start of the record when necessary; the total padding is at most thirty seconds.
Seeding in successive passes	On	The next narrow-band pass starts from the result of the previous pass.
Minimum normalised eigenvalue	0.01	Lower bound that limits the conditioning of the wavelet matching equation.
Off-diagonal reduction	1.0	Reduction factor applied to the interaction terms between wavelets; 1.0 means no reduction.

All the settings of every pass are stored in the pass history and written to the exported summary file. If it is not known with which settings a spectral matching result was produced, that result cannot be reproduced. On the comparison plots of the scaling tab the scaled record is drawn shifted into the t < 0 region by the dynamic initial padding, so that it is aligned with the raw record; the data do not change and a padding note appears on the plot. The “Trim padding (hide t<0 region)” option in the right-click menu of the time comparison panels hides this region in the display only; the record does not change.

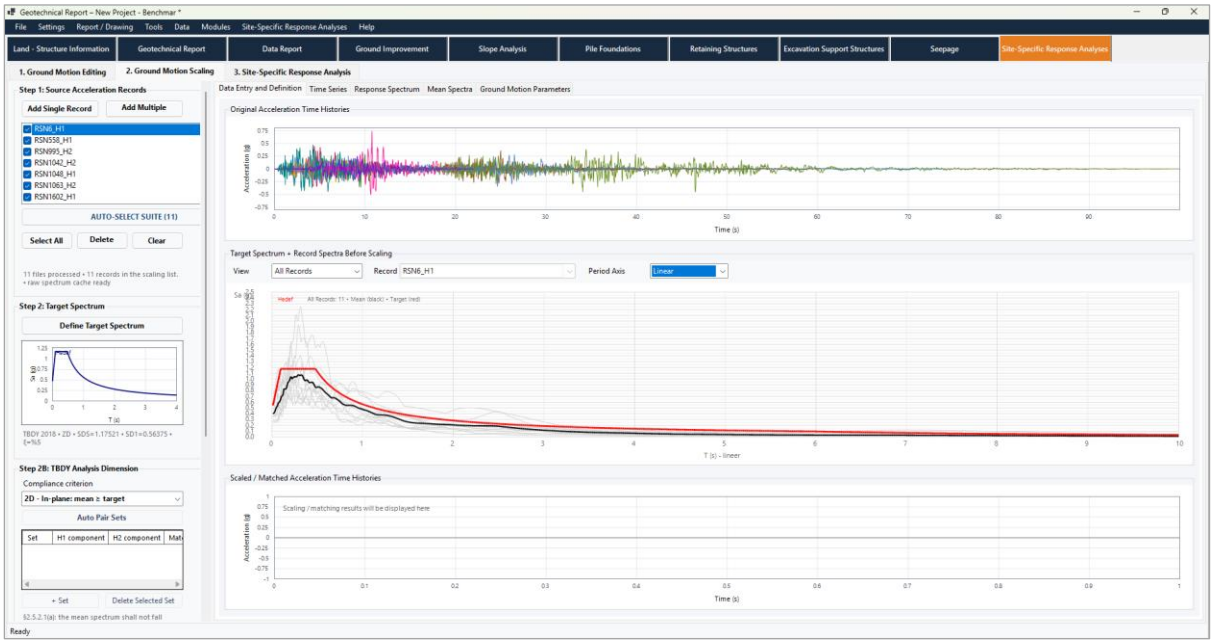


Figure 7. 2 · Ground Motion Scaling: spectra and acceleration time histories after wavelet scaling

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

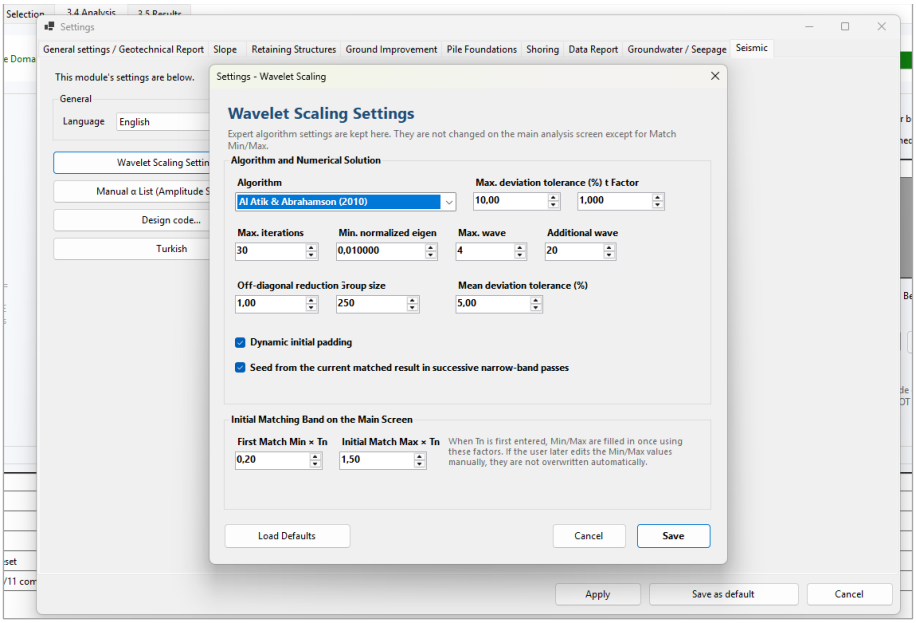


Figure 8. Wavelet Scaling Settings window

4.8 Mean spectrum compliance and the common β

The compliance check is run explicitly with a separate button. Within the check band, the ratio of the mean spectrum of the scaled records to the target is calculated at every period. If the smallest of these ratios is below one, a common second factor β is applied to all records, β being the inverse of the smallest ratio. If the ratio is already above one everywhere in the band, β is taken as one; in other words, β is applied only upwards.

In spatial work the same logic operates on the combined spectra with the factor 1.3: the scale factor per set is found relative to the plain target, the same factor is applied to both components of the set, and then, if the ratio of the mean to the target falls below 1.3 at any point in the band, it is raised with a common β. The factor 1.3 appears only in the compliance criterion.

In spectral matching β is calculated but not applied automatically

In wavelet scaling the mean spectrum criterion is calculated and reported with two readings — within the check band and over all periods; however, the program does not apply β automatically. The reason: for a suite that already fits the target, β largely measures the matching tolerance rather than the seismic demand. Whether it is applied is decided by the engineer of record.

The eleven-record rule

TBDY 2018 requires at least eleven ground motion records or record sets for time-domain analyses. The program counts the records; if there are fewer than eleven, it adds a note on both the scaling and the site analysis side and highlights the number in colour. The analysis continues: this is a rule of scope, not of calculation, and a study made with fewer records is still valid engineering work — provided it is not presented as a statement of code compliance.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

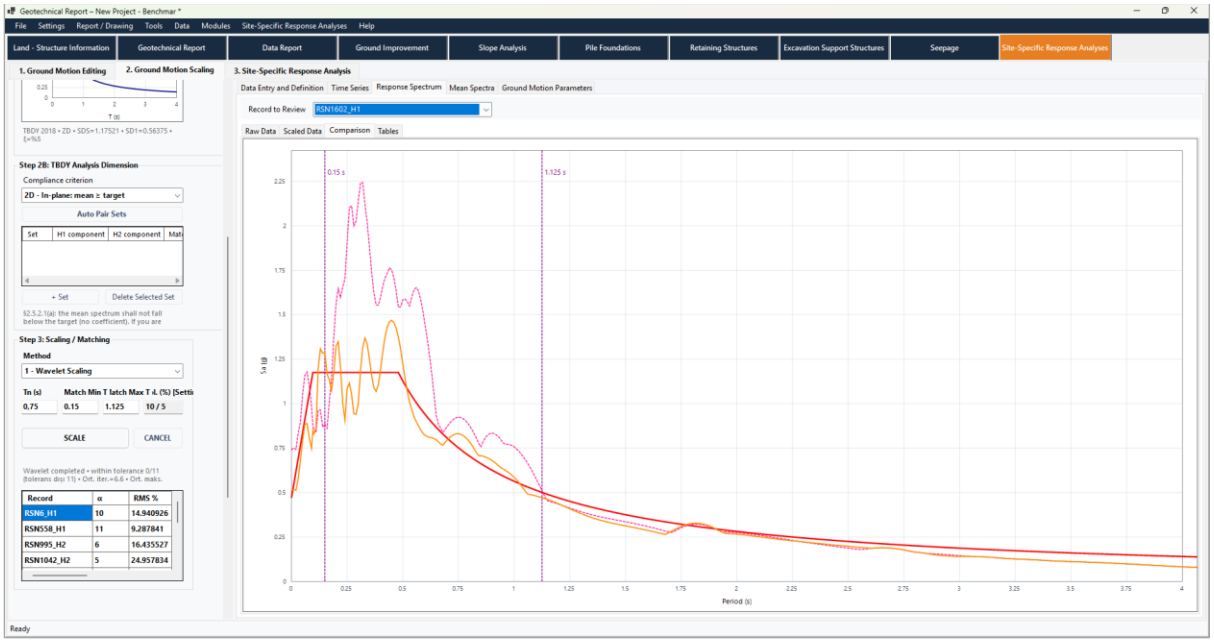


Figure 9. Mean Spectra tab: TBDY mean check and final β

4.9 Outputs of this section

There are three outputs, and all three use the final records; in other words, if a β has been applied after spectral matching, that β is included in the exported time series.

Table 11. Outputs of the scaling section

Output	Content
Text file of the selected final record	A single record, two columns. The file name carries the method and the factor, so it can be read from the file name which processing the record has gone through.
All final records	One text file per record and a summary file in the selected folder. The summary carries the number of records, T_n, the reference periods, the common β and, if spectral matching was used, all the algorithm settings and the pass history.
Word analysis report	Records, target spectrum, method and settings, fit measures per record, and the compliance check. Generation is followed in a progress window and can be stopped; if it is stopped, the partial file is deleted. If automatic suite selection was used, the selection criterion paragraph is also included in the report. Numbers and symbol subscripts are written in the format given in 10.1.

The Excel output is taken from the site analysis section. The time-scaling method is not available in this version; if it is selected, the program says so and performs no operation.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

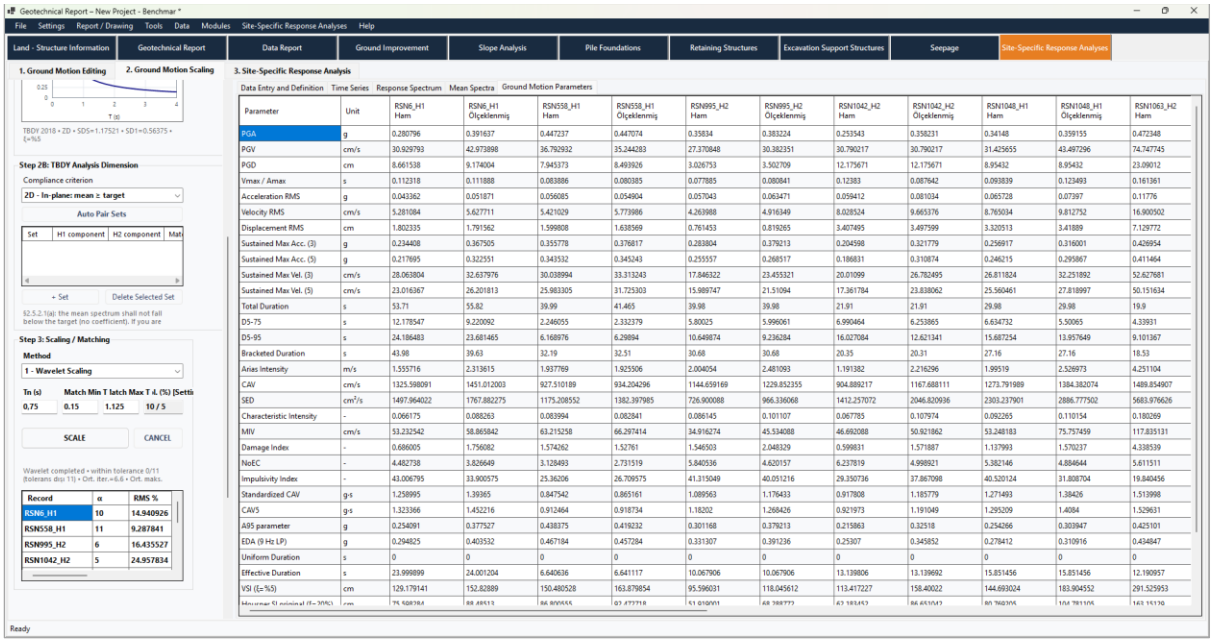


Figure 10. Ground Motion Parameters tab and export buttons

5. Soil Profile and Calculation Model

The third numbered tab runs the one-dimensional site response analysis. The tab has five steps of its own, and their order is fixed by their numbers on the screen: soil profile and settings, profile creation, record selection, analysis and results. This section describes the first two steps.

5.1 Main soil layers

The profile is entered in quantities familiar to the engineer: layer name, thickness, soil type, natural and saturated unit weight, angle of internal friction and cohesion separately for the top and bottom of the layer, liquid limit, plastic limit and fines content. Being able to enter separate strength parameters for the top and bottom of a layer allows the strength to vary with depth within a layer; values at intermediate depths are derived linearly.

The top and bottom levels of the layers and the plasticity index are not entered; they are derived and shown read-only. The reason is the rule that also appears elsewhere in the guide: keeping two separate input fields for the same quantity means, sooner or later, two numbers that do not agree.

A reference dynamic curve model is also selected here for each main layer; this choice is the subject of Section 6. The soil type is chosen from sand, silt, clay and gravel and is used to determine in which layers pore water pressure generation is meaningful.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

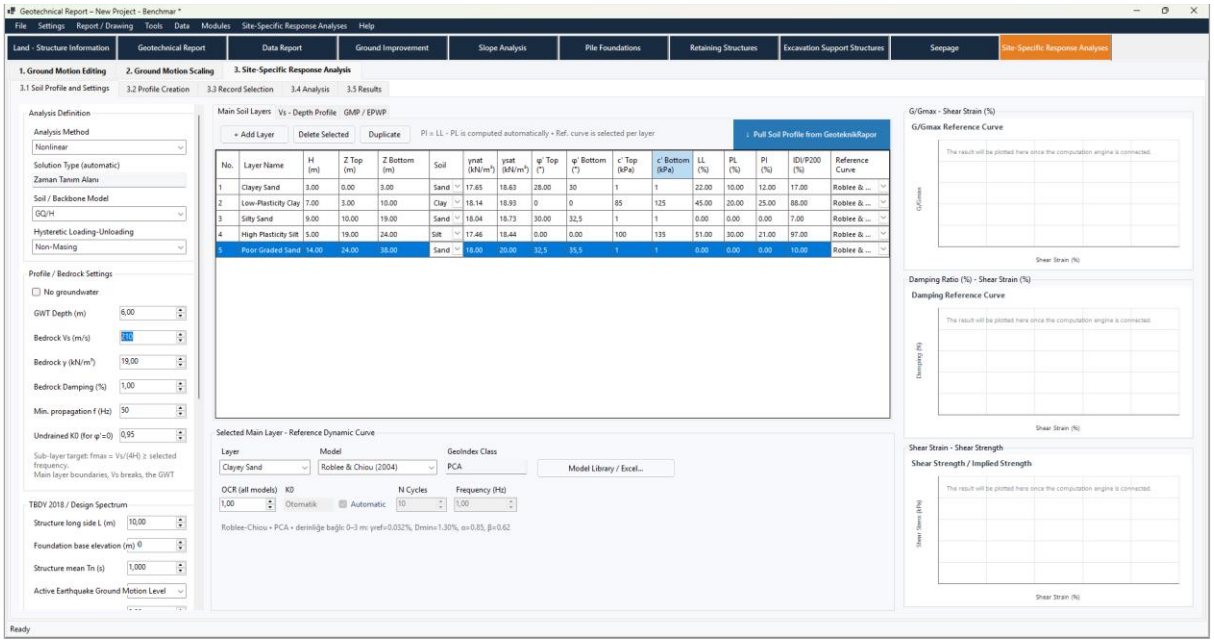


Figure 11. 3.1 Soil Profile and Settings tab: analysis definition and main soil layers

5.2 Groundwater and bedrock

The groundwater depth is entered, or it is marked that there is no water. Below the water level the pore water pressure is calculated as hydrostatic and the vertical effective stress is found accordingly. The water level is a mandatory break point when the profile is subdivided: since the gradient of the effective stress changes there, a calculation sub-layer is not allowed to straddle the water level.

For the bedrock, the shear wave velocity, unit weight and damping are entered; the defaults are 760 m/s, 22 kN/m^3 and two per cent respectively. Whether these three values enter the calculation depends on the input motion type described in Section 7 and becomes clear when the input motion type is selected: with the option in which the motion is applied to a rigid base these fields are disabled, because in that case the bedrock properties do not enter the calculation.

5.3 Shear wave velocity profile

The shear wave velocity is entered in a separate table as depth–velocity pairs. In this module V_s is not generated from correlations: it is either entered by hand, transferred from the main program or read from the main project file. Generating a measured quantity from a correlation means presenting an unmeasured profile as if it had been measured.

There are two input modes, and the difference between them directly affects the result.

Table 12. V_s input modes

Mode	Meaning
Stepped (default)	Each row means a constant V_s from that depth to the depth of the next row; the velocity in the last row is not used. It is a staircase representation, closest to the form given by a borehole measurement. In this mode the boundary of every V_s interval is a mandatory subdivision point.
Linear	Linear interpolation between the control points. The V_s control points do not create subdivision points.

The two modes give different natural periods of the profile from the same data; the program shows both values on the screen.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

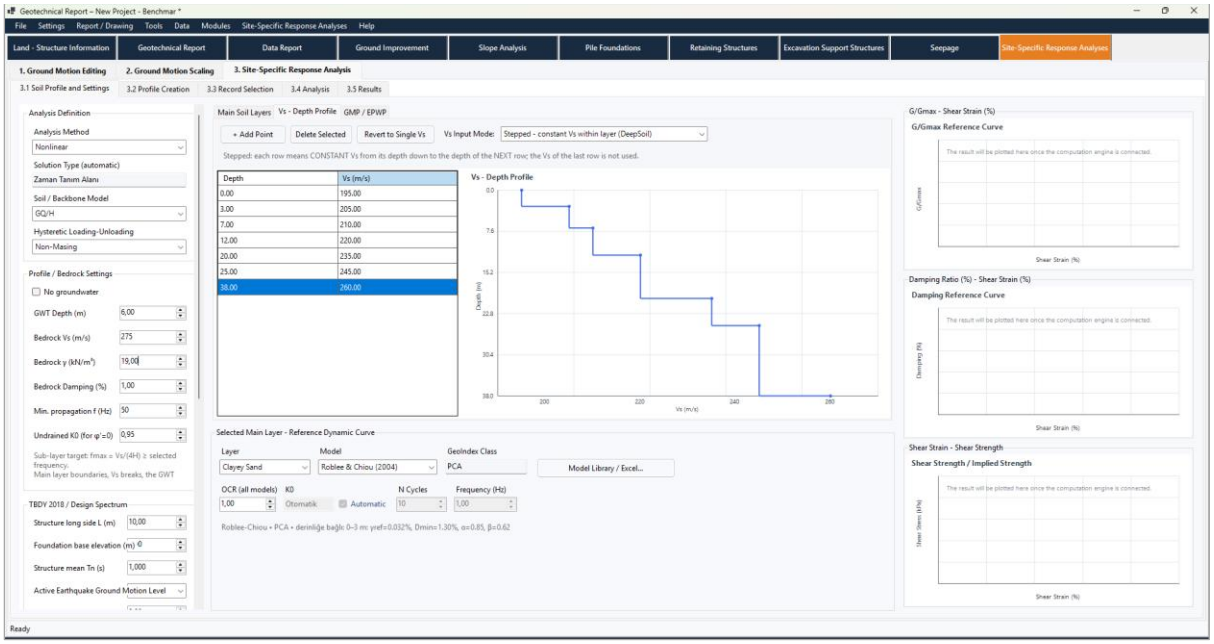


Figure 12. V_s – Depth Profile tab: control points and profile

5.4 Taking the profile from the main program

During the transfer the unit conversion is done on the main program side, and the incoming data are in this module's own units. Two V_s points arriving at the same depth are reported as an error; they are not merged without notifying the user. If no groundwater information arrives, the existing fields are left untouched. The transferred V_s is always switched to the stepped mode; the geophysical steps are not turned into a linear ramp. Since the V_s table of the main program starts at the D_f level, the V_s of the layer at the D_f level is written into the upper gap 0…D_f, and this is stated explicitly in the transfer summary; the value can be changed in the first row of the V_s table. If the geophysical measurement goes deeper than the borehole, a layer named "BELOW BOREHOLE - GEOPHYSICS ONLY - FILL IN PARAMETERS" is added and filled with the module defaults, and a warning is given that this row must be completed before the analysis. If the V_s profile is shorter than the soil profile, the last value is extended to the base.

5.5 Generating the calculation sub-layers

The main layers entered are not used directly in the analysis. The program subdivides them into calculation sub-layers. The criterion for subdivision is a physical constraint: the highest frequency a sub-layer can transmit is the ratio of the shear wave velocity in that layer to four times its thickness. The user enters in a single field up to which frequency waves are to be transmitted; the default is 50 Hz. In each interval the program takes the smallest V_s in that interval, calculates the largest thickness that satisfies this frequency, and divides the interval into a sufficient number of sub-layers of equal thickness.

Mandatory subdivision points

The top and bottom of the profile; the upper and lower boundary of every main layer; the groundwater level, the boundary of every V_s interval in the stepped mode, and, in layers that use a reference curve model based on depth bands, the band boundaries of that model.

These points are points at which some quantity is discontinuous. A sub-layer straddling such a point would mean that the sub-layer represents two different materials as a single material.

There is no separate maximum sub-layer thickness field; the thickness limit follows from the selected frequency. When generation is complete, the program writes on a single line how many main layers have been divided into

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

how many sub-layers, the smallest transmissible frequency obtained and whether it meets the target; the natural period and natural frequency of the profile are shown as well.

The sub-layer table gives, side by side for each sub-layer, the input and all quantities derived from it: depths, thickness, velocity, unit weight, vertical and mean effective stress, selected model, plasticity class, reference strain, small-strain shear modulus and damping, target shear strength together with the strength and friction angle implied by the calibrated curve, and the highest frequency the sub-layer can transmit. The profile plots draw the same quantities against depth.

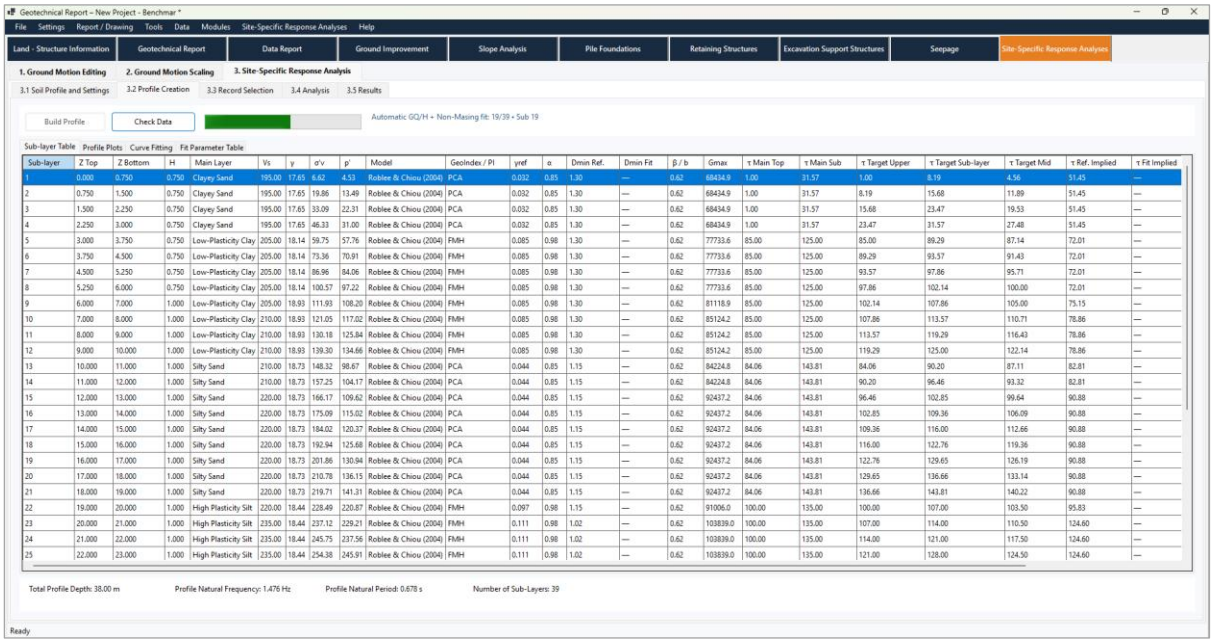


Figure 13. 3.2 Profile Creation tab: sub-layer table

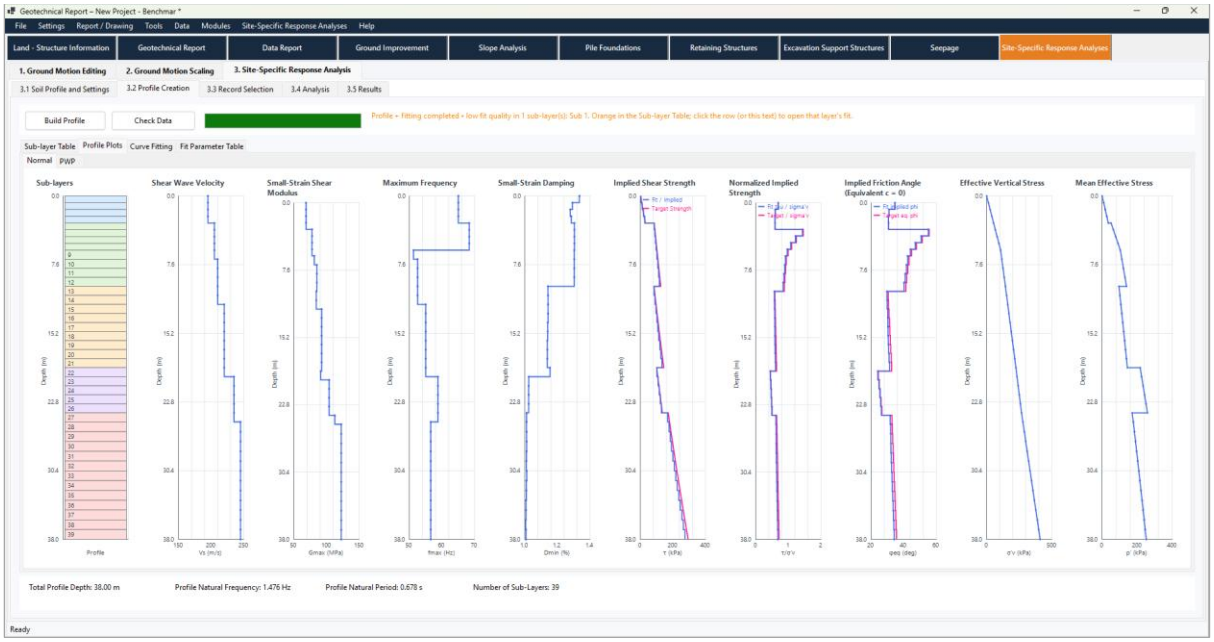


Figure 14. Profile Plots: V_s, G_{max}, f_{max}, damping and stresses along the sub-layers

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

6. Dynamic Curves and Curve Calibration

The dynamic behaviour of soil is described by two curves: the reduction of the shear modulus with strain and the increase of damping with strain. The program handles these curves in two stages. First a reference curve is selected; this is a model published in the literature or a data set coming from the laboratory. Then a backbone curve that the solver can use is calibrated to this reference curve (Fit on the screen). The two are kept separate and shown side by side in the report, because the difference between the calibrated curve and the reference curve is part of the result.

6.1 Reference curve library

Eight families are offered. Each uses its own inputs; if an input required by a model is missing from the profile, that model does not give a meaningful result for that layer, and the library window states for each model which soils it suits and which inputs it uses.

Table 13. Reference dynamic curve families

Model	Inputs used	Suitable soils
Roblee & Chiou (2004)	PI, fines content, depth	General purpose, depth-banded
Darendeli (2001)	PI, OCR, mean effective stress, K_0, number of cycles, frequency	Broad scope, the most widely used
Ishibashi & Zhang (1993)	PI, mean effective stress	Unified for clay and sand
Menq (2003)	Coefficient of uniformity, D_{50}, mean effective stress, number of cycles	Granular soils
Vucetic & Dobry (1991)	PI	Design curves by plasticity
Seed & Idriss (1970) — Sand	—	Sand, published average curve
Seed et al. (1986) — Gravel	—	Gravel, published average curve
User Defined (Excel)	Point-by-point curve from the laboratory	Any soil that has been tested

The model is selected per main layer; every calculation sub-layer within that layer inherits the same model but evaluates it at its own depth, its own mean effective stress and with its own index properties. In other words, a single model choice produces a family of curves that varies with depth.

For a user-defined curve an Excel template is exported, filled in and read back. The curve is checked during reading: there must be at least four points, the strain must be strictly increasing, the modulus reduction ratio must be decreasing within a given tolerance, the damping must be non-decreasing, and the last point must reach a sufficiently large strain. A curve that fails these checks is not accepted, because a backbone calibrated to a physically inconsistent curve does nothing but turn the inconsistency into numbers.

6.2 Calibration of the backbone curve

The backbone used by the solver is the generalised quadratic/hyperbolic (GQ/H) form of Groholski et al. The reason for choosing this form is a single property: it is strength-controlled. Classical hyperbolic models can go far above or below the real shear strength of the soil at large strains; the GQ/H backbone can be fitted to the shear strength targeted during calibration.

The target shear strength is calculated point-wise in that sub-layer with Mohr-Coulomb: cohesion plus vertical effective stress times the tangent of the angle of internal friction. The calibration acceptance criterion also comes from here: the calibrated backbone must reach at least ninety-five per cent of the target strength at ten per cent strain. If the criterion is not met, the program says so; for the calibration to be considered reliable it is also required that the error along the whole curve stays below a certain threshold and that no fallback solution has been used.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

The calibration window is entered by the user: it determines over which strain range the curve is calibrated with greater weight; the default is 0.050 per cent. When this value is changed, all existing calibrations are considered invalid and the analysis is locked until calibration has been carried out again. The program reports the error inside the window and the error outside the window separately, because a calibration that looks perfect in a narrow window can be very poor at large strains — and in a site response analysis the region of interest is very often exactly there.

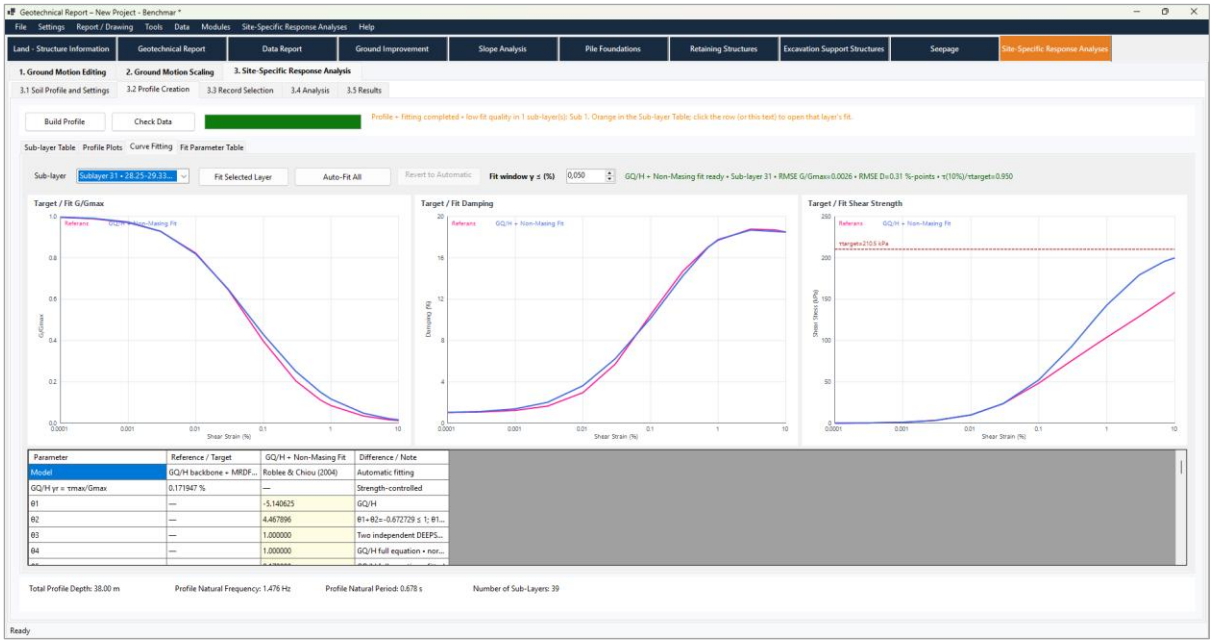


Figure 15. Curve Fitting tab: target and calibrated curves for G/G_{max}, damping and shear strength

6.3 Damping: non-Masing correction

Hysteretic damping derived from a backbone curve with the Masing rules rises markedly above the measured damping at large strains. This is a deviation known and quantified in the literature. The program uses the MRDF-UIUC approach, which corrects the Masing damping with a reduction function so that it fits the damping of the reference curve; the parameters of the reduction function are sought for each sub-layer by least squares. The small-strain damping is tied to the value of the reference curve at its smallest strain.

Small-strain damping is not entered directly

Soil damping is not entered by hand. The damping comes from the selected reference model and is redetermined during calibration; the value used in both the equivalent linear and the nonlinear solution is the calibrated value. The only damping entered by hand is the bedrock damping. Instead of Rayleigh damping, the nonlinear solution builds a frequency-independent damping matrix; therefore no target frequencies or modes need to be entered.

6.4 What the user sees, and the gate of calibration

Calibration is carried out automatically after the profile has been built; it can also be repeated by hand for a single layer or for all of them. The result is shown in three plots: reference and calibrated modulus reduction curves, reference and calibrated damping curves, and target and implied shear strength. In addition, a table is given that carries, for each sub-layer, all calibration (Fit) parameters, the reference and calibrated small-strain damping, the target and achieved strength, and separate error measures for the two curves.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

The analysis does not start until calibration is complete

This is not a warning but a hard gate: until calibration has been completed for every calculation sub-layer, the analysis button does nothing, and the number of sub-layers completed is displayed. The reason is simple: an uncalibrated sub-layer is a sub-layer whose material is undefined.

7. Record Selection and Analysis

7.1 Record library and input motion type

The records to be analysed are selected by ticking them. Records can be added from a text file or taken from the scaling section with a single button; the transfer is in memory, no intermediate file is written, and if a record with the same name exists it is updated with the most recent final series. The library is persistent: it lives at program level, and opening or closing a project does not delete it.

For each record the peak acceleration, velocity and displacement, Arias intensity, significant duration and predominant frequency are shown in a table; the time series, Fourier amplitude spectrum and five-per-cent-damped response spectrum are plotted. This is so that what goes into the analysis can be seen before the analysis.

Table 14. Input motion type

Option	What it means
Rock Outcrop Motion (default)	The record is applied at the elastic half-space boundary at the base of the profile. The velocity, unit weight and damping of the bedrock enter the half-space impedance and the radiation damping; in other words, part of the energy can travel back downwards. The application depth is locked to the base of the profile.
Within / Downhole Motion	The record is imposed directly at the specified depth and the base is assumed rigid. With this option the bedrock velocity, unit weight and damping do not enter the calculation, and the program disables these fields.

All ticked records are run with a single button; the records are solved one after another. If a run is cancelled while a record is in progress, only that record is discarded; records already completed are kept. In the top strip of the Analysis tab, right-aligned, the “BUILD MODEL” button, the progress bar, and the “CANCEL” and “RUN ANALYSIS” buttons are arranged from left to right; while the solution is running, the last button is renamed “■ STOP ANALYSIS”. The buttons do not overlap even when the window size or the screen scaling changes.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.



Figure 16. 3.3 Record Selection tab: record library and input motion definition

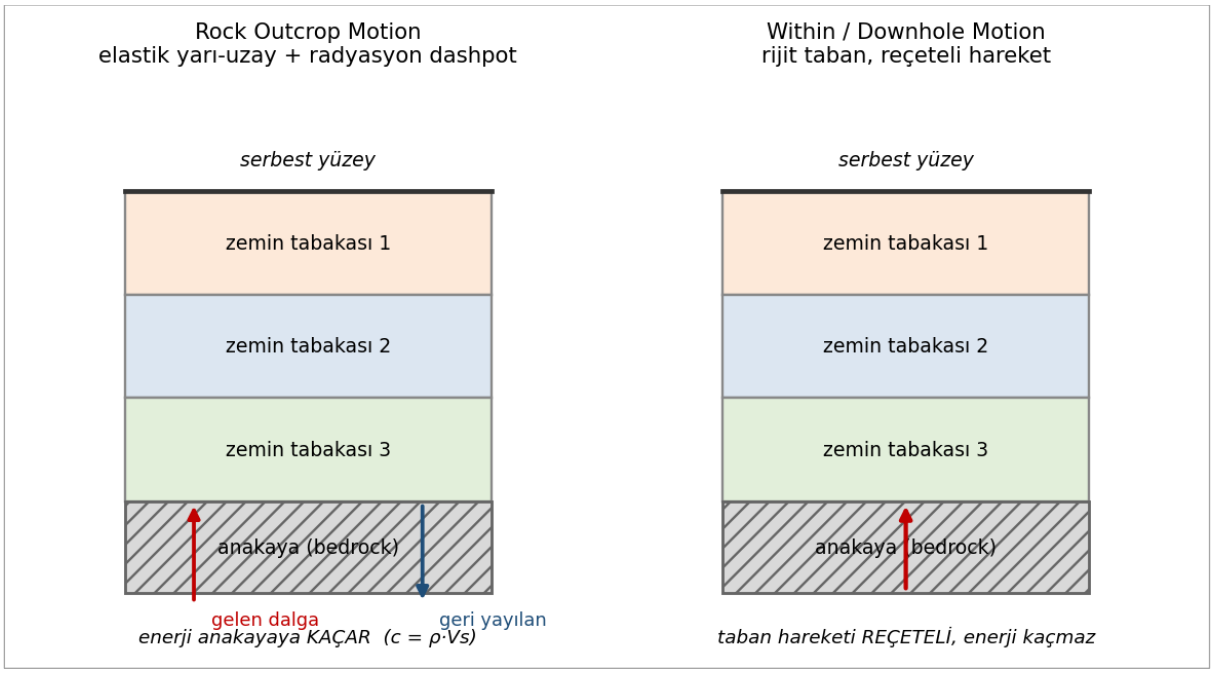


Figure 17. The physical difference between the two base boundary conditions: Rock Outcrop (elastic half-space) and Within (rigid base) (Turkish interface shown)

7.2 Equivalent linear solution

The equivalent linear solution is the default method and works in the frequency domain. The nonlinear behaviour of the soil is represented in each sub-layer by one shear modulus and one damping value, which are updated iteratively according to the strain obtained from the solution. The effective strain is taken as a ratio of the maximum strain; the default ratio is 0.65. The iteration stops when the change in modulus and damping in all layers falls below the given tolerance; the default tolerance is one per cent and the maximum number of iterations is fifteen. When the iteration is finished, a final stress and strain solution is always carried out.

Wave propagation is a transfer-matrix solution set up with the complex shear modulus. The program states explicitly on screen which definition of the complex modulus it uses, and notes that another widely used program

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

uses a different definition under the same name, and that this difference is negligible at low damping but marked at high damping. Assuming that two options with the same name are the same thing is the most frequent mistake when comparing the results of two programs.

The iteration history is kept in a separate table: record, iteration number, sub-layer, maximum and effective strain, modulus ratio, damping and two change percentages. The convergence check plot shows how the effective strain settles with depth over the iterations.

7.3 Nonlinear solution

The nonlinear solution works in the time domain. The soil column is discretised as a shear beam; at every time step the material is evaluated with the calibrated GQ/H backbone and non-Masing loading–unloading rules. The time integration is the implicit Newmark scheme with the average acceleration assumption; at every step equilibrium is achieved with Newton iterations until the residual force is small enough.

Control of the time step is left to the user. The recommended and default choice is the flexible step: the program does not allow the strain to increase within one step by more than a given limit and, if necessary, proceeds by halving the step; the default limit is 0.0050 per cent. With the fixed-step option the step size is either determined automatically or entered by hand. How intermediate points are generated can also be selected.

Small-strain damping is represented by a frequency-independent damping matrix built from the calibrated damping values. The matrix is built once from the initial stiffness and is not updated during the solution; the only exception is when pore water pressure feedback is on — there, the matrix is rebuilt when the stiffness degrades beyond a certain ratio, and the number of rebuilds is reported in the diagnostics table.

The numerical behaviour of the solution is not hidden. A separate diagnostics table gives the number of Newton attempts, the number of linear solves, the average number of iterations, cap exits, discarded subdivision attempts, and the percentage of time spent on each task. How hard a result was to obtain carries as much information as the result itself.

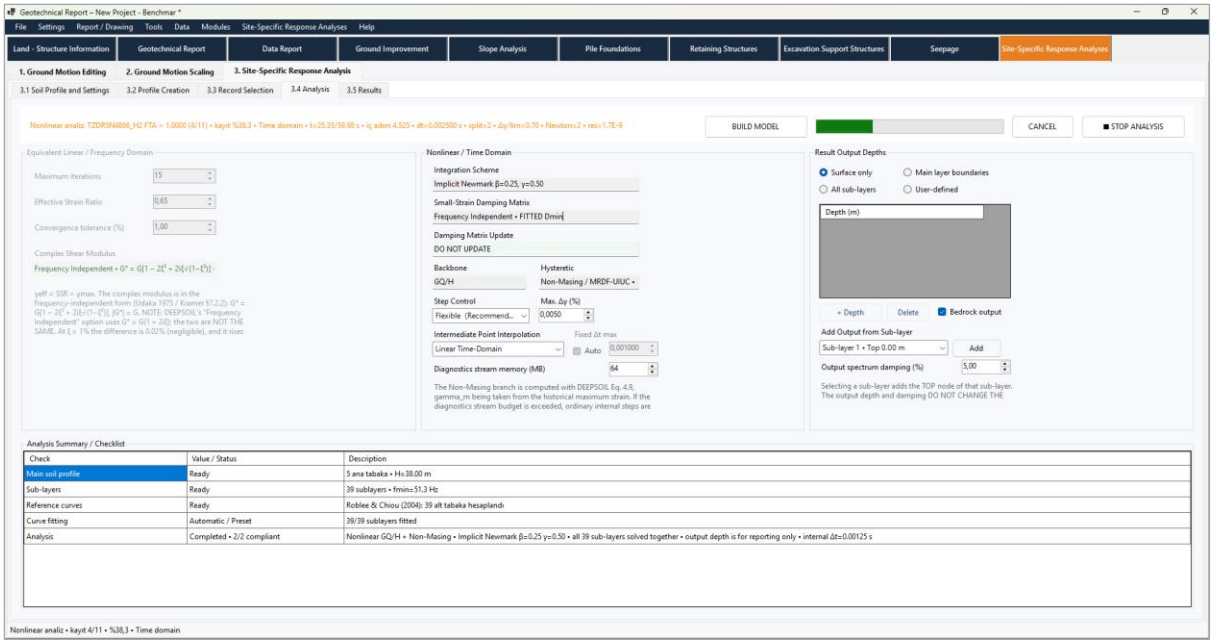


Figure 18. 3.4 Analysis tab: nonlinear solution settings and analysis summary

7.4 Pore water pressure generation

Pore water pressure generation is optional, off by default and meaningful only in the nonlinear solution. The approach used is energy-based: the unit hysteretic energy dissipated in a sub-layer is accumulated, and this

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

accumulation is converted into a pore water pressure ratio by dividing it by the energy capacity of that soil required for liquefaction. The energy capacity is calculated from a published relation depending on relative density and fines content, or entered by hand.

Two degradation factors are derived from the pore water pressure ratio: for stiffness, the square root of the complement of the pressure ratio; for strength, a power relation. These two factors directly reduce the shear modulus and the shear strength of the material; the reference strain is rebuilt accordingly.

Table 15. Pore water pressure solution modes

Mode	What it does
Stage 1 — Diagnostics (default)	The pore water pressure is calculated and reported but not fed back to the solver. The results of the total stress analysis do not change; the user sees where and when pressure develops.
Stage 2 — Quasi-effective stress	The degradation factors are applied to the material of the next accepted step. The pressure ratio is held constant during the Newton iterations of a step and updated only after the step has been accepted; the solution is therefore not fully coupled but staggered (quasi-effective), and the program calls it by that name.

In which layers generation operates: the user ticks this per layer, and by default the tick is on only for sand and for silt of low plasticity. During the analysis, only calculation sub-layers that are ticked AND below the water level enter the calculation; there is no fixed depth limit. The relative density can be entered by hand or estimated from the shear wave velocity through a chain of published relations; the estimate is made in each sub-layer with its own local velocity and effective stress, and applicability warnings are collected in the status column of the layer.

Dissipation and settlement

Pore water pressure is generated; since consolidation is not solved, the pressure ratio and the accumulated energy increase monotonically. Post-earthquake settlement is outside the scope. The numerical cap on the pressure ratio is not a liquefaction threshold but a numerical safeguard of the solution.

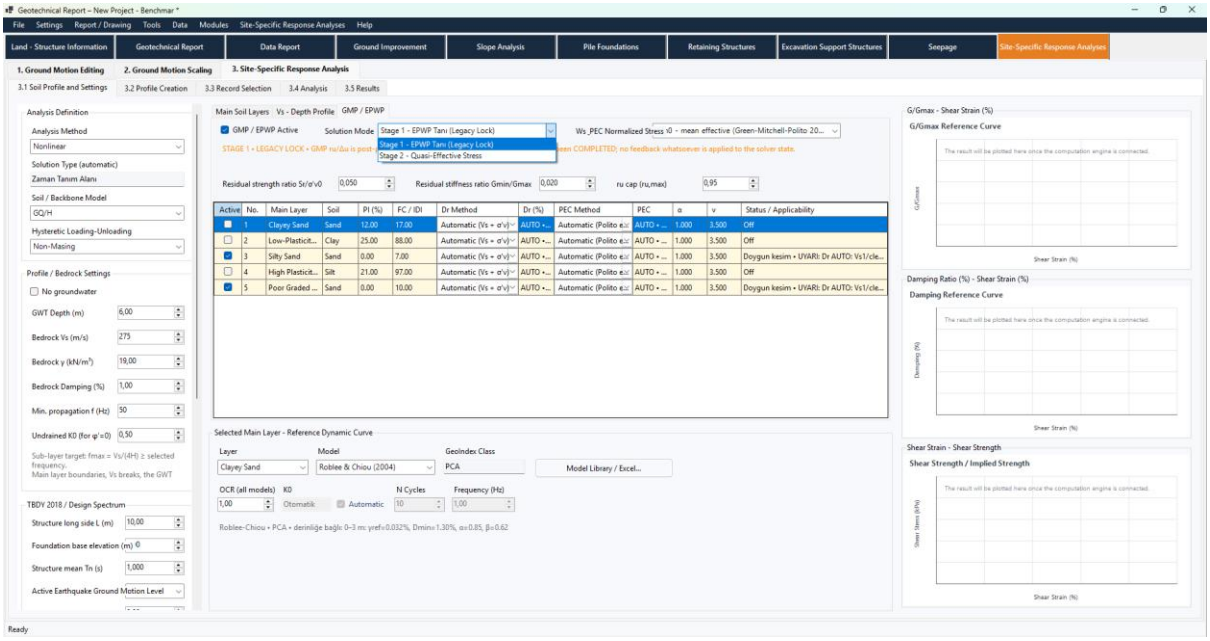


Figure 19. GMP / EPWP tab: pore water pressure model and layer-by-layer settings

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

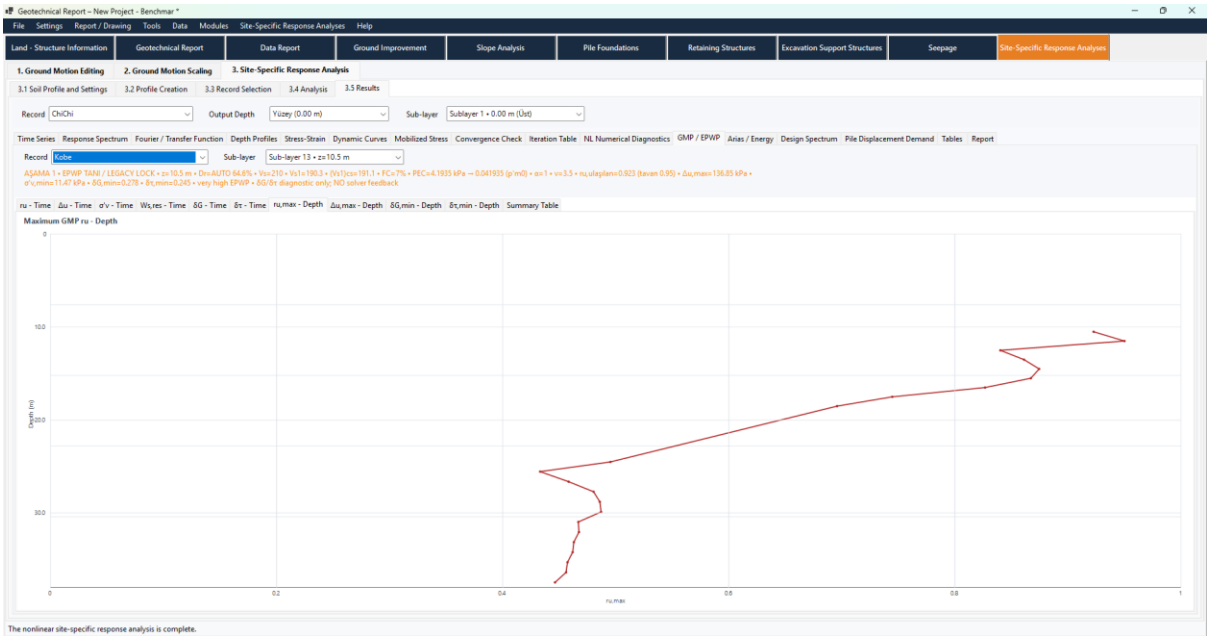


Figure 20. Results, GMP / EPWP — depth distribution of the maximum r_u

7.5 Output depths

You select at which depths results are stored: surface only, all sub-layers, main layer boundaries or a user-defined list; output at the bedrock can be ticked separately. A separate damping can be entered for the output spectrum. The following note is written on the screen: the output depth and output damping do not change the analysis; the design spectrum is always derived from five per cent damping. The foundation base level is automatically an output point in every analysis.

8. Results, Design Spectrum and Checks

8.1 Result views

The results are collected under sixteen headings, and all of them can be filtered with the record, output depth and sub-layer selectors.

Table 16. Result headings

Heading	Content
Time series	Acceleration, velocity and displacement time histories and input–output comparison. Acceleration is the total value; velocity and displacement are relative to the input motion, and this is written on the screen.
Response spectrum	Surface spectrum and amplification together; period axis linear or logarithmic.
Fourier and transfer function	Amplitude spectrum and amplification function; each axis linear or logarithmic.
Depth profiles	Peak acceleration, relative velocity and displacement, maximum strain and shear stress, modulus ratio, damping and degraded shear wave velocity.
Stress–strain	Hysteresis loops and their evolution over time; also a numerical data table and its export.
Mobilised stress	Mobilised shear stress, its ratio to the vertical effective stress, and the equivalent mobilised friction angle.
Convergence and iteration	Equivalent linear convergence plot, iteration table and nonlinear numerical diagnostics.
Pore water pressure	Variation with time of the pressure ratio, excess pressure, effective stress and degradation factors; depth profiles; summary table carrying the threshold times.
Arias and energy	Cumulative Arias intensity and duration measures.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Heading	Content
Design spectrum and pile demand	Subject of the two subsections below.

In the nonlinear solution the modulus ratio and damping are indicators

In the nonlinear solution the modulus and damping of the soil are not direct outputs of the solver; the modulus ratio, damping and degraded velocity shown in the depth profiles are indicators read from the calibrated curve at the maximum strain. The program states this both on screen and in the report.

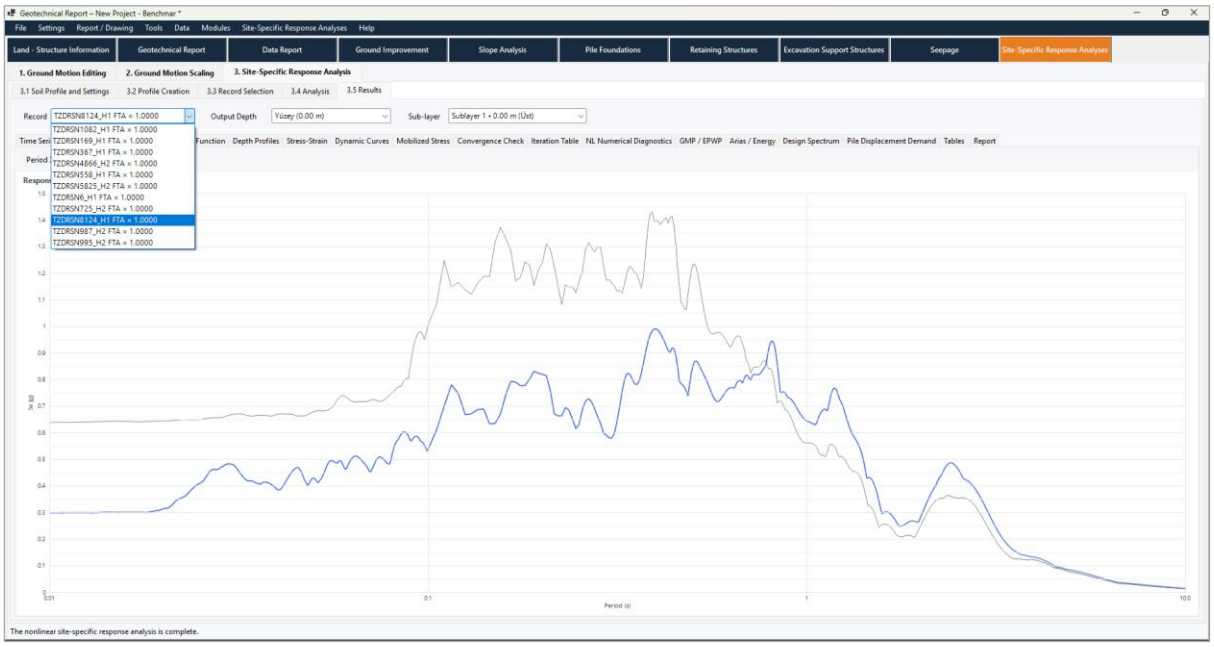


Figure 21. 3.5 Results, Response Spectrum: input and surface motion

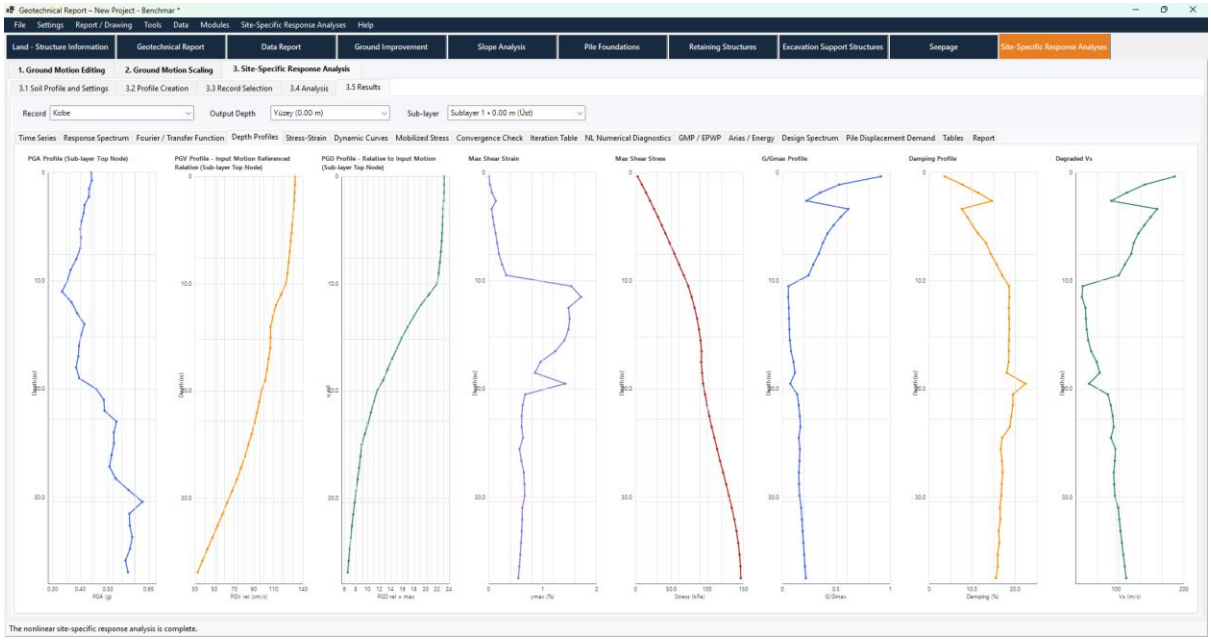


Figure 22. Depth Profiles: PGA, PGV, PGD, γ_{max}, maximum stress, G/G_{max}, damping and degraded V_s

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

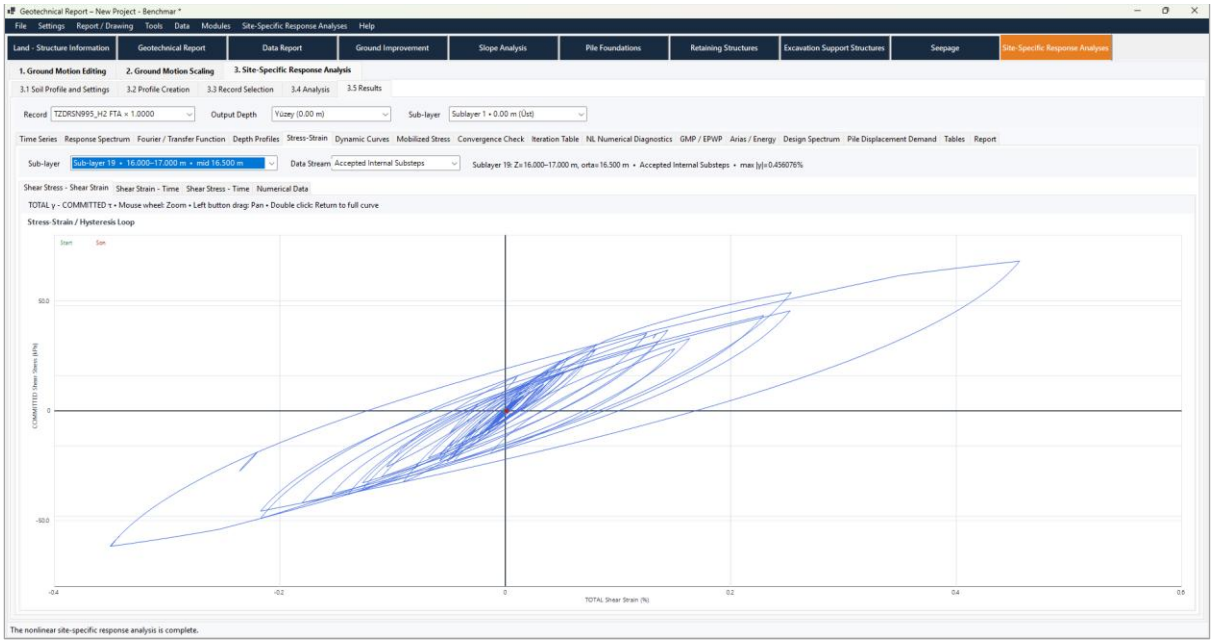


Figure 23. Stress-Strain tab: hysteresis loops of the selected sub-layer

8.2 Building the site-specific design spectrum

The site-specific design spectrum is built from the analysis results in five steps.

- For each record, the five-per-cent-damped spectral acceleration at the foundation base level is taken. The governing motion is the one at the depth where the foundation sits, not at the surface. A record without a valid spectrum is not discarded without notifying the user.

The engineer of record's own values can be used instead of the coefficients proposed by the program; there are separate fields for this, and the following note is written on the screen: first calculate the program's proposal. The summary table shows the proposed and the used values, their source, the number of records and the analysis depth together; in other words, the reader of the report sees where each number comes from.

If the ratio of the profile depth to the long side of the structure is insufficient, the program gives a warning but does not block the analysis. If there are fewer than eleven records, a warning is likewise given, but nothing is blocked.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

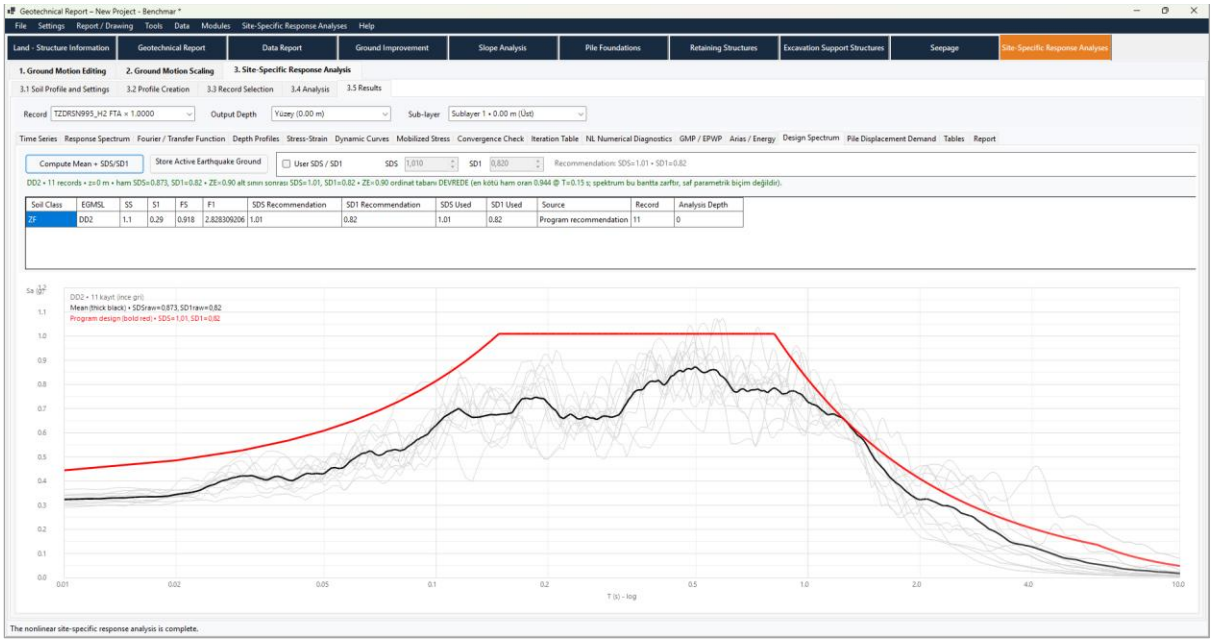


Figure 24. Design Spectrum tab: surface spectra of the records, mean and program design spectrum

8.3 TBDY §16.5.2 applicability checks

When an equivalent linear analysis is finished, the program checks two code clauses and writes its findings to the console, if necessary to an information window, and in every case to the Word report.

- Shear strain limit: all record and depth pairs at which the maximum strain exceeds one per cent are listed from largest to smallest, and the overall maximum value is always reported together with the record and the depth at which it occurs. Exceeding this limit indicates that the equivalent linear approach has lost its representativeness at that point.
- Soils with liquefaction potential: the sublayers that are active in the pore water pressure generation (GMP) table and lie below the groundwater level are listed. If liquefaction potential is established in these layers according to §16.6, the code requires a nonlinear time-domain analysis instead of the equivalent linear analysis (§16.5.2.6). If pore water pressure generation is off in the analysis, the layers cannot be listed and the program asks the user to check this point.

The checks are informative

The checks do not stop the analysis; deciding whether a code clause is satisfied is the job of the engineer who uses the number, not of the program that produces it. The liquefaction assessment itself is not the subject of this module, and the program states this explicitly.

8.4 Pile kinematic displacement demand

The second design quantity obtained from the analysis is the free-field kinematic displacement demand profile. The depths and spacing of the pile nodes are entered; at every depth and for every record the program takes the maximum over time of the displacement relative to the base.

Why displacement relative to the base, not total displacement

The total displacement includes the base motion. Since the base motion acts at all depths at the same time and in the same direction, the total displacement profile flattens out; the curvature seen by the pile, and therefore the kinematic moment, come out smaller than they really are. The displacement relative to the base represents the relative movement that strains the pile.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Two aggregations are made over the records, and both are built point-wise for each depth: the envelope, which is the largest of the records at each depth, and the mean of the records at each depth. They are not added together. Since the relevant appendix of the code is based on the mean of the record results, both profiles are exported, and which one to use is decided in the pile module.

Relationship with the pile module

This module produces the free-field kinematic displacement demand. The bending stiffness, curvature, kinematic moment and lateral subgrade reaction curves of the pile are calculated on the pile side. The profile produced is the input for the Method III kinematic interaction calculation within the scope of TBDY 2018 Appendix 16C.4.2. The same information is also written on the relevant screen of the program.

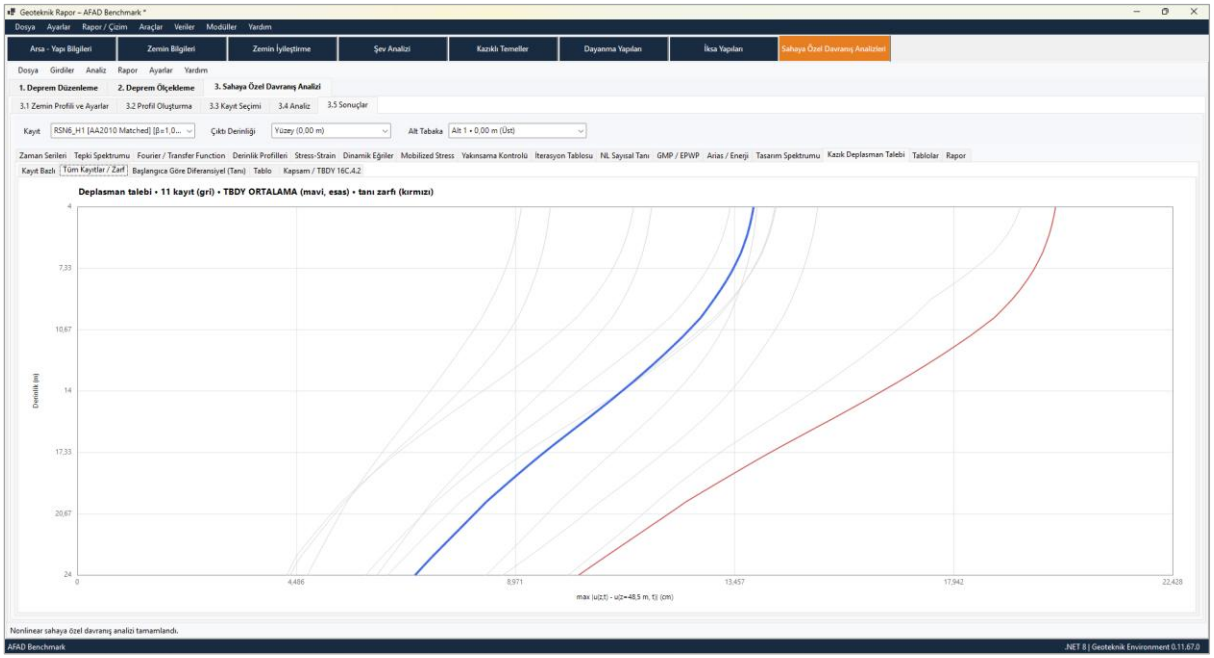


Figure 25. Pile Displacement Demand tab: records, TBDY mean and diagnostic envelope (Turkish interface shown)

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

9. Verification and Comparisons

This section gives, as they are, which quantity of the module has been compared with what, and the result of the comparison. Only quantities for which a comparison exists are included.

9.1 Three levels of comparison

Table 17. Verification levels

Level	What it proves
Comparison with published record measures	Shows that the record processing section produces the quantities published for the same record by a widely used record processing program.
Comparison with another site response program	Shows how far the results of two programs diverge for the same profile, the same curve parameters and the same record.
Closed-form solution and internal consistency	With the theoretical solution in the linear range, and by the same quantity coming out the same along different routes.

9.2 Record processing quantities

A validation record is embedded in the program and is loaded with a single button from the import window. When it is loaded, the program writes side by side to the console the published target values and its own calculation for peak acceleration, velocity and displacement, maximum incremental velocity, impulsivity index, standardised cumulative absolute velocity, effective number of cycles and damage index. For the effective number of cycles and the damage index there are small differences relative to the published values; they come from the residual and half-cycle details of the cycle counting and have not been closed with a correction coefficient. Use these two quantities with caution.

9.3 Site response solution

This subsection gives, with numbers, comparisons of the soil column solution made with two independent programs: two profiles with DeepSoil (Comparison 1 and Comparison 2) and one profile, two records and two analyses with RSSeismic (Comparison 3). All comparisons have been set up according to the following principles:

- First the inputs are made identical. The number of sub-layers, the thicknesses, the V_s value of every sub-layer, the vertical effective stress profile and the bedrock parameters are compared row by row in the two programs. The output comparison relies on the inputs being the same.
- Then the outputs are compared. The surface response spectrum, the depth profiles (γ_{max}, τ/σ'_v, PGA, displacement) and the peak values are compared point by point.
- The numbers have not been forced to equal the reference; the differences are given as they are.
- The comparison is repeated on several independent profiles. Agreement on a single profile may be a coincidence; agreement repeated for different soils, different depths and different layering is not.

Comparison 1 — DeepSoil, Benchmark 1: 40 m sand profile

A profile forty metres deep, divided into thirty-four sub-layers, has been compared with DeepSoil for the same record. The comparison is made in terms of peak acceleration and displacement at six depths; the program also adds this comparison to its report for that record and writes the percentage difference per depth. No pass/fail threshold has been set for this comparison: the difference is written, and the interpretation is left to the reader.

The same earthquake record was used in both DeepSoil comparisons: the ChiChi record from DeepSoil's own library, 11,800 points, Δt = 0.005 s, PGA = 0.1829 g; it was applied at the base of the profile as Rock Outcrop. In both analyses the pore water pressure module is off and there is no groundwater.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Table 18. Benchmark 1 — general profile and analysis parameters

Parameter	GeoteknikPro	DeepSoil
Total profile depth	40 m	40 m
Number of main layers	4	4
Number of calculation sub-layers	34	34
Groundwater	None	None
Bedrock V_s	300 m/s	300 m/s
Bedrock unit weight	19.00 kN/m³	19.00 kN/m³
Bedrock damping	1.00%	1.00%
Base boundary condition	Elastic half-space (Outcrop)	Elastic Halfspace
Natural frequency of the profile f_0	1.5789 Hz	1.5789 Hz
Natural period of the profile T_0	0.6333 s	0.6333 s
Analysis method	Nonlinear, GQ/H + non-Masing	Nonlinear, GQ/H + MRDF

All four soil layers are sand: γ_n = 18 kN/m³, γ_{sat} = 19 kN/m³, Roblee and Chiou (2004) curves, OCR = 1, K_0 = 0.50.

Table 19. Benchmark 1 — soil layer definitions (identical in both programs)

Layer	Depth	ϕ′ top → bottom	c′	V_s top → bottom	R&C γ_{ref} / a / D_{min} / B
Layer 1	0 – 10 m	30° → 32°	1 kPa	200 → 230 m/s	0.032% / 0.85 / 1.30% / 0.62
Layer 2	10 – 20 m	32° → 34°	0	230 → 260 m/s	0.044% / 0.85 / 1.15% / 0.62
Layer 3	20 – 30 m	34° → 36°	0	260 → 290 m/s	0.061% / 0.85 / 1.02% / 0.62
Layer 4	30 – 40 m	36° → 38°	0	290 → 290 m/s	0.061% / 0.85 / 1.02% / 0.62

Input verification: the 34-sub-layer profile generated by DeepSoil was exported and compared row by row with the program's sub-layer table.

Table 20. Benchmark 1 — input verification results

Input quantity	Comparison	Result
Number of sub-layers	34 / 34	Identical
Sub-layer thicknesses	34 rows (1.0000 / 1.1111 / 1.2500 / 1.4286 m)	34/34 identical
Sub-layer V_s values	34 rows (201.500 … 290.000 m/s)	34/34 identical
Vertical effective stress σ'_v	34 sub-layer mid-points	Difference 0.00%
Natural frequency of the generated profile	Via $\Sigma H/V_s$	1.5789 Hz — identical in both

Table 21. Benchmark 1 — comparison of peak values

Quantity	GeoteknikPro	DeepSoil	Difference
Surface PGA	0.187747 g	0.187444 g	+0.16%
Peak spectral acceleration S_a	0.674699 g @ 0.790 s	0.685427 g @ 0.775 s	−1.57%
Maximum shear strain γ_{max}	0.13407% @ 39.29 m	0.12752% @ 39.29 m	+5.14%
γ_{max} peak depth	39.286 m	39.286 m	Identical
Surface relative displacement	6.8825 cm	6.6627 cm	+3.30%
Surface relative velocity PGV	28.53 cm/s	—	—

Table 22. Benchmark 1 — depth profiles and spectrum statistics (34 points)

Profile	Mean difference	RMS	Maximum difference
Vertical effective stress σ'_v	+0.00%	0.00%	0.00%

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Profile	Mean difference	RMS	Maximum difference
Maximum shear strain γ_{max}	+0.18%	1.48%	5.14%
Maximum stress ratio τ/σ'_v	+0.12%	0.91%	3.48%
Peak acceleration PGA	−1.23%	2.29%	5.33%
Maximum relative displacement	+3.96%	4.01%	5.08%
(T ≥ 0.05 s)	−1.04%	2.16%	5.68%

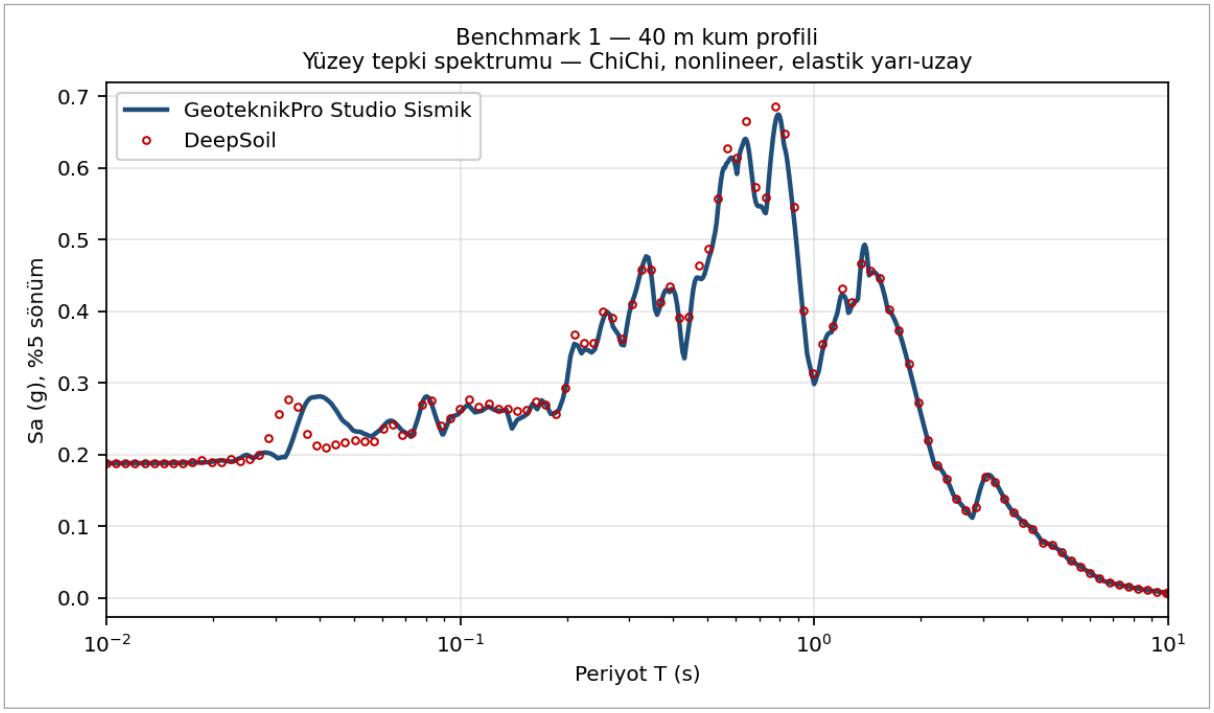


Figure 26. Benchmark 1 — comparison of surface response spectra (Turkish interface shown)

Comparison 2 — DeepSoil, Benchmark 2: 30 m clay / sand / clay profile

Table 23. Benchmark 2 — general profile and analysis parameters

Parameter	GeoteknikPro	DeepSoil
Total profile depth	30 m	30 m
Number of main layers	3	3
Number of calculation sub-layers	29	29
Groundwater	None	None
Bedrock V_s	320 m/s	320 m/s
Base boundary condition	Elastic half-space (Outcrop)	Elastic Halfspace
Natural frequency of the profile f_0	2.068 Hz	2.068 Hz
Analysis method	Nonlinear, GQ/H + non-Masing	Nonlinear, GQ/H + MRDF

Table 24. Benchmark 2 — soil layer definitions (identical in both programs)

Layer	Depth	Soil	γ_n / γ_{sat}	Strength	PI / FC	R&C class and γ_{ref}
Layer 1	0 – 10 m	Clay	18.0 / 19.0	c′ = 60 → 105 kPa	20 / 75	FMH, γ_{ref} = 0.085%
Layer 2	10 – 20 m	Sand	18.5 / 19.1	ϕ′ = 30° → 33°	0 / 10	PCA, γ_{ref} = 0.044%
Layer 3	20 – 30 m	Clay	19.1 / 20.0	c′ = 175 → 290 kPa	20 / 88	FMH, γ_{ref} = 0.111%

The V_s profile varies linearly with depth: 180 at 0 m, 220 at 5 m, 235 at 10 m, 255 at 15 m, 268 at 20 m, 300 at 25 m and 300 m/s at 30 m. OCR = 1 and K_0 = 0.50 were used in all layers.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Table 25. Benchmark 2 — comparison of peak values

Quantity	GeoteknikPro	DeepSoil	Difference
Surface PGA	0.204572 g	0.206644 g	−1.00%
Peak spectral acceleration S_a	0.743800 g @ 0.565 s	0.762709 g @ 0.568 s	−2.48%
Maximum shear strain γ_{max}	0.11442% @ 13.89 m	0.11632% @ 13.89 m	−1.63%
γ_{max} peak depth	13.889 m	13.889 m	Identical
Surface relative displacement	4.7066 cm	4.5293 cm	+3.91%
Surface relative velocity PGV	24.45 cm/s	—	—

Table 26. Benchmark 2 — depth profiles and spectrum statistics (29 points)

Profile	Mean difference	RMS	Maximum difference
Vertical effective stress σ'_v	+0.00%	0.00%	0.00%
Maximum shear strain γ_{max}	+0.44%	1.99%	5.99%
Maximum stress ratio τ/σ'_v	+0.32%	1.28%	3.53%
Peak acceleration PGA	−1.39%	1.73%	2.70%
Maximum relative displacement	+4.42%	4.45%	5.08%
($T \geq 0.05$ s)	−0.79%	1.49%	5.06%

The correlation coefficient of the surface spectrum is r = 0.99871.

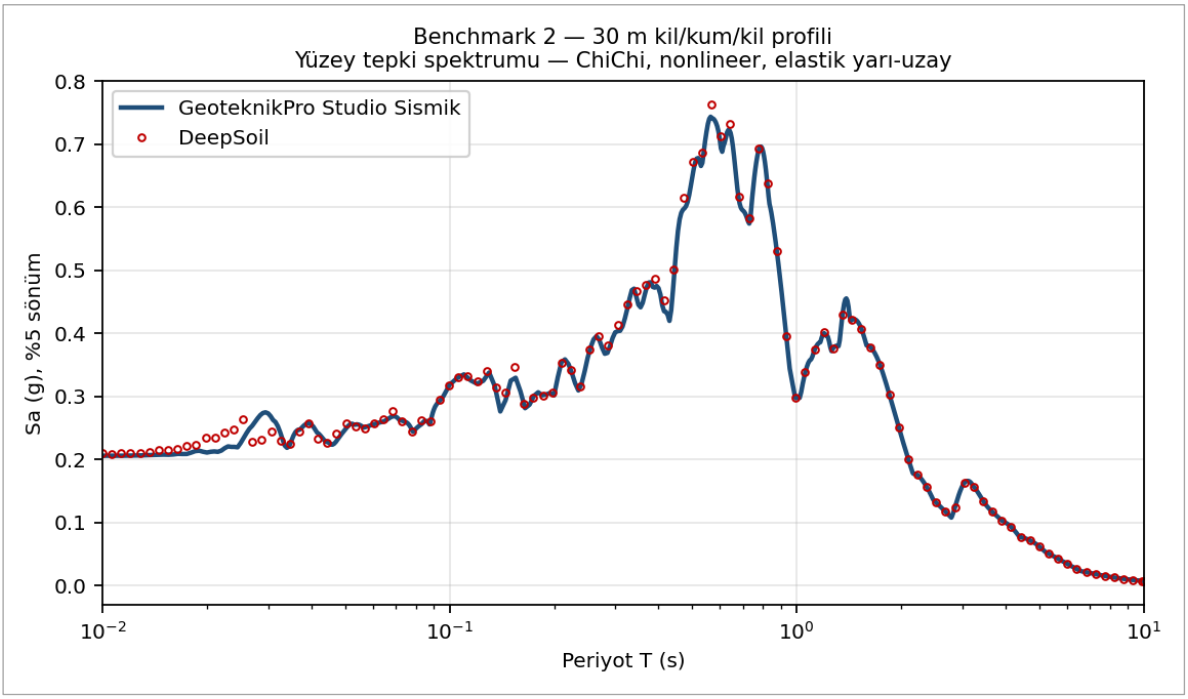


Figure 27. Benchmark 2 — comparison of surface response spectra (Turkish interface shown)

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

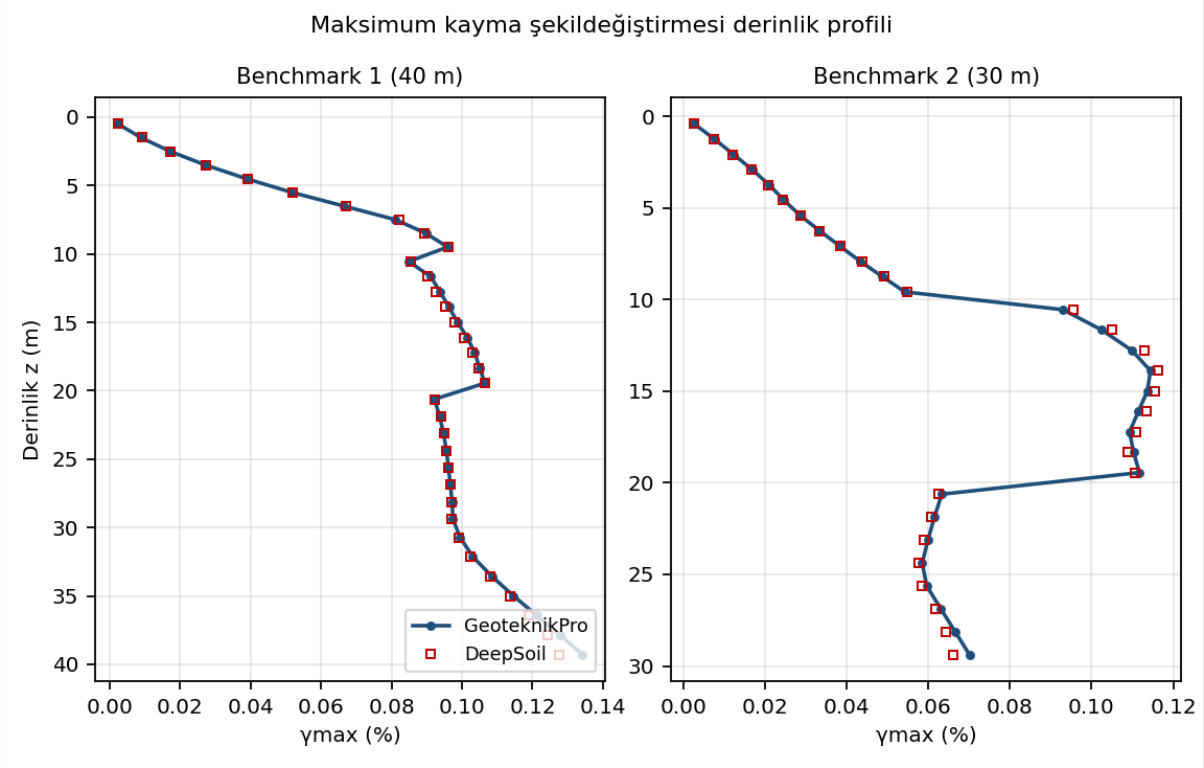


Figure 28. Depth profile of maximum shear strain for both benchmarks; the depth of the peak is the same in both programs (Turkish interface shown)

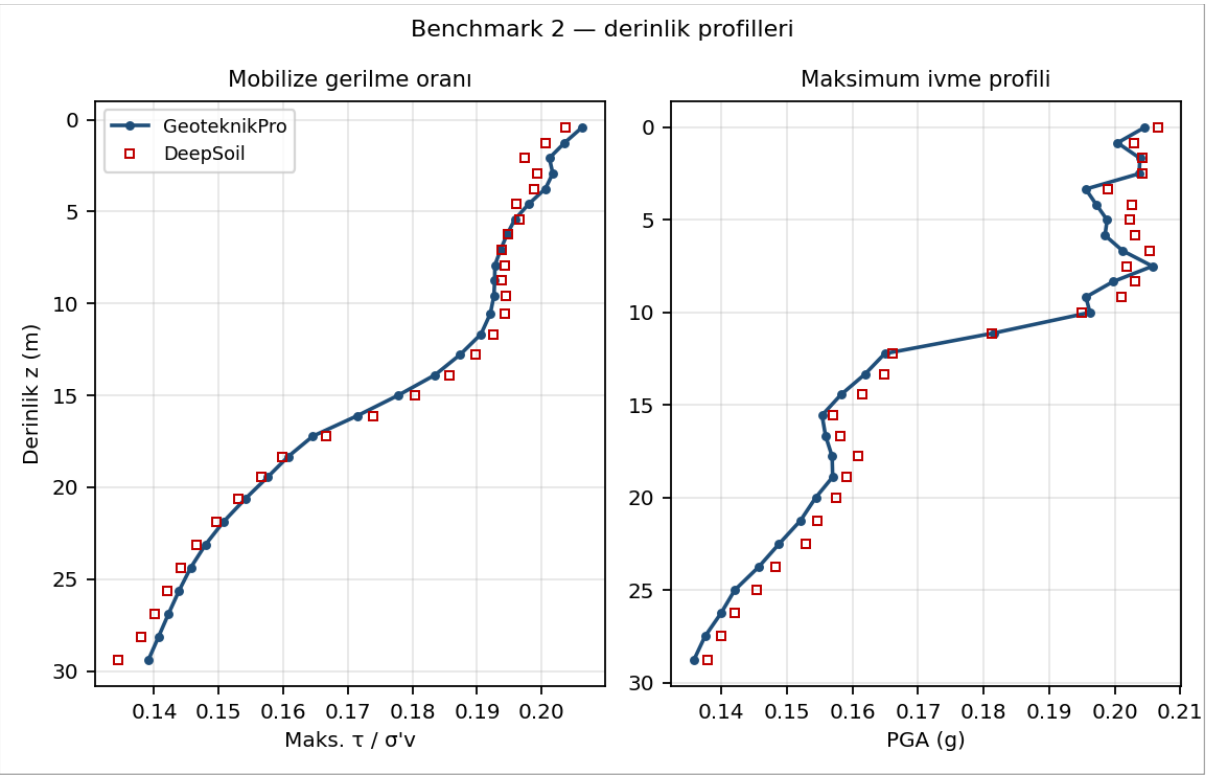


Figure 29. Benchmark 2 — depth profiles of mobilised stress ratio and maximum acceleration (Turkish interface shown)

Comparison 3 — RSSeismic, Benchmark 3: 20 m three-layer profile, total and effective stress

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

The third comparison was made with RSSeismic on a twenty-metre, three-layer profile. RSSeismic's backbone and damping parameters (θ_1–θ_5, D_{min}, P_1–P_3) were adopted as they are; since the parameters are shared, the remaining difference is purely a solver difference. It was run with the Kobe and ChiChi records, first in total stress and then with pore water pressure generation switched on.

Table 27. Results of Comparison 3

Analysis	Reported difference
Total stress	Surface peak acceleration about two per cent; peak displacement about two per cent; maximum strain up to six per cent; stress ratio about one and a half per cent.
Pore water pressure generation	For one record the pressure ratio agrees within a six per cent band, acceleration and displacement within six per cent; for the other record the pressure ratio in the deep layers is on average nine per cent higher than in RSSeismic. Use the pore water pressure results in deep layers with caution.

A method difference between the two programs

The two programs compared build the shear strength of a sub-layer differently: RSSeismic interpolates linearly between the ends of the main layer, while this program calculates the strength at every point from the local effective stress. The small difference arising from this method difference remains in the results; the program keeps its own method.

Table 28. Benchmark 3 — model

Quantity	Value (identical in both programs)
Main layers	Clay 0–5 m · Sand-1 5–10 m · Sand-2 10–20 m
Sub-layers	f_{max} = 50 Hz → 9 × 0.5556 + 8 × 0.625 + 14 × 0.7143 m = 31 sub-layers
Unit weight	Clay 18 · Sand 18.8 kN/m³ · γ_w = 9.807 kN/m³
Groundwater	5.0 m (top of Sand-1)
V_s	120→130 · 130→150 · 150→170 (10–15 m) · 170→210 m/s (15–20 m)
Strength	Clay c = 40→70 kPa · Sand ϕ = 28°→30° and 30°→33°
Curves and model	Roblee and Chiou (2004); nonlinear, time domain, GQ/H + MRDF-UIUC, non-Masing, frequency-independent damping
Base	Elastic half-space, V_s = 210 m/s, γ = 19 kN/m³, ξ = 1%
Input	Outcrop. Kobe: 2400 points, Δt = 0.02 s, PGA = 0.821 g · ChiChi: 11,800 points, Δt = 0.005 s, PGA = 0.183 g
Analyses	Analysis A: pore water pressure off (total stress) · Analysis B: pore water pressure generation on with GMP

σ'_v at 19.64 m is 221.68 / 221.7 kPa in the two programs.

Table 29. Benchmark 3, Analysis A — total stress results

Quantity	GeoteknikPro	RSSeismic	Difference
Kobe surface PGA	0.4974 g	0.508 g	−2.1%
Kobe surface PGD	21.36 cm	20.9 cm	+2.2%
Kobe γ_{max} @ 5.31 m	2.873%	3.05%	−5.8%
Kobe γ_{max} @ 6.56 m (peak)	3.162%	3.245%	−2.6%
Kobe γ_{max} @ 19.64 m	0.896%	0.874%	+2.5%
Kobe τ/σ'_v @ 7.19 m	0.4706	0.478	−1.5%
ChiChi surface PGA	0.1808 g	0.185 g	−2.2%
ChiChi γ_{max} @ 9.69 m	0.2500%	0.251%	−0.4%

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

Table 30. Benchmark 3, Analysis B — pore water pressure on, ChiChi

z (m)	r_u GeoteknikPro	r_u RSSeismic	γ_{max} GeoteknikPro	γ_{max} RSSeismic
5.31	0.310	0.315	0.205%	0.210%
9.69	0.373	0.374	0.262%	0.265%
14.64	0.313	0.310	0.263%	0.272%
19.64	0.195	0.184	0.214%	0.202%

Comparison 4 — Constitutive model

This comparison is not a verification of the solver and is not presented as such. The constitutive model of a single layer was fed with another program's own strain history and its own parameters, and the resulting stress histories were compared. The reported agreement is a high correlation over the whole history and a mean difference of the order of a few kPa, with a numerically negligible difference at the outer reversal points. This shows that the loading–unloading rules have been set up correctly; it does not demonstrate the solution of the soil column.

Verification statement

The DeepSoil comparisons cover the total stress path. Pore water pressure generation (GMP) was compared in Comparison 3 with RSSeismic, using two records. The equivalent linear path has been checked at low amplitude.

Closed-form solution

In the linear range, for a single-layer column on an elastic half-space, the peak value of the theoretical transfer function and the program's calculation agree to within about two per mille. The calculations in this module have been checked against independent verification examples and hand calculations.

What it has not been compared with

The module has not been compared with field measurements (pairs of downhole records), nor with two- or three-dimensional finite element solutions. There is no comparison for post-earthquake settlement or post-liquefaction behaviour; the module does not calculate these quantities.

Some of the comparisons can be run with a single button in the 'Run benchmarks...' window in the Analysis menu (see 9.4). Not all of the DeepSoil and RSSeismic comparisons are included in this window; their results are given in the tables above.

9.4 The Run benchmarks window

The 'Run benchmarks...' command in the Analysis menu compares the program's own calculations with reference values stored in the program, in a single window. Each row shows the quantity, reference, calculated value, percentage error, tolerance and source; the result can be saved as a CSV or text file. The tolerance is a relative percentage. A row without a tolerance is marked MONITORED: the number is written, but no pass or fail verdict is given. Comparisons whose reference is not available in the program, or which cannot yet be run in this window, are listed as MISSING together with the reason; they are not shown as if they had been run.

The calculations in this module have been checked against independent verification examples and hand calculations. The window contains the record processing quantities (SeismoSignal references), the DeepSoil profile subdivision and the curve calibration comparisons; the values calculated by the program can be seen row by row in the window.

The record processing references are the values reported by SeismoSignal for the same record (raw record, no processing). The damage index and the effective number of cycles show small differences relative to

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

SeismoSignal; they come from the residual and half-cycle details of the cycle counting. Use these two quantities with caution.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

10. Outputs, Project File and Bridges

10.1 Selective export

Word, Excel and image outputs pass through a single table-of-contents window. This window is divided into two groups: the main report scope and optional heavy appendices. The main scope contains the project and profile inputs, the reference curve and calibration summaries, the record and result tables, the depth plots per record, the pore water pressure summaries, and the design spectrum and pile displacement demand; in the recommended preset all of these are on. The heavy appendices — time series at all depths, all iteration rows, all constitutive model diagnostic points — are off by default. The seismic Word report is built directly by the program, not from an editable template; this is why the module does not appear in the Report / Drawing › Report templates… window, and the window says so.

The window estimates live how many rows will be produced for the selection and turns its warning red when the selection exceeds a certain size. Saying it before the document is produced was preferred to explaining afterwards why a document took half an hour.

Table 31. Site analysis outputs

Output	Content
Word report	Analysis definition and settings; main soil profile; calculation sub-layers; reference curves and calibration appendices; records used; results per record; record suite means; determination of the design spectrum; pile kinematic displacement demand profile; code applicability check; engineering check notes. The last four headings appear only when they are applicable, and the numbering shifts accordingly.
Excel workbook	The numerical form of the same scope; when the heavy appendices are selected, the time series and iteration histories are also written here.
Image files	Saving the plots individually.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

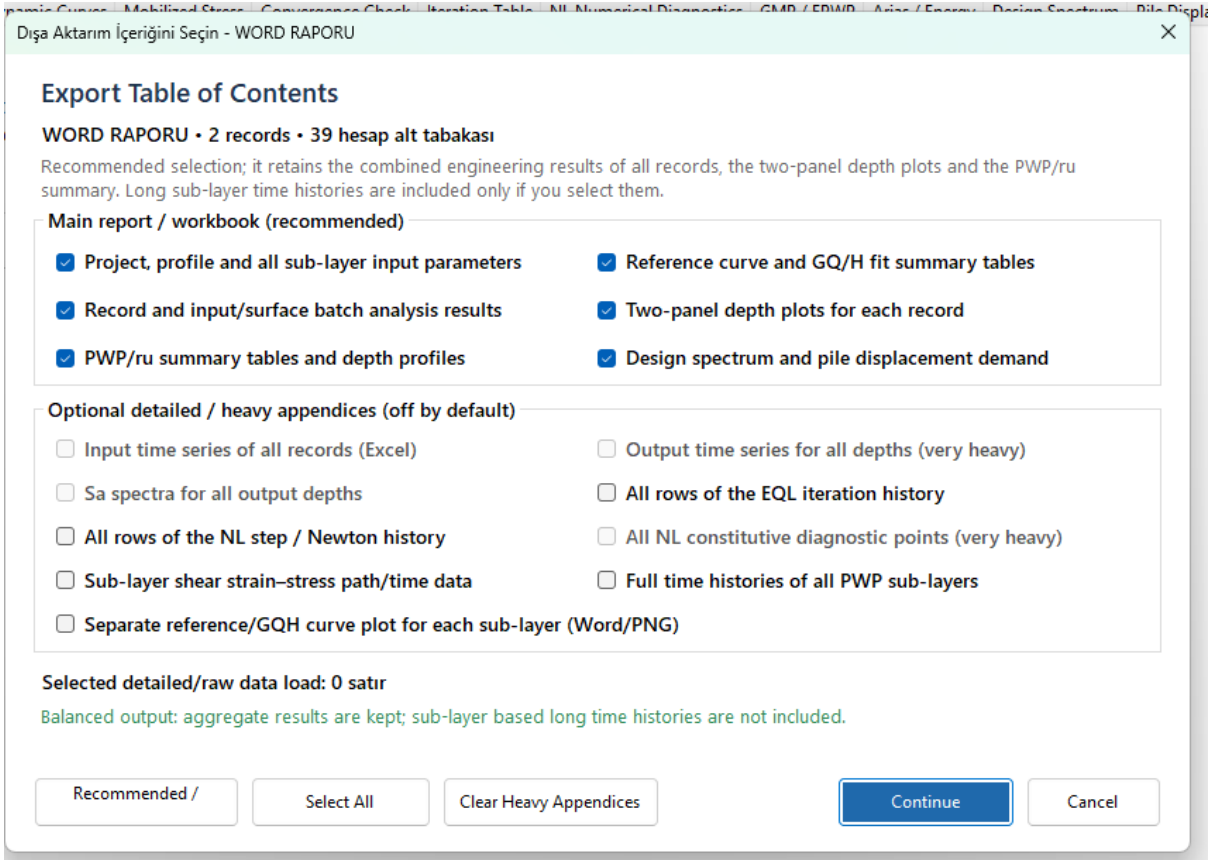


Figure 30. Export Table of Contents window

10.2 Project file

The site analysis data are not written to a separate file; they go into the single project file of the main program (*.geos) as one section. Saving and opening are done from the File menu of the main program. The module's menu contains only the "New Project (this module only)" command: this command resets only this module's data and rebuilds the module from scratch, without touching the other modules of the main project. The menus sit in the common ribbon at the top and are visible while this module's tab is open.

The "Design code..." command under Settings opens the common design code window; the code according to which the calculation is made is selected here and saved together with the main project file. Only codes implemented in the program (Active) can be selected; the others appear greyed out with the note "Not available in this version." In this module the default, and today the only option, is TBDY 2018. The selection goes into the main project file and the input record and is written to the settings table in the report.

At the end of the Settings submenu there is also a "Language" submenu (Türkçe, English, Español, Русский). The choice also changes the common language of the program. The module's own texts are in Turkish and English; when Español or Русский is selected, the module works with the English texts, and texts that have an entry in the common dictionary appear in the selected language. Changing the language only refreshes the texts on screen; it does not touch the inputs or the results.

The ground motion records are carried in the main project file together with their time series. In addition, a persistent record library is kept at program level; opening or closing the project, or using the "New Project (this module only)" command, does not delete this library.

10.3 Bridge to the Pile Foundations module

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

When all results are exported, the free-field kinematic displacement demand profile is also written as a separate text file. The first column of the file is depth, and the following columns are each record plus, in addition, the mean profile; the header lines state which code clause it is the input for, the node spacing and the units. When the export is finished, the program says how many records were written and where this file is to be selected in the pile module. If no analysis has been carried out, the file is not written and this is stated as well — an empty file would present a non-existent result as if it existed.

When the pile module reads this file, the kinematic interaction path in the relevant appendix of the code is opened and the group reduction relation comes into play. Since the two modules work as separate solutions, the transfer is via a file; in embedded use the transfer is also made in memory.

10.4 Bridge to the main program

When the module is run embedded in the main program, a two-way link is established. In the incoming direction, the soil profile defined in the geotechnical report module can be written into the tables of this module. In the outgoing direction, all site analysis data are written as a single compressed text into the project file of the main program (*.geos) and read back from there; this way the user carries a single file. Long number arrays are written in a lossless, compressed form. A project file saved with this version cannot be opened by older versions of the program.

10.5 Currency of the results

When the analysis starts, a record of all the project input is taken and stored with the result. If the input changes afterwards (water table, bedrock, record data, equivalent linear and nonlinear solution settings, output depths, design and pile parameters, design code), the result is not deleted; the warning '⚠ STALE RESULT — the model has changed, run the analysis again.' appears on screen. Before Word, Excel or full-package output is produced the program asks: Yes re-runs the analysis, No continues with the old result, Cancel produces no output. The ticks in the record list, the open tab and the record colour do not enter this record. A result for which no analysis has ever been run is not considered stale.

10.6 PLAXIS 2D site response script

The 'PLAXIS 2D site response script...' command in the Analysis menu generates, from the current calculation profile (sub-layer thickness, unit weight, V_s and small-strain damping), a command script that builds a narrow soil column in PLAXIS 2D. The window has three tabs: 'Commands only' (text copied to the clipboard; contains no comment lines), 'Annotated' (section headings, derivations and markers for unverified lines) and 'Notes' (assumptions and the list of unverified lines).

Poisson's ratio, column width, maximum frequency, f_2/f_1 ratio, lateral boundary (tied degrees of freedom or free field) and base type (compliant base for a rock outcrop record, rigid base for a downhole record) can be changed and the script regenerated with 'Refresh'. The soil model is linear elastic by default and is used together with Rayleigh damping; G_0 is derived from the unit weight and V_s. The Rayleigh coefficients are calculated so as to provide the small-strain damping of each layer at the natural frequency of the profile f_1 and at $f_2 = n \cdot f_1$ (default $n = 5$). The criterion that the element size must not exceed one eighth of the smallest wavelength is reported.

The dynamics-specific lines (Rayleigh coefficients, dynamic phase type and time interval, boundary conditions, base displacement and multiplier table) have not yet been tried in a PLAXIS session; they are marked 'NOT VERIFIED' in the annotated preview and listed one by one on the Notes tab. Check these lines before using them in PLAXIS. The script is not a calculation solution but a starting script for the model to be built in PLAXIS; the PLAXIS results have not been compared with the equivalent linear or nonlinear solution of this program.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

11. Points to Watch

The following are the points that most often lead to wrong results in this module. None of them is a defect of the program; all of them arise from a decision that belongs to the user.

- The unit of the record. If the acceleration unit is chosen wrongly, everything looks right, only the scale of the magnitudes is wrong. The first check is to look at the peak acceleration calculated in the import preview.
- The ‘Out of tolerance’ label in spectral matching. The label reports that the record does not meet the convergence criterion, together with the maximum and mean deviation reached; the record is not hidden. Whether it is used is the decision of the engineer of record.
- Automatic suite selection. The selection is based only on the criterion of amplitude scaling (minimising the common β); it does not assess the duration and frequency content of the records or their suitability for the site conditions. The earthquake identity is guessed from the file header; if it is wrong, it must be corrected in the window.
- The stale result warning. After the input has changed, the result shown on screen is the result of the old input. Unless the input was changed deliberately, the re-analysis question asked by the program before a report or Excel output is produced should be answered with ‘Yes’.

12. Scope and Limitations

The module performs one-dimensional, horizontally layered site response analysis. The following topics are outside its scope; no numbers relating to them are produced on the relevant screens.

- Two- and three-dimensional site response; basin effects, topographic amplification, inclined layers and propagation modes other than vertical waves. The solution is one-dimensional and horizontally layered.
- Calculation of pile stiffness, curvature, kinematic moment and lateral springs. The free-field profile produced by this module is the input to the kinematic interaction method; the method is carried out on the pile foundations side.
- Dissipation of pore water pressure, the associated consolidation, and post-earthquake settlement.
- Constitutive degradation depending on the number of cycles. The number-of-cycles input on the screen affects only the damping coefficient of the reference curve; the backbone and the degradation are independent of the number of cycles.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.

13. References

The references below are the publications on which the methods implemented in the module are based. The list is intended to show where each method comes from; the coefficient sets and implementation details of the methods are not the subject of this guide.

Codes and standards

- Turkish Building Earthquake Code (TBDY 2018) [Türkiye Bina Deprem Yönetmeliği] — in particular Chapter 2 (selection and scaling of ground motion records), Chapter 16 and Appendix 16C (site-specific site response and pile kinematic interaction).

Record processing and ground motion measures

- Arias, A. (1970). A measure of earthquake intensity.

Scaling and spectral matching

- Al Atik, L. and Abrahamson, N. (2010). An improved method for nonstationary spectral matching.

Dynamic soil properties and one-dimensional response

- Darendeli, M. B. (2001). Development of a new family of normalized modulus reduction and material damping curves. PhD thesis, Department of Civil, Architectural and Environmental Engineering, The University of Texas at Austin.
- Groholski, D., Hashash, Y., Kim, B., Musgrove, M., Harmon, J. and Stewart, J. (2016). Simplified model for small-strain nonlinearity and strength in 1D seismic site response analysis. Journal of Geotechnical and Geoenvironmental Engineering, 142(9), 04016042. DOI: 10.1061/(ASCE)GT.1943-5606.0001496.
- Kramer, S. L. (1996). Geotechnical Earthquake Engineering. Prentice Hall, Upper Saddle River, N.J.
- Menq, F.-Y. (2003). Dynamic properties of sandy and gravelly soils. PhD thesis, Department of Civil, Architectural and Environmental Engineering, The University of Texas at Austin.
- Park, D. and Hashash, Y. M. A. (2004). Soil damping formulation in nonlinear time domain site response analysis. Journal of Earthquake Engineering, 8(2), 249–274.
- Phillips, C. and Hashash, Y. M. A. (2009). Damping formulation for nonlinear 1D site response analyses. Soil Dynamics and Earthquake Engineering, 29, 1143–1158.
- Roblee, C. and Chiou, B. (2004). A proposed geoindex model for design selection of non-linear properties for site response analyses. Caltrans Geo-Research Group, Sacramento, CA.
- Schnabel, P. B., Lysmer, J. and Seed, H. B. (1972). SHAKE: A computer program for earthquake response analysis of horizontally layered sites. Report No. EERC 72-12, Earthquake Engineering Research Center, University of California, Berkeley.
- Seed, H. B. and Idriss, I. M. (1970). Soil moduli and damping factors for dynamic response analyses. Report No. EERC 70-10, Earthquake Engineering Research Center, University of California, Berkeley.

Pore water pressure generation

- Green, R. A., Mitchell, J. K. and Polito, C. P. (2000). An energy-based excess pore pressure generation model for cohesionless soils. Proceedings: John Booker Memorial Symposium, Melbourne, Australia, 16–17 November 2000.

© 2026 Medra Mühendislik Ltd. Şti. — This guide was prepared by Medra Mühendislik Ltd. Şti., which reserves all rights. No part of the guide may be reproduced or distributed without written permission, nor quoted without acknowledgement of the source.