

Comparison of geotechnic softwares - Geo FEM, Plaxis, Z-Soil

Comparison du logiciel géotechnique – Geo FEM, Plaxis, Z-Soil

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ABSTRACT: GEO FEM is geotechnical software based on the finite element method utilized friendly platform from GEO4 programs. In this article after short description of GEO FEM program selected soil mechanics problems are analyzed next to illustrate and validate the program. For the comparison was used commercial geotechnical software based on the finite element method: Z – Soil and PLAXIS and analytical solution if available.

1 INTRODUCTION

GEO FEM offers an attractive alternative to traditional approaches to geotechnical problems (especially for GEO 4 users). It uses recent advances in nonlinear finite element techniques to perform analysis of complex geotechnical problems like load carrying capacity, deformation and stress fields inside the layered soil body, solve stability, consolidation of saturated soils, plastic modeling of soils, modeling of structures and the interaction between the structures and the soil (anchors, rockbolts, sheeting walls) and excavation sequences. The main goal of this paper is illustrate and validate the capabilities of the GEO FEM program. For the comparison we used typical benchmarks and two commercial geotechnical software based on the finite element method: Z – Soil and PLAXIS. In this article the main features of GEO FEM program (preprocessing, constitutive models, postprocessing) is described first, then comparison on the benchmarks and finally conclusions.

2 MAIN FEATURES OF GEO FEM

GEO FEM is a finite element package specifically intended for the two dimensional analysis of deformation and stability in geotechnical engineering projects and is built on the same original friendly platform as the GEO 4 - geotechnical software. GEO FEM is equipped with special features to deal with the numerous aspects of many geotechnical engineering projects involve the modelling of structures and the interaction between the structures and the soil. In particular the program offers the following essential features:

- The input of soil layers, structures, construction stages, loads and boundary conditions is based on GEO 4 platform (highly interactive user interface), which allows for a detailed modelling of the geometry cross section – Fig. 1. You can use material database including material properties for soil, as well as for structural elements.
- Automatic mesh generator with the bandwidth optimizer for the finite-element discretization allows you to generate finite element mesh (of thousands of element) with options for global and local mesh refinement. Finite element mesh is easily generated from the input 2D geometry model.
- Automatic generation of standard boundary conditions that apply in most cases. These boundary conditions may be changed by the special conditions that can be imposed on the geometry lines as well as in points.
- Quadratic 3 node and 6 node triangular elements are available to model the deformations and stresses in the soil. Beam elements (based on the Mindlin theory) are used to model the bending of retaining walls, tunnel linings, shells, and other slender structures. To model prestress conditions (anchors) the

elastoplastic spring elements are used. Frictional contact interface elements are available to model soil structure. The elements mentioned above offer the flexibility to model any configuration of the soil profile.

- Contact interface elements may be used to simulate the thin zone of intensely shearing material at the contact between a tunnel lining and the surrounding soil. Values of interface friction angle and adhesion are generally not the same as the friction angle and cohesion of the surrounding soil.
- Interfaces: Joint elements are available to interaction. For example, these elements may be used.
- Stability analysis is simpler and more general than usual sliding surface approaches due to C-phi reduction and stress level algorithms.
- GEO FEM enables a realistic simulation of excavation and construction stages by activating and deactivating of construction parts, application of loads, boundary conditions etc.
- GEO FEM offers a variety of advanced soil models to simulate the nonlinear, time dependent soil behavior. In addition to the Mohr - Coulomb, Drucker Prager and Cam Clay models (elastoplastic type of hyperbolic model) are available.
- For displaying computational results exists a fully integrated postprocessor. Values of required results (displacements, stresses, strains and structural forces) can be also gained from the output tables. All plots and tables can be modify, exported to other software or send to clipboard.

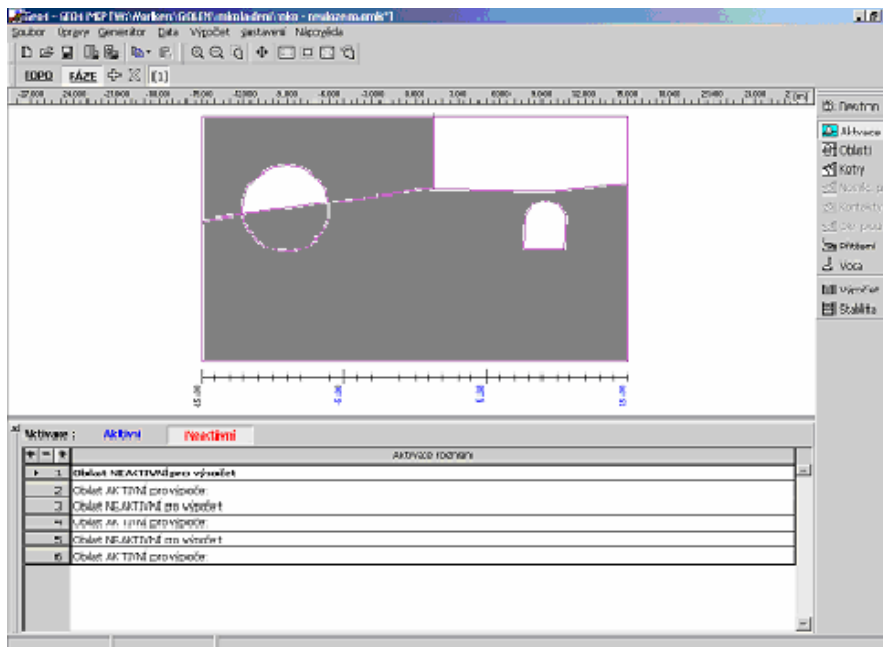


Figure 1. Modelling of the geometry cross section in GEO FEM

3 VALIDATIONS

For the comparison of the GEO FEM program described above we used analytical solution (if available) and results from two commercial products for the solution based on the finite element analysis:

PLAXIS ver. 7.1

Z SOIL ver. 5.76

Validation of the computer simulation was performed on the typical soil mechanics problems. To this paper two examples have been selected. The first example represents slope stability problem and the second example involves a diaphragm wall.

3.1 Slope stability

Fig. 2 depicts the geometry of the first validation example (height of slope varies from 7 m to 14 m), a natural slope stability in a homogeneous media, and Table 1 contains a list of the material parameters. For the analysis the following general assumptions were considered:

- Plane strain conditions.
- Linear elastic and perfectly plastic material with the Mohr-Coulomb and Drucker Prager failure criterion.
- The slope safety factor is defined as the factor of reduction applied to the yield surface coefficients when failure occurs.
- For a homogeneous medium the critical height of the cut is independent of the dilatancy angle ψ .
- The initial stress state was set to $\sigma_v = \gamma H$, $\sigma_h = K_0 \gamma H$.

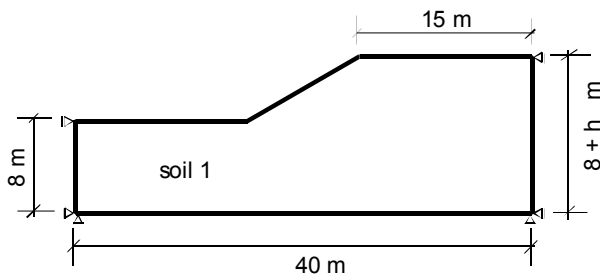


Table 1. Material parameters for „slope stability example

		Soil 1	Soil 2	
Young modulus	E	5000	10000	[kPa]
Poisson ratio	ν	0,3	0,35	[-]
Weight	γ	24	18	[kN/m ³]
Cohesion	c	20	5	kPa
Friction angle	ϕ	10 – 30	10/30	[°]
Dilatancy angle	ψ	0	0	[°]

Figure 2. Geometry of natural slope stability example

We are focused in this type of problem on the slope safety factor and the displacement field. The displacement field allows a clear identification of the slip surface as shown on Fig. 3 (you can compare the layout of graphical output from the next software on Fig. 4 and Fig. 5). Here it is the localization of the strain field which is indicative of the failure. The results for two selected soils are in Table 2.

Table 2. Comparison of results for „slope stability“ example

Type of soil	h	ϕ	Sarma	Bishop	Petterson	Z-Soil M-C	Z-Soil DP	Plaxis M-C	GEO FEM M-C	GEO FEM DP
1	7	10	1,3	1,22	1,18	1,21	1,19	1,22	1,31	1,20
2	7	10	0,68	0,66	0,63	0,71	0,69	0,68	0,73	0,66
1	7	20	1,72	1,65	1,58	1,64	1,59	1,65	1,71	1,61
2	7	20	1,06	1,02	0,98	0,95	1,2	0,99	1,17	1,08
1	7	30	2,17	2,08	1,99	1,98	1,8	2,09	2,19	2,00
2	10,5	10	0,46	0,45	0,43	0,46	0,43	0,44	0,48	0,43
1	10,5	10	0,89	0,84	0,82	0,83	0,81	0,85	0,91	0,82
2	10,5	20	0,71	0,69	0,70	0,71	0,69	0,71	0,73	0,66
1	10,5	20	1,20	1,15	1,11	1,14	1,04	1,17	1,18	1,10
2	10,5	30	0,97	0,95	0,92	0,98	0,91	0,97	1,03	0,81
1	10,5	30	1,53	1,47	1,42	1,52	1,44	1,45	1,54	1,46
2	14	10	0,34	0,33	0,35	0,34	0,32	0,35	0,35	0,31
1	14	10	0,63	0,60	0,59	0,61	0,59	0,59	0,63	0,60
2	14	20	0,54	0,53	0,51	0,54	0,50	0,53	0,59	0,48
1	14	20	0,87	0,84	0,82	0,84	0,81	0,82	0,86	0,82
2	14	30	0,75	0,74	0,71	0,75	0,72	0,74	0,73	0,66
1	14	30	1,11	1,08	1,05	1,07	1,03	1,06	1,10	1,05

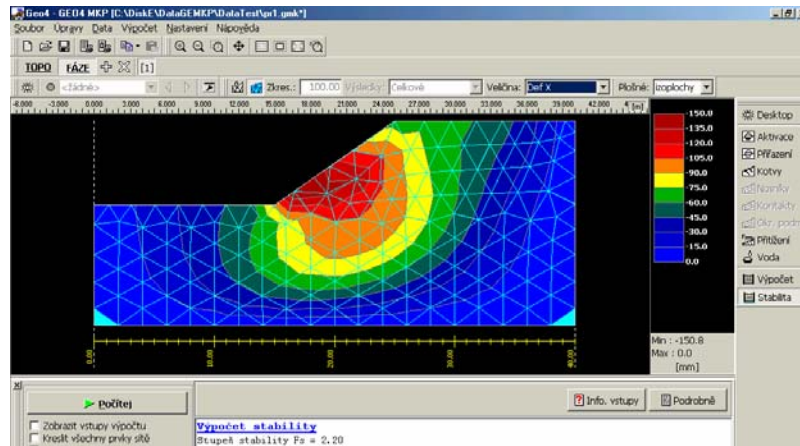


Figure 3. Results after analysis (displacement field) in GEO FEM

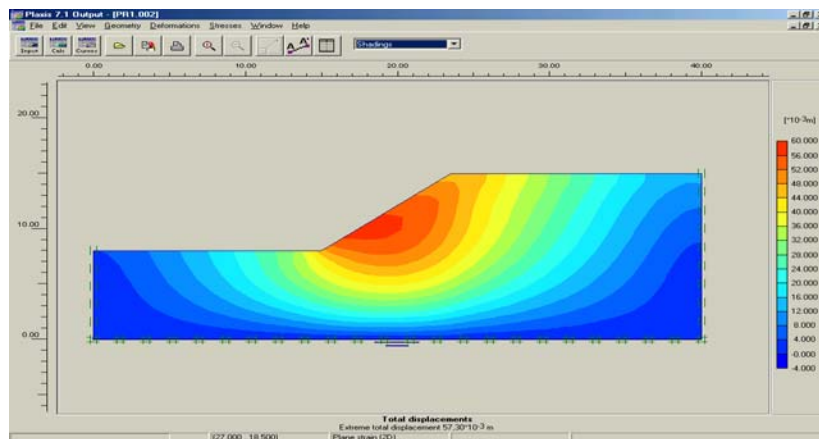


Figure 4. Results after analysis (displacement field) in PLAXIS

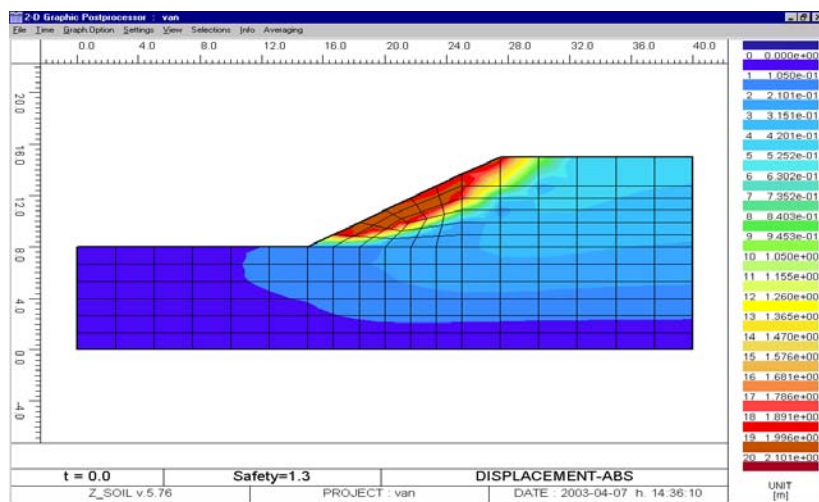


Figure 5. Results after analysis (displacement field) in Z-SOIL

3.2 Diaphragm wall

Figure 6 illustrates the geometry and the excavation stages analysed in this example. In the Table 3 are relevant parameters for the “diaphragm wall” example. Following assumptions are as follows:

- Plane strain conditions.
- Linear elastic – perfectly plastic analysis with Mohr – Coulomb failure criterion.
- Between the diaphragm wall and the ground is perfect bonding.
- Initial stresses were established without the wall.
- Diaphragm wall was modelled using beam elements.
- Struts (rigid members) fixed the horizontal degree of freedom.
- The initial stress state was set to $\sigma_v = \gamma H$, $\sigma_h = K_0 \gamma H$.

- The excavation process includes the following construction stages:
- Construction stage 1: First layer of soil is removed to a level of –4.0 m.
 - Construction stage 2: Excavation step to a level of –8 m, and strut at level of –3 m is installed
 - Construction stage 3: Final layer of soil is removed to a level of –12 m, and strut installed at – 7.0 m.

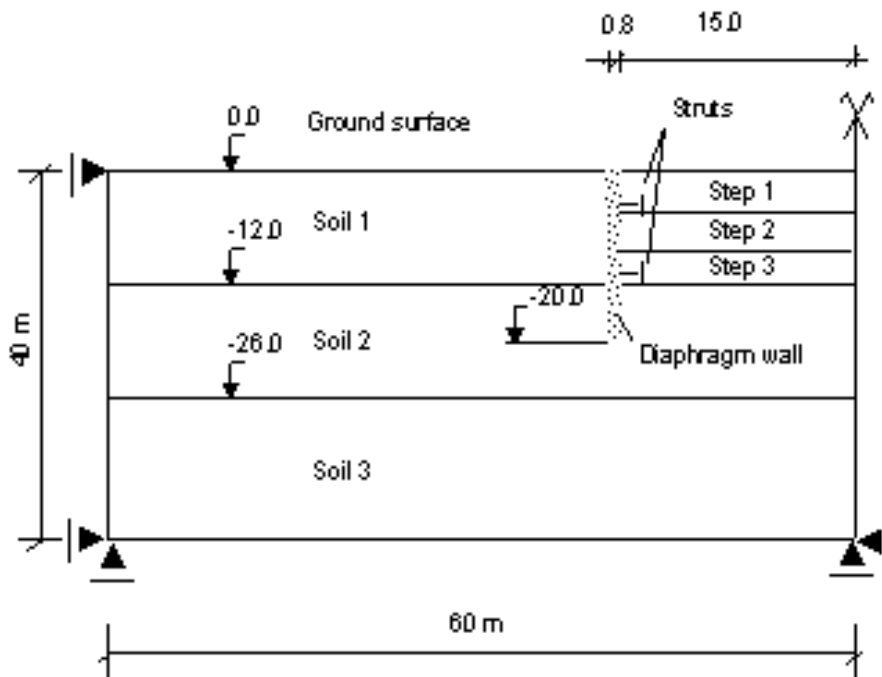


Figure 6. Geometry of the “diaphragm wall” example

Table 3. Material parameters for “diaphragm wall” example

	E [kN/m ²]	ν	ϕ [°]	c [kN/m ²]	γ [kN/m ³]
Soil 1	20 000	0,3	35	2,0	21
Soil 2	12 000	0,4	26	10,0	19
Soil 3	80 000	0,4	26	10,0	19

The results for the vertical displacement of surface behind the wall (the construction stage 1 and final) are in Figure 7. It is apparent from the Figure 5 that GEO FEM gives higher values for the vertical displacement in the final stage of the construction, but the results are evenly distributed between the limiting values. Significant differences were not observed in the horizontal displacement of the bottom of the wall, the heave inside the excavation and the earth pressure distributions. It is known, that elasto-perfectly plastic constitutive model is not perfect for the modeling surface displacement behind the high wall, but for the comparison of the program behaviour it is unimportant.

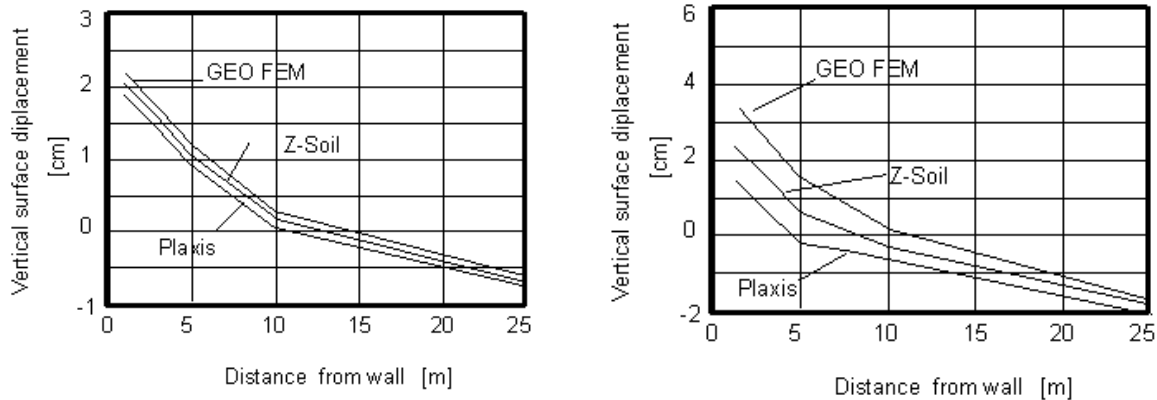


Figure 7. Vertical displacement of surface behind wall (on the left construction stage 1, on the right final stage)

4 CONCLUSIONS

It was not the aim of this research to compare results with actual field observation, but principally to see what differences are obtained when using for the models under defined conditions commercial softwares based on the finite element method. To study the behaviour of the software sample examples has been prepared. These examples modelled for instance slope stability, cut stability analysis, initial state analysis, load carrying capacity, excavation of the tunnel, cut and cover tunnel. In this paper are mentioned in brief only two examples. For the problems of stability of the natural slope we can say, that the associated safety factor corresponds to the one obtained by the $c - \phi$ reduction algorithm (comparison with classical methods). As compared to FEM approaches, the plasticity based on Drucker Prager appears to yield comparable results. Generally numerical methods are more flexible when more general slip surfaces occur. In the case of the diaphragm wall the results are not explained in detail. Significant differences were not found, bending moments varies within 32%, results are the distribution in the limiting values. For the deep excavations we observed short growth in the limiting values, but not so significant. From comparison with results from Plaxis and Z-Soil we can say that GEO FEM can give satisfactory results

5 REFERENCES

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