BULLETIN

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IN THIS ISSUE:

Editorial

It has been quite some time since the previous Plaxis Bulletin. Many things have happened in between, among which the move of the Plaxis company to its new office in Delft, the release of the Dynamic module and the development of the 3D tunnel program.

About 75 persons attended the celebration of the new Plaxis location in the BTC building at Delftechpark 26 in Delft, The Netherlands. Some words were spoken about the past and, more important, about the future of Plaxis. It was a good occasion to 'rethink the future'. A strategic long-term plan was formulated which required new staff to join the company. At the moment the Plaxis company employs 9 persons (9 fte) whereas in June 1999 only 5 persons were employed. The contents of this strategic plan are presented under New Developments in this edition. From the plan it is clear that new developments in advanced analysis are required, like advanced constitutive modelling and 3D calculations, to cope with the state of the art in science and the daily practice of high-end consulting.

Some of the developments of the Plaxis program are executed as CUR projects. The final report of the work of the latest CUR committee has just been published (see further in this bulletin). This publication describes the scientific as well as the practical backgrounds on recently implemented Plaxis features.

By the time you receive this bulletin, the Dynamics module will be available. The dynamics module, developed a.o. in co-operation with Université Joseph Fourier, Grenoble (F), enables the modelling of single source vibrations as well as earthquake motion. An example of a project in which dynamic loads and vibrations are of great importance is described in the Plaxis Practice section.

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Column Vermeer

Soil mechanics is by no means an easy subject of civil engineering. It focuses first of all on the stability of foundations and earth structures and one thus needs a good knowledge of limit equilibrium. In this „Coulomb line" of thinking one can deal with problems of bearing capacity, ultimate pressure on walls, slope stability etc. Besides stability analyses, soil mechanics is oriented towards settlements and displacements. Even when considering basically simple problems of one-dimensional compression, soil mechanics now involves non-linear laws of compressibility.

I have no difficulties in teaching the above to my students, but I do find it difficult to combine these various different topics with groundwater considerations, as it increases the complexity considerably. However, many problems of stability and settlement do involve pore pressures and we thus have to teach Terzaghi's principle of effective stress already in undergraduate courses. I even teach them 1D-consolidation, but I reserve undrained soil behaviour for the graduate students. No doubt, the concepts of undrained shear strength and undrained Young's modulus and their proper use in geotechnical engineering are tricky and need a lot of explanation. Again and again I also notice that Plaxis users do not always fully understand the options of undrained material behaviour. That is why I will try to explain it on the basis of a simple shear test.

To improve the (direct) shear test, Roscoe (1953) devised the Cambridge simple shear apparatus with the purpose of applying uniform stress and strain conditions. Much later the Geonor simple shear apparatus was developed for testing cylindrical samples. Here the sample and the end plates are surrounded by a rubber membrane as also used in triaxial testing. To prevent horizontal straining the membrane is internally reinforced by a fine helical wire. In practical testing stress-strain conditions will never be completely uniform, but for the present purpose I assume uniformity.

In Stuttgart we recently started to do undrained simple shear tests on overconsolidated clay samples. For our particular samples, test results appear to be explained reasonably well by the elementary Mohr-Coulomb model in combination with the standard Plaxis option of undrained behaviour. On consolidating the sample up to a given axial stress we obtain an axial strain

$$\epsilon = \frac{\sigma'}{E'_{oed}} \; , \; E'_{oed} = 2G \, \frac{1 - \nu'}{1 - 2\nu'}$$

For our particular samples of overconsolidated clay, the compression is only slightly non-linear and the above oedometer modulus E_{oed} is a more or less fixed soil property. To avoid any confusion with the so-called undrained Poisson ratio ν^u, the effective one is denoted as ν'. Similar to the Poisson ratio we have an effective oedometer modulus E'_{oed} and an undrained one E^u_{oed}. The latter can be directly measured in a so-called B-test. On loading the sample undrained by an axial (total) stress increment of $\Delta\sigma$, we observe a very small strain increment of

$$\Delta\epsilon = \frac{\Delta\sigma}{E^u_{oed}} \quad \text{or} \quad \Delta\epsilon = \frac{\Delta\sigma'}{E'_{oed}}$$

The better the saturation of the sample the smaller the strain increment. In addition to strain, we measure the excess pore pressure, Δu, to compute the factor $B \equiv \Delta u / \Delta\sigma$. A fully saturated sample would yield $B = 1$, but we obtain lower values of $B \approx 0.95$. In triaxial testing we get better B-values, but in our special type of simple shear apparatus we obtain values from 0.99 down to 0.95. From the above equations it can now be deduced that

$$\frac{E^u_{oed}}{E'_{oed}} = \frac{\Delta\sigma}{\Delta\sigma'} = \frac{\Delta\sigma}{\Delta\sigma - \Delta u} = \frac{1}{1-B}$$

Hence

$$E^u_{oed} = \frac{E'_{oed}}{1-B} \approx 20 \; E'_{oed}$$

at least for our nearly saturated samples with $B \approx 0.95$. On using the measured B-factor, we can also compute the undrained Poisson ratio ν^u. According to the basics of elasticity theory we have

$$E^u_{oed} = \frac{(1-\nu^u)\cdot E^u}{(1+\nu^u)(1-2\nu^u)} = \frac{1-\nu^u}{1-2\nu^u} \, 2G$$

Please note that we have $G = G^u$, i.e. there is no difference between the effective shear modulus and the undrained shear modulus. This statement simply follows from the fact that water cannot sustain any shear stresses, so that all shear stiffness comes from the soil skeleton. Hence we use the notation G without any superscript. On combining equations for E^u_{oed} and E'_{oed}, the constant G drops out and we get

$$\frac{E^u_{oed}}{E'_{oed}} = \frac{1-\nu^u}{1-2\nu^u} \cdot \frac{1-2\nu'}{1-\nu'}$$

Inserting $E'_{oed} / E^u_{oed}, = 1\text{-}B$, it follows that

$$\nu^u = \frac{\nu' + B \cdot (1\text{-}2\nu')}{1 + B \cdot (1\text{-}2\nu')}$$

For full saturation with $B = 1$, this equation yields the logical result of $\nu^u = 0.5$. If there is no pore water at all, i.e. $B = 0$, we get another trivial result of $\nu^u = \nu'$.

It would now be logical that Plaxis requires the input of B, as together with ν' this would give ν^u. Indeed combined with the input of G, it would be possible to perform calculations for undrained elastic soil behaviour. However, to prevent numerical difficulties for nearly incompressible material with $\nu^u = 0.5$, Poisson's ratio is preset to be $\nu^u = 0.495$. The use of a constant undrained Poisson ratio implies a B-factor of

$$B = \frac{\nu^u\text{-}\nu'}{(1\text{-}2\nu')(1\text{-}\nu^u)} \approx \frac{0.98 - 2\nu'}{1 - 2\nu'}$$

For undrained analyses, we thus get a B-factor that depends on ν'. The usual Poisson ratio of $\nu' = 0.33$ yields a nice B-factor of 0.96, i.e. nearly incompressible soil behaviour with $\Delta u = 0.96 \cdot \Delta\sigma$ and $\Delta\sigma'$ only three per cent of the total stress increment. For relatively high values of ν', on the other hand, one obtains poor B-factors. For example, it is found that B is only 0.9 for $\nu' = 0.44$. For this reason, the program does not accept values of ν' beyond 0.35, at least not in combination with undrained soil behaviour.

I consider Poisson ratios around $\nu' = 0.33$ as more or less realistic values for use in the Mohr-Coulomb soil model, as it implies realistic lateral earth pressures in oedometer loading, i.e. coefficients around $K^{nc}_0 = 0.5$. On using more advanced soil models lower Poisson ratios are appropriate, as also used in the standard settings of these models.

From the above considerations it may be clear that Plaxis does not need the input of an undrained Poisson ratio and an undrained Young's modulus. Indeed, the former is simply preset to be $\nu^u = 0.495$ and the latter is automatically computed as $E^u = 2G \cdot (1 + \nu^u)$. If the effective Young's modulus, E', is given instead of the shear modulus, G, then the latter is automatically computed from the relationship $E' = 2G \cdot (1 + \nu')$. Similar to the generation of undrained stiffness properties from effective ones, Plaxis offers such a possibility for the generation of the undrained shear strength from c' and φ'. This option is to be commented in the next bulletin. We then come to the second stage of the simple shear test, i.e. the shearing part.

P.A. Vermeer, Stuttgart University

New Developments

After many years of successful Plaxis developments it was time to rethink the future. In particular, the recent 3D developments require a clear approach in order to maintain the well-known Plaxis concept of robust comprehensive and easy-to-use finite element software. New ideas were formulated in a strategic plan for Plaxis developments in the coming years. Parts of this plan will be described in this article.

With respect to three-dimensional (3D) models it was concluded that such models are significantly more complicated than 2D models and that 3D modeling should be separated from 2D modeling. In addition, to enhance the practical applicability, 3D models should focus on specific types of applications, such as Tunnels, Excavations or Foundations[1]. Hence, although the 2D program always had and will still keep a geotechnics-wide orientation, special programs ('specials') will be developed for specific types of 3D applications. On one hand this concept will restrict the general possibilities of a particular 3D model, but on the other hand it will provide specific options for the type of practical problems it is designed for. This should make the user more comfortable in solving practical 3D problems

1 Vermeer P.A. (1999), On the future of Plaxis. In: Beyond 2000 in Computational Geotechnics - Ten Years of Plaxis International (ed. R.B.J. Brinkgreve). Balkema, Rotterdam.

without the need of going through all the possibilities of a general-purpose tool.

Nowadays, engineers are increasingly being involved in tunnel design, both on NATM types of tunnels in hard soils or rock and on TBM-driven tunnels including shield tunnels. These types of applications often require a 3D analysis (bore front stability, partially unsupported excavation, spatial arching, anisotropic rock behaviour). The 3D developments of the last two years, based on an extension of a 2D mesh in z-direction, are very suitable for tunnel analyses. Hence, these developments will become available soon as a Plaxis 3D Tunnel special. This first version of a new product line will have dedicated options to model 3D aspects around bored or NATM type of tunnels, but creative users may discover many other applications beyond the scope of tunnel analyses. Besides a program for tunnel analyses, other 3D programs will be developed in the future for specific types of practical problems.

With respect to the 2D line, additional modules (add-on's) are planned. Recently we released a new module for dynamic analyses (vibrations and earthquakes) and we are working on a module for user-defined soil models. Further more, development is planned in the groundwater flow module in order to improve the robustment of steady state flow calculations and to cope with transient and unsaturated conditions.

User-defined soil models is one of the developments toward Plaxis Version 8 (2D). This feature enables users to include self-programmed soil models in the calculations. Although this option is most interesting for researchers at universities and research institutes, it may also be interesting for practical engineers to benefit from this work. In the future, validated and well-documented user-defined soil models may become available on the Internet.

The Plaxis development strategy is presented in Fig. 1.

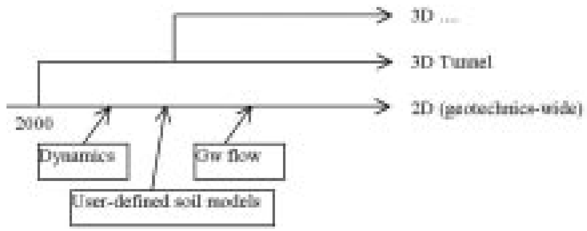


Figure 1. Plaxis development strategy

The figure clearly shows that, after the former Plaxis developments, that were concentrated around one product, there will be different products in the future, all based on the well-known Plaxis concept of robustness, user-friendliness and adequate user-support.

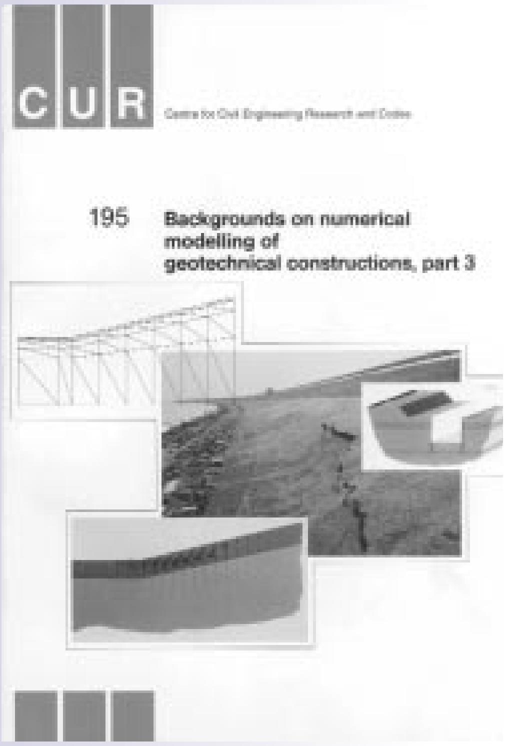
Ronald Brinkgreve
Plaxis BV

Recent activities

In May this year the special publication "Backgrounds on numerical modeling of geotechnical constructions, part 3, NR 195" was released as the final report of the CUR C113 Plaxis phase 3 committee. Previous publications with a similar title (in Dutch) were released in 1995 (part 1, NR 178) and in 1997 (part 2, NR 191)

This third publication describes most Plaxis developments in the years 1997-1999. In this publication descriptions are given of 3D finite element models, extension and improvement of constitutive models, submergence of soil and the determination of model parameters. For the latter, correlations to generally accepted methods of soil investigation are presented as well as a design philosophy about the relation between constitutive models and soil investigation.

In addition, a number of geotechnical case studies are included in which Plaxis was used, for example the construction of a lock, the extension of a road embankment, the water pressure distribution underneath a hydroelectric power plant, the stability and time-dependent behavior of a river embankment and a 2D and 3D analysis of the stability of a diaphragm wall excavation.



CUR ("Center for Civil Engineering Research and Codes") is an independent, non-profit organization that is involved in the development, acquisition and transfer of knowledge and experience in the broad field of civil engineering. CUR coordinates joint research projects with public and private parties. The results are disseminated to the users through the publication of reports, recommendations and codes of practice and through the organization of seminars.

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Plaxis Version 7.2

Some additional refinements and the release of the Dynamics module this year have resulted in Plaxis Version 7.2. The Dynamics module is an optional module that can be purchased at your local dealer, for more information send an email to info@Plaxis.nl. The update from Version 7.12 to Version 7.2 is free available on the Internet at www.Plaxis.nl ('user services'). Please note that the update does not include the Dynamics module.

Plaxis in China

On request by the Worldbank, the Dutch Ministry of Public works organised a seminar on Dutch design and engineering methods for river embankments. This in relation with the Yangtze Dike Strengthening project in China. The project includes (a) rehabilitation of 600 km of main dikes and associated structures on the middle reach of the Yangtze River; (b) rehabilitation of the river embankment; and (c) upgrading of flood emergency management and advanced flood forecasting systems. One of the topics during this seminar included a presentation of design and analysis tools, such as Plaxis.

Other on-going cooperation projects between the Dutch and Chinese recently resulted in a Plaxis course given at Hohai University in Nanjing. Some 25 participants attended, mainly from government organisation like the China Institute of Water resources and the Changjiang Water resource commission, but also from Universties like Hohai, Tsinghua and Zhejiang University.

One of the main lecturers in the course was Prof. Er-Xiang Song, who obtained his Phd from Delft University in 1990, where he also worked in the Plaxis team.

Plaxis Practice

MODELING OF A REINFORCED SOIL WALL SUBJECT TO BLAST

1. Introduction

A field experiment on explosive testing of a geotextile reinforced soil wall was carried out in Singapore. The objective of this field experiment is to study the dynamic behaviour of the reinforced soil wall subject to blast. Three total pressure cells were installed in the wall to measure the increase in horizontal stress in the soil during blast. Figure 1 shows the geometry of the geotextile reinforced soil wall as well as the location of the total pressure cells. The measurement by the total pressure cells provides a good understanding of the dynamic response of the reinforced soil wall.

This report presents a finite element modeling of the geotextile reinforced soil wall using Plaxis version 7.12. The blast loading on the wall front was simulated using the newly implemented Dynamic Module in the program. The results from the program are compared with the field results in order to evaluate the performance of the program. Two blast events with blast loading of different magnitudes, one with peak pressure of about 180kPa and the other with peak pressure of about 130kPa were modeled with Plaxis and then compared with the field results.

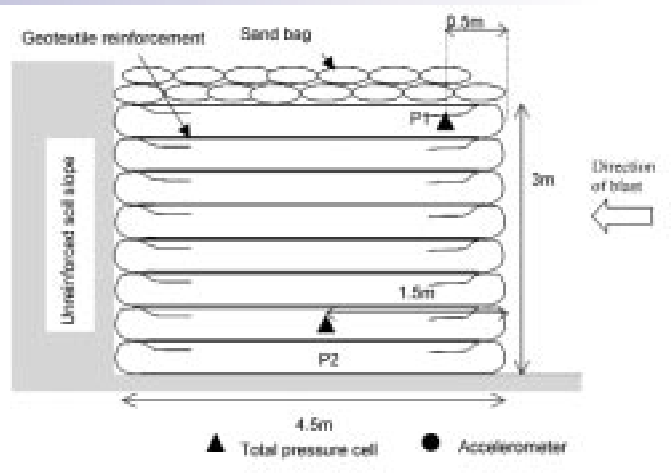

Figure 1 Side elevation of reinforced soil wall with instrument locations (not to scale)

2. Modeling of a Reinforced Soil Wall with the Plaxis Dynamic Module

2.1 Geometry of the Model

The geometry of the geotextile reinforced soil wall model is shown in Figure 2. The height of the wall is 3m and the width of the reinforcement is 4.5m. The vertical distance between the geotextile reinforcement is 0.3m. The facing wall was wrapped around with geotextile reinforcement. The boundaries are far enough so that they will not influence the results.

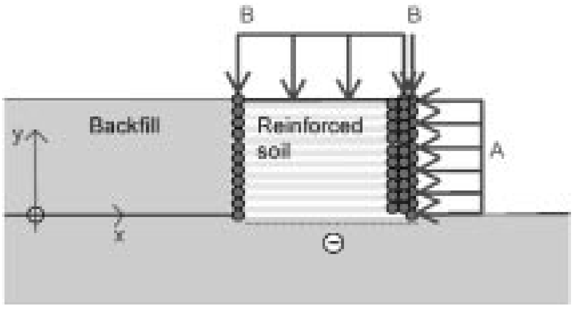

Figure 2 Geometry of the geotextile reinforced soil wall

2.2 Material Properties

Singapore residual soil was used as backfill material for the reinforced soil wall. The soil behind the reinforced soil was also Singapore residual soil but with slightly different soil properties. The material model used for both soil types is Mohr-Coulomb model. The properties of these two Mohr-Coulomb soil models are shown in Table 1. The geotextile used in the model has an equivalent axial stiffness (EA) value of 1200 kN/m.

Table 1 Properties of Mohr-Coulomb soil model

Type	γ_{dry} (kN/m³)	γ_{wet} (kN/m³)	E_{ref} (kN/m²)	k_x / k_y (m/ms)	c_{ref} (kN
Reinforced Soil	16	20	$2.2x10^5$	$1.1x10^{-5}$	25
Backfill	17	20	$2.2x10^5$	$1.1x10^{-5}$	30

2.3 Dynamic Analysis

A dynamic analysis of two different blast events was carried out. The blast pressure acting on the wall was simulated by applying an uniformly distributed load A on the wall front, which instantaneously increased in magnitude to its peak value and then gradually decreased to zero after a certain duration (Yogendrakumar and Bathurst, 1993). The magnitude of the uniformly distributed load A was made to vary with time by applying a total multiplier of varying magnitude with time based on an input text file. Figure 3 shows the blast pressure-time histories for the two events. The blast pressure-time history acting on the boundary of the reinforced soil wall was determined by means of an approximate method based on some empirical charts and equations (Bulson, 1997 and Baker 1983).

A special type of boundary conditions have been defined to account for the fact that in reality the soil is a semi-infinite medium. This is the absorbing boundary condition which absorbs the increments of stresses on the boundaries caused by dynamic loading, that would otherwise be reflected inside the soil body and create unrealistic results. To account for material damping Rayleigh damping coefficients α and β are set to 0.01.

f l/m²)	φ (°)	Ψ (°)	R_{inter}
	35	0	Vary
	38	0	Vary

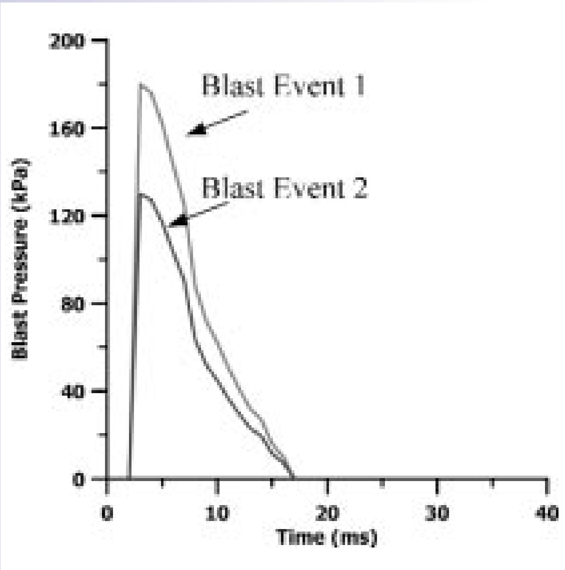

Figure 3 Blast pressure-time history for the two blast events with different peak pressure

The sequence of all calculation steps used in the analysis is as follows:

Phase 1: Generate initial stress condition.
Phase 2: Apply surcharge on top of the reinforced soil wall (Total multiplier).
Phase 3: Nil-step (Staged construction) to balance unbalanced forces.
Phase 4: Dynamic analysis (Total multiplier).

3. Comparison of the Results between Plaxis and a Field Experiment

Figure 4 shows the total stress state of the model after blast loading. Figures 5 through 8 show the horizontal stress variation with time during blast event 1 and 2 calculated with Plaxis and from the field results for location P1 and P2.

Figures 5 and 7 show that for the dynamic pressure response at location P1, the numerical results obtained from the Plaxis Dynamic Analysis program generally agree with the field instrumentation results. The peak pressure at location P1 from the numerical results is slightly higher than the field instrumentation results. The peak dynamic pressures at P1 are approximately 130kPa and 110kPa as observed from numerical and field instrumentation results respectively for blast event 1. The peak dynamic pressures at P1 are approximately 175kPa and 156kPa as observed from numerical and field instrumentation results respectively for blast event 2. Nevertheless, the dynamic pressure responses at P1, as observed from numerical and field instrumentation results for both events are almost similar. The dynamic pressure responses for different values of interface reduction factor (R_{inter}) are similar, which means that dynamic pressure response at location P1 is independent of R_{inter}. Both Plaxis and the field results show that the dynamic pressure in the soil dissipates to zero after the blast.

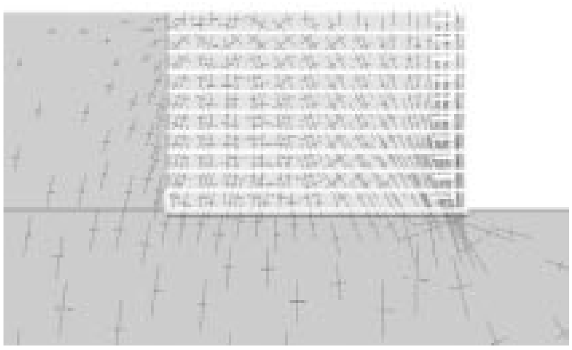

Figure 4 Typical total stress state of the model after blast loading

Figures 6 and 8 show that the dynamic pressure response at location P2 is dependent on R_{inter}. The peak dynamic pressure varies from approximately 90kPa to 50kPa when R_{inter} varies from 0.3 to 0.9. However, there is not much difference between the peak dynamic pressures when R_{inter} changes from 0.7 to 0.9. Plaxis results show that there is residual stress in the soil at location P2, whereas field results show no residual stress after blast. This could be due to the fact that the total pressure cells in the field were unable to measure residual stress in the soil after blast. The total pressure cells might have lost contact with the soil after the blast. This residual stress in the soil at location P2 also varies with R_{inter}. It varies from approximately 20kPa to 7kPa when R_{inter} varies

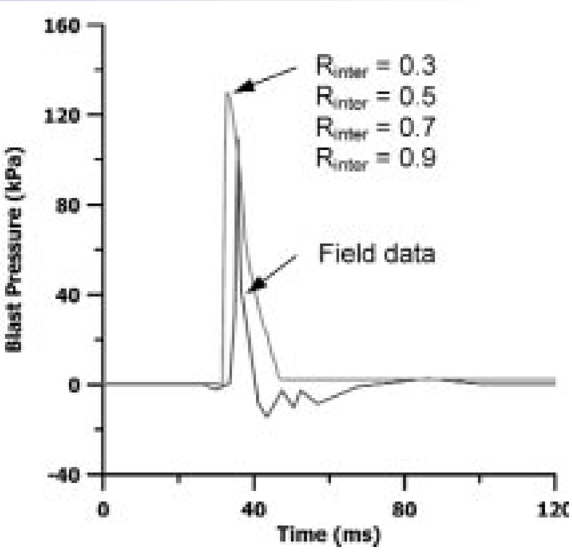

Figure 5 Horizontal stress variation with time during blast event 1 for location P1

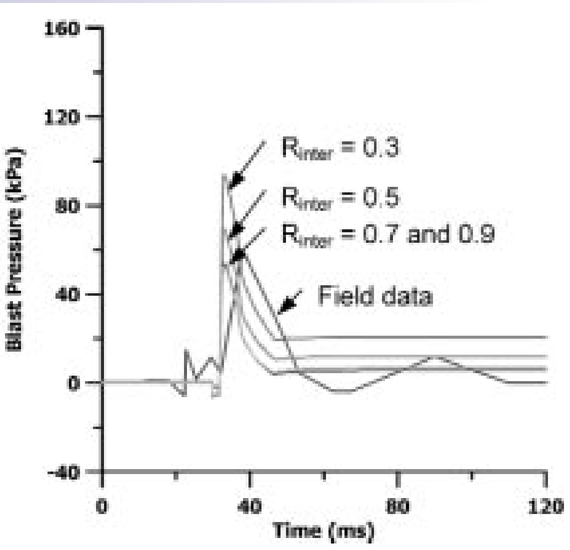

Figure 6 Horizontal stress variation with time during blast event 1 for location P2

from 0.3 to 0.9. Again, there is not much difference between the residual stresses when R_{inter} changes from 0.7 to 0.9. As observed from Figures 6 and 8, the appropriate value of R_{inter} to be used for this problem shall be between 0.5 to 0.7.

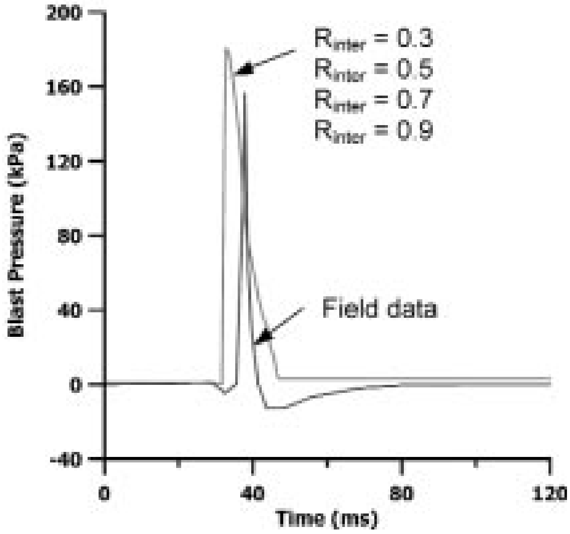

Figure 7 Horizontal stress variation with time during blast event 2 for location P1

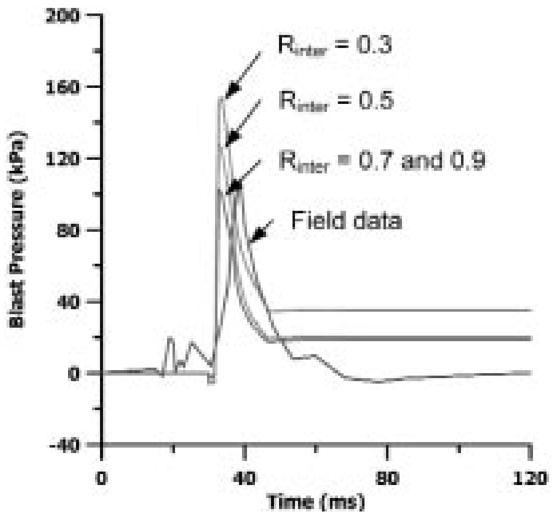

Figure 8 Horizontal stress variation with time during blast event 2 for location P2

4. Conclusion and Recommendation

The dynamic response of a geotextile-reinforced earth wall structure was studied using the new Plaxis Dynamics Module. Despite the difficulty of modeling the exact details of the problem, the program is able to produce results that match reasonably well with the lateral stress measurements at two different locations of the reinforced soil mass for two separate blast events. For the stress point close to the base of the wall, the interface element plays a very crucial role to model realistic soil slippage between the earth wall and the original ground, which is reflected in the matching of the stress response for this location P2. Though exact matching is not possible, the overall trend of stress increase and dissipation with the blast loading is adequately shown in the calculations. This shows that Plaxis Dynamic Module is able to model the dynamic response of a reinforced soil wall subjected to blast loading.

Authors: Assoc. Prof. Tan Siew Ann, Asst. Prof. Chew Soon Hoe, Mr. Ng Chew Chiat
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Users Forum

Projects that have been analysed before are often re-used for various reasons. When modifying existing projects it is sometimes unclear to what extend the finite element data or calculation data has to be re-generated or re-defined. In this user forum we like to give more insight in these aspects.

There may be a number of reasons why existing projects are re-used:

- To adapt the design
- To include more detail in the model
- To make solutions more accurate
- To perform a parameter study
- To add new calculation phases (intermediate construction stages, consolidation phases or safety factor calculations)

The first four points will be discussed now, the last point will be discussed in the next Bulletin.

In case of the first four points, one can go to the input program and apply a refinement of the mesh, a change in the geometry, a modification of material data sets (or introduce new sets) or apply a different loading or boundary condition. The question is: What data has to be re-generated and what would be the effect on the calculation list? The following possibilities are considered.

A) Changes in the geometry or mesh refinements.

- If the geometry has been changed, which is the case when new geometry points have been entered or old points have been adjusted, then the finite element mesh has to be re-generated. Note that double clicking on a Geometry point is already considered as a possible change of coordinates. One has to be cautious now, because all construction phases are reset and one has to re-define the phases involving staged construction, including a regeneration of water pressures, if applicable.
- If the mesh is re-generated in order to obtain a mesh refinement (global and/or local) without changing geometry points, then all construction phases are also reset and they have to be re-defined, including water pressures, if applicable.

Note that after mesh generation the initial situation is reset to a situation in which all elements are active. If this is not desired, then the proper initial configuration should be restored before generating the initial stresses.

B) Changes in the input that do not require a re-generation of the mesh:

- No mesh re-generation is required when only point forces or traction loads are entered on existing geometry points, or when new input values are assigned to loads. Similar to loads, fixities can be changed in the input, without the need to re-generate the mesh. Simply save the input after changing the data and continue the calculation. It is important to follow the tool bar in the normal way instead of using the general button in the upper left corner to proceed to the calculations program.

- If the parameters of existing material data-sets are changed without re-assigning the data-sets, then there is no need to re-generate the mesh. Save the input after changing the data-sets and proceed to the calculation in the normal way. Be careful if the weight of a material set is changed and that material set is initially used, then the initial stresses must be re-generated.

re-define or re-generate	A	B
Water pressures	yes	no
Initial geometry configuration	yes	no
Initial stresses (K0-procedure)	yes	no*)
Staged construction (SC) phases:		
Geometry configuration	yes	no
SC phases: Material data sets assignment to clusters	yes	no
SC phases: New water pressure distribution	yes	no

**) yes, in the case that the weight of soil layers that are initially present is changed.*

It can be concluded that for situation A water pressures and initial stresses have to be re-generated and construction stages have to be re-defined before the project is re-calculated. For situation B no further changes have to be made and the project can directly be re-calculated.

Parameter studies

It is possible to perform parameter studies with Plaxis in order to see the influence of small variations of model parameters. A change of parameters can be achieved by modifying an existing material data set or by creating a new set and assigning the new set to the corresponding clusters. In the latter case it must be noted that when new data sets are assigned to clusters in the initial state, these data sets are not automatically assigned to the clusters in staged construction phases. This has to be done for each individual construction stage manually. Hence, the most efficient way to perform parameter studies is to copy the full Plaxis project and modify the parameters in the existing data sets.

Question:

Some calculation phases contain many intermediate steps that I'd like to analyze. How can I get access to all the calculation steps?

Answer:

To analyse an intermediate step you have to switch off the (default) option 'delete intermediate steps' in the calculations program under parameters. For a consolidation, phi-c or dynamics calculation the option 'delete intermediate steps' is already switched off by default. Start Plaxis Output and choose 'open' from the 'file' menu. You will see a file requester (figure 1a) in which you can choose a project and a list of the number of phases. By clicking on the header 'phase' this list will change in the number of existing calculation steps (figure 1b). Now the desired step can be selected. See also Reference Manual page 5-5.

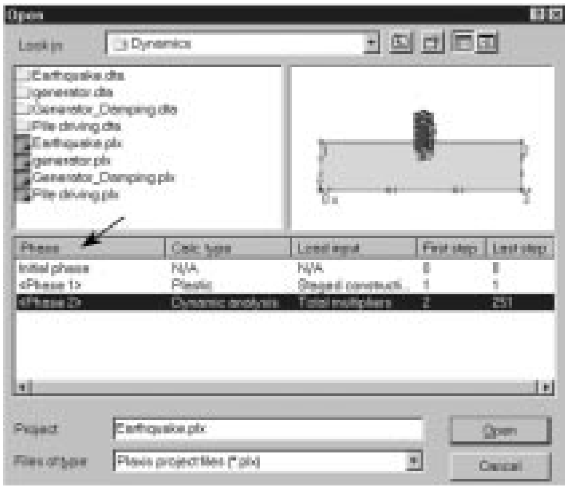

Figure 1a File requester with the number of phases shown

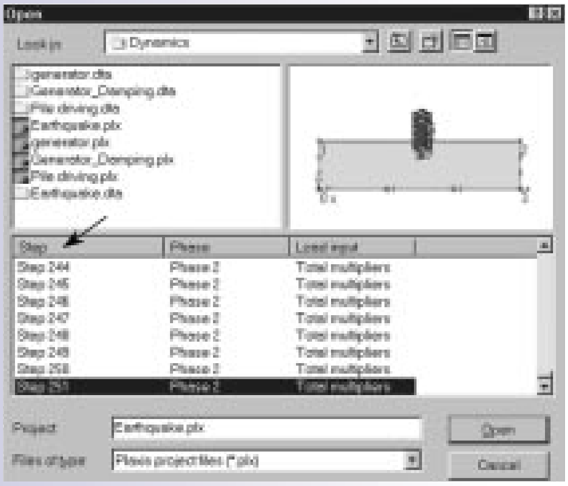

Figure 1b File requester with the number of steps shown.

Question:

Can I define a cohesion increasing with depth?

Answer:

If the Linear-Elastic, Mohr-Coulomb or Hardening Soil model is used, a user defined cohesion increment $c_{increment}$ can be assigned in a soil material dataset.

A reference cohesion c_{ref} (kN/m^2) should be defined at a reference level (depth) y_{ref} (m). y_{ref} defines from what reference level (absolute depth) the cohesion c_{ref} should increase with increment $c_{increment}$ (kN/m^2/m) per meter depth. The cohesion above the reference level y_{ref} has a constant value cref.

Apart from a cohesion increasing with depth also a stiffness increasing with depth can be defined in the same way for the Linear-Elastic and Mohr-Coulomb model. The stiffness starts to increase from E_{ref} at the same reference level y_{ref} with $E_{increment}$ (kN/m^2/m) per meter depth.

For example: Consider the situation in figure 2. The clay layer in cluster 1 and 2 (figure 2) has a reference level y_{ref} at -5.0 m, a c_{ref} of 10.0 kN/m^2 and a cohesion increment $c_{increment}$ of 1.0 kN/m^2 per meter. The deep clay layer in cluster 3 has a reference level y_{ref} at -15.0 m, a c_{ref} of 50.0 kN/m^2 and a cohesion increment $c_{increment}$ of 2.5 kN/m^2 per meter.

From the top (y=0.0 m) to a depth of -5.0 m the cohesion is equal to c_{ref} = 10.0 kN/m^2 (the reference level y_{ref} is at -5.0 m). At a depth of -15.0 m the cohesion is 10.0 + 1.0 * 10.0 = 20.0 kN/m^2 for the clay layer (figure 3).

The cohesion in the deep clay layer at -15.0 m is 50.0 kN/m^2, at the base of the geometry (y=-20.0 m) the cohesion is 50.0 + 5.0 * 2.5 = 62.5 kN/m^2.

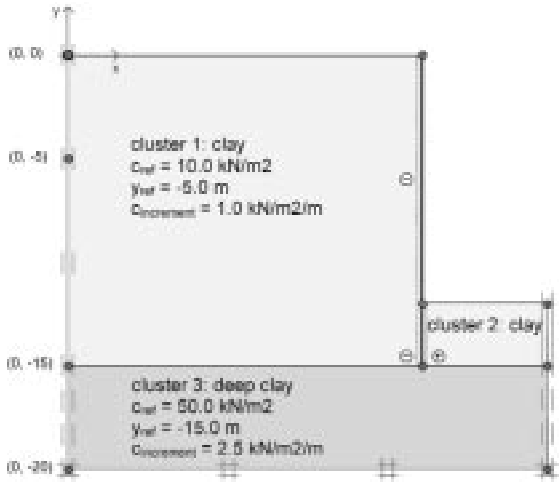

Figure 2 Geometry with two clay layers and their parameters.

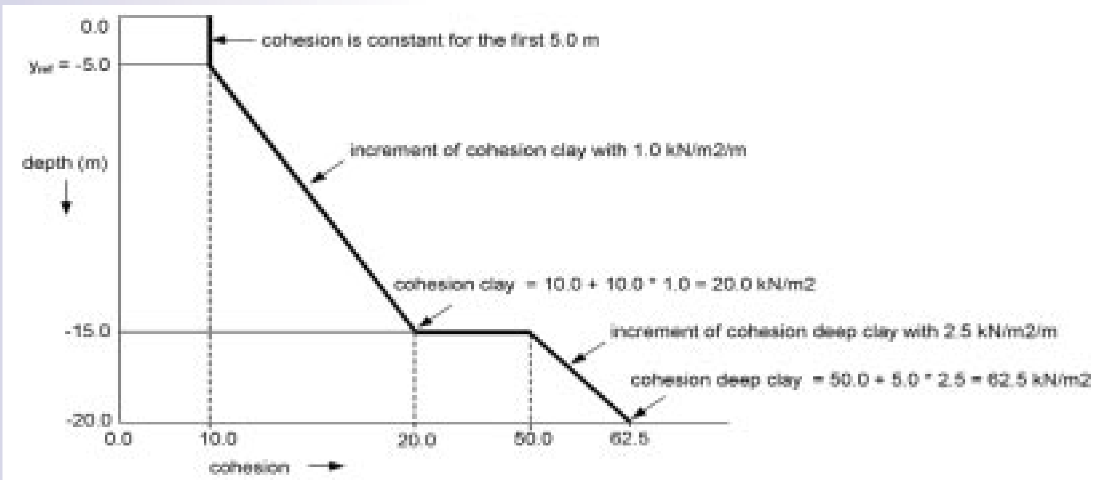

Figure 3 Increment of cohesion with depth.

PLAXIS

ACTIVITIES

OCTOBER, 2000

Plaxis workshop (English)
Buenos Aires, Argentina

18-20 OCTOBER, 2000

Short course on Computational Geotechnics (French)
'Pratique des éléments finis e Geotechnique'
Paris, France

OCTOBER, 2000

Workshop of Dutch Plaxis Users Association (Dutch)
Delft, the Netherlands

1-3 NOVEMBER, 2000

Plaxis Workshop (English)
El Ain, United Arab Emirates

9-10 NOVEMBER, 2000

European Plaxis Users meeting (English)
Karlsruhe, Germany

20-22 NOVEMBER, 2000

Plaxis workshop (English)
Trondheim, Norway

22-24 JANUARI, 2001

Short course on Computational Geotechnics (English)
Noordwijkerhout, The Netherlands

19-21 MARCH, 2001

Short course on Computational Geotechnics (German)
'Finite Elementen Anwendungen in der Grundbaupraxis' Stuttgart, Germany

26-29 MARCH, 2001

International course for experienced Plaxis users (English)
Noordwijkerhout, The Netherlands

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