Should We Upgrade to *Phase²* 6.0?

Rocscience has released version 6.0 of Phase², the popular two-dimensional finite element program for analyzing and designing surface and underground excavations in rock and soil.

For current users, as well as others who are considering purchasing the program for the first time, this article describes new features in version 6.0 that will provide compelling reasons for you, the geotechnical professional, to acquire this new program, expanding your analysis capabilities.

Introduction

The origins of geotechnical engineering can be traced to antiquity, but as an identifiable discipline of engineering it was born in the 1920's. It has experienced significant advances since its inception, and continues to advance rapidly today. *Phase²* 6.0 was developed as a result of new geotechnical knowledge and advances in finite element technology, for the purpose of helping engineers improve their understanding and prediction of behaviour. As well, it was created to address user requests for features, which enhance productivity and engineering creativity.

Because the new and improved *Phase²* 6.0 resulted from progress in the field, and in response to the wishes of geotechnical professionals, it is a useful tool for most excavation designers. It will allow you to develop solutions that are more reliable and innovative than was previously possible. From the new shear strength reduction (SSR) method of slope analysis and integrated finite element groundwater module to new excavation support models and expanded set of strength models (especially for soils), *Phase²* 6.0 is truly the most complete software solution ever developed for practical, every day excavation engineering, as well as for the rare, unique and complex problem.

The new version provides more design and analysis capability than its predecessor and other competing products on the market. It enhances its already outstanding model building and modification functionalities. This is why we believe that *Phase²* 6.0 will satisfy the modelling requirements of a variety of geotechnical engineers.

The rest of this document will outline the engineering philosophy governing the development of *Phase²* 6.0, and briefly describe a few of its major features.

The Engineering Philosphy of *Phase*^{2} 6.0

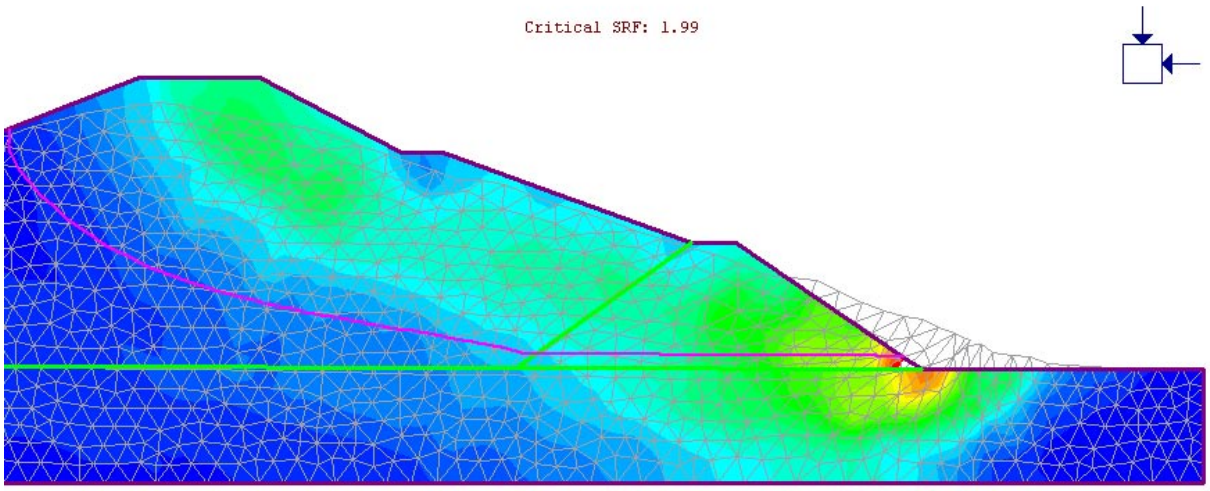
Geotechnical engineers deal with materials manufactured by nature over vast time spans. These materials are highly variable, and their behaviour is not readily captured by theoretical models. From very limited observations, engineers infer sub-surface conditions and properties of these materials. Uncertainty and risk, as a result, are central to the geotechnical profession.

Geotechnical engineers cope with uncertainty by analyzing problems under the conditions most likely to occur, and then examining behaviour in worst-case scenarios. They use numerical modelling mainly as a tool for gaining insight, and for exploring trade-offs and alternative solutions. They also stay alert to situations or outcomes not previously considered, which modelling can uncover.

Phase^2 6.0 was designed with this geotechnical engineering philosophy in mind. Its developers sought to create a tool that helps engineers to clarify, analyze, probe, and explore both conventional and unorthodox ways of understanding behaviour. Its features, a few of which are described next, were intended to facilitate stimulating inquiry, and to assist engineers bring ideas to life.

Some Key Features of *Phase*^{2} 6.0

In the next few sub-sections, we will describe some of the main additions made to *Phase*^{2} 6.0. These features provide compelling reasons to purchase or upgrade to this new version.



Shear Strength Reduction analysis of dam.

Shear Strength Reduction Analysis

The Shear Strength Reduction (SSR) method is a technique that enables the stability of slopes to be evaluated with finite element analysis. The concepts and steps of SSR analysis are very simple. The factor of safety of a stable slope is determined by:

- First developing a finite element model of the slope
- Reducing the shear strength envelopes of slope materials by a factor
- Re-computing the analysis with the reduced strength parameters

The shear strength reductions are carried out until model computations do not converge to results. The critical reduction factor at which non-convergence begins to occur is assumed to be the factor of safety. *Phase²* version 6.0 highly automates SSR procedures for calculating factors of safety. In some cases, the tool is even easier to use than conventional limit-equilibrium analysis.

The SSR method has certain advantages over limit-equilibrium methods of slope stability analysis. Whereas the latter can be awkward for analyzing stability problems that involve failure by deformed wedges, as occurs in cases such as cantilever and retaining walls, the SSR method seamlessly handles such mechanisms.

Additional advantages of the SSR include its ability to model stresses and deformations, ability to consider the history of slope formation, and no prior assumptions on the shape or location of failure surfaces. Unlike limit-equilibrium methods, SSR analysis can calculate the deformations, stresses and bending moments of reinforcement elements, such as anchors and piles, at failure. It has also been argued that SSR techniques are advantageous since the magnitude of deformations is a better predictor of stability than factor of safety values.

The new *Phase²* can automatically read *Slide** files. It automatically converts *Slide* limit-equilibrium models into fully meshed, finite element equivalents. Thereafter SSR analysis can be performed in *Phase²* 6.0 with the simple click of a button. Version 6 has specially formulated algorithms, which enable it to perform SSR analysis for non-linear material strength models such as the Hoek-Brown and Generalized Hoek-Brown criteria. Competing products do not have such capabilities.

The SSR method is a highly effective tool that complements conventional limit-equilibrium analysis. Because it expands understanding of slope behaviour, at times providing fascinating insights, it will help geotechnical engineers improve the quality of slope designs. It is also quite possible that the technique can be applied to other geotechnical problems such as tunnelling and foundations.

* *Slide* is a Rocscience program for performing limit-equilibrium slope stability analysis.

Multi-stage Groundwater/ Seepage Analysis

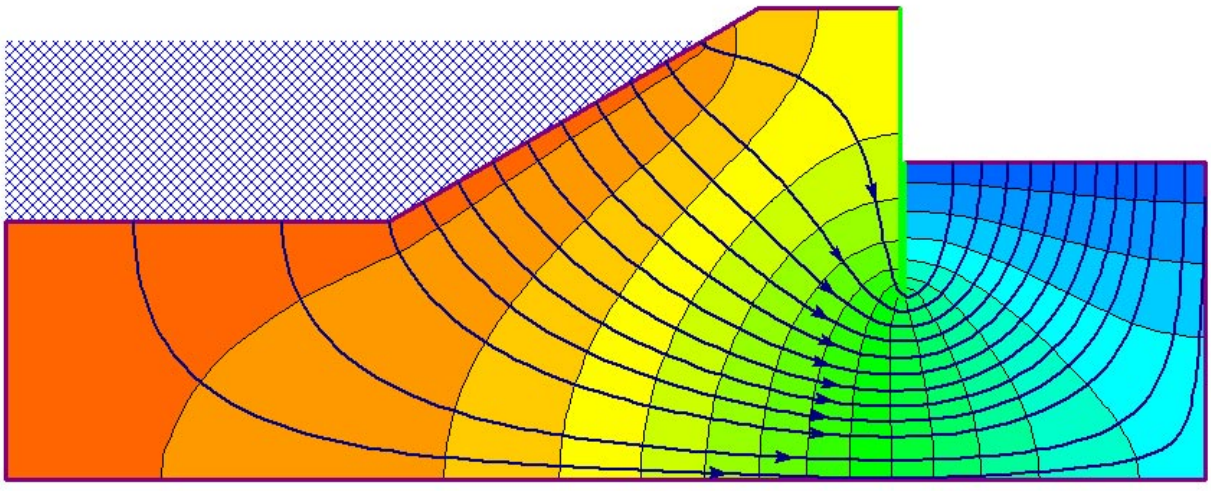
Groundwater conditions can significantly influence the geotechnical behaviour of excavations. For example, they can affect stability through generation of positive and negative pore pressures that alter stress conditions, and changes to the bulk density of materials.

A steady-state groundwater analysis module is built into *Phase²* 6.0. It computes groundwater flows, pressures and gradients using finite element analysis. To allow users to model a broad range of problems, and to test various assumptions on groundwater conditions, several different boundary conditions have been implemented in the module.

The new *Phase²* provides several options for specifying material permeability. Users have the choice of applying theoretical models such as the van Genuchten function, or of directly using data obtained from laboratory testing.

A powerful and unique feature of the groundwater module is its ability to model staged construction conditions. This is especially useful, since it allows realistic capturing of the influence of sequencing on final groundwater conditions. Since the groundwater module is integrated, incorporation of its results into stress analysis is seamless. The module can also be used for general steady-state seepage modelling, independent of stress analysis.

In addition to finite element groundwater analysis, *Phase²* 6.0 allows other methods for specifying pore pressures. Pore pressures can be applied in the form of piezometric lines, water pressure grids, or Ru values.



Flow underneath sheet pile wall.

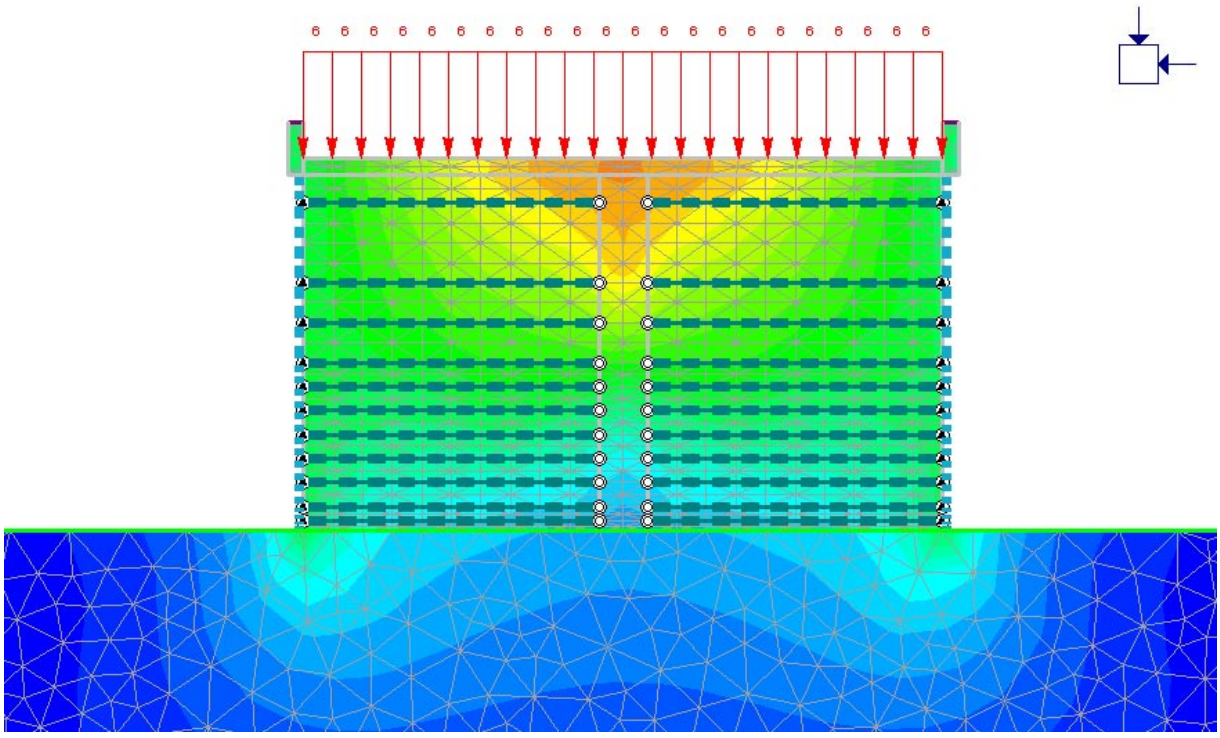
Expanded Collection of Material Strength Models

In *Phase²* 6.0 users have access to several of the most popular formulations for modelling the strength of soil and rock materials. It offers the following failure criteria: Mohr-Coulomb, Drucker-Prager, Hoek-Brown, Generalized Hoek-Brown, Duncan-Chang, Cam-Clay, Modified Cam-Clay. The Duncan-Chang, Cam-Clay, and Modified Cam-Clay models cater to the needs of geotechnical engineers who deal mostly with soils.

Specification of strength parameters in version 6 is accomplished through simple, intuitive dialogs. Strength properties can be easily copied from one material to another. As well, the program allows elastic modulus, and Mohr-Coulomb parameters to vary with depth.

New and Improved Support Models

To stabilize or reinforce geotechnical and mining excavations, engineers use a variety of support systems. *Phase²* 6.0 offers three main types of excavation support – bolts, liners and structural interface elements. The program supplies the following five bolt models: end-anchored, fully bonded, plain strand cable, Swellex/split-sets, and tiebacks. The first four bolt types improve upon the implementations in previous versions of *Phase²*, while the tieback model is new.



Raised roadway supported by liners and geogrids.

Phase² allows for the modelling of simple and composite liners. A simple liner comprises a single support applied to an excavation or material boundary. A typical example is a layer of shotcrete. Composite liners can consist of up to four different layers of support. The layers can be applied at different stages, and the effect of the interface between the excavation boundary and the initial liner layer can be simulated with a joint.

Bolts and liners can be added, deleted, moved, stretched or shortened with a few mouse clicks. They can be easily imported or exported from one *Phase²* model to another through the DXF format.

The structural interface element is new. It is used for modelling support systems characterized by sliding interfaces between support elements and surrounding material. Piles, geosynthetic materials such as geogrids and geotextiles, and struts are some of the support systems that can be modelled with the new structural interface option.

New Loading Options

The option to apply uniform distributed loads along boundaries has always existed in *Phase²*. Based on popular demand, however, version 6 offers automated tools for specifying triangular and trapezoidal loads. It also has a specialized option for defining loads induced by ponded water, such as the action of impounded water on dam surfaces.

Concentrated loads are now easier to apply. And moment boundary conditions for liners can now be applied (e.g., a zero moment "hinge" or an active non-zero moment load).

Improved User Interface

The already easy-to-use tools for entering and editing model geometry have been substantially improved in *Phase²* 6.0. These tools, a few of which will be described next, can be quickly accessed with the help of various right-click pop-up menus and keyboard shortcuts.

Version 6 provides four methods of entering the coordinates of geometric entities. One can use the keyboard, mouse clicks, a coordinate table, file import facilities, or combinations of these options to specify geometry.

The coordinate table option is the newest of the tools. It comes in the form of a dialog with an embedded spreadsheet. A user can type coordinates directly into the spreadsheet, can paste them from another spreadsheet application, or import them from comma, tab or space-delimited files. Coordinates can also be imported from other *Phase²* files.

Geometric entities such as boundaries and whole excavations can be easily edited in *Phase*^{2} 6.0 using features very similar to those commonly offered in programs such as Microsoft Word. As well, when boundaries are being added or edited, *Phase*^{2} supplies built-in logic, which automatically determines intersections of boundaries with each other, and automatically removes invalid segments.

Many of the dialogs, menus and modelling procedures have also been enhanced in version 6. For example, boundary conditions, loads, material assignments in a model are now remembered even if the mesh is reset. This allows users to edit models with minimum effort and minimal loss of mesh dependent information.

In version 6, menus relevant to actions being undertaken pop up with mouse right-clicks. These menu options are very useful and time saving. For all dialogs in the program, context-sensitive help can be readily obtained.

Concluding Remarks

The modelling capabilities of *Phase*^{2} 6.0, some of which are described in this article, combined with user-friendliness and intuitiveness, offer benefits that only enhance the practice of geotechnical engineering. The program's capabilities facilitate creative solution of a broad range of excavation problems, and promote engineering excellence. Because it is designed for both occasional and power users, the instinctive and well-designed interface minimizes time spent on training or re-training. This ensures its ready application to problems at all times.

In features such as the SSR and support models, *Phase*^{2} 6.0 provides access to cutting-edge knowledge that significantly betters design. The program also comes with substantial documentation that includes over a hundred verification examples, and supplies exhaustive online help and several tutorials. Lastly, users obtain timely and free technical support. These are the reasons why we believe that this upgrade is a must for most geotechnical excavation design engineers.

For further information, visit the *Phase*^{2} Software Page