Introducing Settle$^{3D}$. . .

Rocscience will soon be releasing Settle$^{3D}$, a totally new software package for analysis of consolidation and settlement under foundations, embankments and surface excavations.

For the geotechnical professional who has been doing settlement calculations ‘on the back of an envelope’, Settle$^{3D}$ is our new program to quickly and accurately help you solve your settlement problems in three dimensions.

Introduction

Many civil engineering projects include placing loads on the ground. Estimating time-dependent settlements due to these loads is an important part of any project. In the case of high-cost structures such as buildings, bridges, towers and power plants, an accurate estimation of settlement is crucial. Yet, most consulting engineers do not have the resources to perform rigorous three-dimensional analyses, so ad-hoc one-dimensional approaches and rules-of-thumb are prevalent.

Settle$^{3D}$ has been developed to combine the simplicity of one-dimensional analysis with the power and visualization capabilities of much more sophisticated three-dimensional programs.

The engineering philosophy of Settle$^{3D}$

Traditionally, a one-dimensional analysis method is used to solve consolidation and settlement problems. Vertical stresses due to three-dimensional loads are estimated using charts, ad-hoc methods (such as the 2:1 method) or at best, elastic analyses such as the Boussinesq method. Calculating differential settlements requires multiple one-dimensional analyses at different locations; a tedious and error prone approach. Our solution? A new program to simultaneously compute settlements at hundreds of locations around your foundation, embankment or excavation. Combined with the usual intuitive Rocscience interface, the result is a powerful analysis tool for calculating and visualizing time-dependent settlements in three-dimensions.

Fast techniques for calculating 3D stresses, excess pore pressures and non-linear displacements in layered soils allow for near real-time visualization of results with changing loads, geometries or material properties, allowing the engineer to quickly and easily probe the uncertainties in input data.
Key features of Settle$^{3D}$

The following subsections describe the capabilities of Settle$^{3D}$ and why the practicing geotechnical engineer should have a copy in their toolbox.

Settlement Calculations

Obviously, the most important part of a settlement program is the calculation of vertical displacements! In Settle$^{3D}$, an array of points on the surface is automatically generated and settlement is calculated at each point. Three components are computed:

- **Immediate settlement** gives the initial displacement under undrained conditions
- **Consolidation settlement** is the time-dependent displacement that occurs as water is squeezed out of the soil
- **Secondary consolidation or creep** occurs after excess pore pressures have dissipated.

Three types of material may be used in Settle$^{3D}$: linear elastic, non-linear and Janbu. The user has the flexibility to specify multiple horizontal layers, all with different mechanical and hydrological properties.

Settle$^{3D}$ screen capture showing surface settlement in plan view (left) and 3D view (right). Settlement is exaggerated in 3D view.
**Sophisticated 3D stress computations**

The first step in the process of computing settlements is the determination of the stress distribution as a result of surface or sub-surface loadings. Elastic stresses used in settlement calculations are routinely obtained from classical solutions such as those of Boussinesq and Westergaard. The problem with this is that these solutions make simplifying assumptions, which can distort results. For example, they assume the half-space of soil material to be homogeneous.

Solving these problems using 3D finite element approaches will stretch the resources of most practicing geotechnical engineers. Therefore a new stress calculation method, developed at the University of Toronto, has been incorporated by Rocscience into Settle$^{3D}$. Similar to the boundary element method, the new technique is based on what is known as the method of images. Because it is meshless, it is faster and easier than the finite element approach and requires little from the user. However it can accurately simulate the effects of non-homogeneous soil profiles as shown below.

Of course the Boussinesq method and the 2:1 method are included in Settle$^{3D}$ too.

[Diagram of soil layers and loadings]

**Problem of uniform load applied over a square area on the surface. A sand layer (shown in green) is five times stiffer than the surrounding clay.**

**Contours of the vertical stress distribution on the vertical plane through A-A’ calculated using Boussinesq method (left) and by the method of images (right).**

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Flexible loading options

The easy to use CAD interface allows for simple specification of surface loads. Circular, rectangular and polygonal loads can be quickly generated. A different load magnitude can be applied to each vertex and the load across the shape will be calculated by interpolation. In addition, loads may be applied at any depth to simulate piles or raft foundations. Loads may also be staged for time-dependent analysis of construction.

An embankment designer wizard is also included. This enables the engineer to easily generate embankments of complicated geometry built in several stages.

Other loading capabilities include:

- Lowering or raising of groundwater table
- Fill of infinite extent
- Excavations of any shape

Embankment designer window in Settle3D
Time-dependent consolidation

When a saturated soil is loaded, there is an initial increase in pore water pressure that gradually dissipates. Settlement will continue as long as water continues to flow from the soil, a process that could take years for low permeability clays. Knowledge of the time-dependent settlement may be crucial for many engineering projects.

Settle3D uses Terzaghi’s one-dimensional consolidation equation to compute excess pore water pressure with time. The equation is solved using a finite difference technique that allows for different permeabilities in different layers. The finite difference equations are solved implicitly meaning that the solution is obtained extremely quickly, even for models with layers of high permeability contrast. This enables easy parametric studies for probing uncertainties and worst case scenarios.

Other features contributing to time-dependent consolidation included in Settle3D are:

- Specification of Skempton pore pressure coefficients for simulation of partially saturated soil
- Inclusion of wick drains to speed up consolidation
- Consideration of secondary consolidation (creep)

Excess pore water pressure under a circular load after 1 month. The green layer represents a sand layer that is ten times more permeable than the surrounding clay.
Powerful user interface

The easy-to-use CAD tools found in other Rocscience products are also included in Settle3D. Load geometries can be easily entered using the keyboard, mouse, tables or file import facilities. Right mouse clicks present relevant menus for easy editing and data entry. Sophisticated contouring and graphing capabilities are included, or the engineer can easily export data to a spreadsheet for further analysis.

Three-dimensional visualization of geometries and results is easy with a combination of 2D and 3D viewing windows. You can rotate, pan and zoom with a click of the mouse. Data is presented in contour plots projected onto any horizontal or vertical slice, and settlement is easily visualized by observing the deformed surface in 3D.

Also new in Settle3D is easy report generation capabilities that allow consistent presentation of results including a company logo and other project specific information.

Concluding remarks

Settle3D incorporates well-known settlement analysis procedures and a new stress calculation method, into a fast, flexible and easy-to-use package for solving a broad range of engineering problems. The intuitive interface and sophisticated results visualization capabilities allow the engineer to go from zero to solution in a matter of minutes. The broad feature set and extensive flexibility enable much more detailed investigations if required. We are confident that once you have a copy of Settle3D you will wonder what you did without it.