Embankment design and soil settlement prediction

D-Settlement

Deltares systems

Deltares

Enabling Delta Life

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Peat and clay layers will compress significantly after embankment construction, site preparation or other loading. A final magnitude of several metres is not unusual in The Netherlands. Natural settlements take many years to develop, due to slow pore water dissipation and creep. Vertical drains are therefore often applied to speed up the consolidation process. Temporary preloading and enforced dewatering are also applied to reduce the residual creep after the construction period. Uncertainty and spatial variation will cause the actual measurements to deviate from the initial prediction within bounds. Under these complex circumstances, D-Settlement, (previously known as MSettle), supplies all necessary means to get to grips.

General

D-Settlement is practical and easy-to-use software. D-Settlement quickly predicts the transient settlement and its bandwidth during the design stage. D-Settlement can automatically improve this prediction during the construction stage by employing measurements. D-Settlement offers accurate and robust models, capturing consolidation, creep, submerging, drains, staged loading, and unloading and reloading. The dedicated graphical user interface supports convenient data input and easy interpretation of results. Reliability is guaranteed by well-established solution methods, thorough validation, high-level expertise of the developer and a large user-base. The user documentation includes comprehensive tutorial examples, to get you started at a glance. Some specific features in D-Settlement are:

- **Design**
  Automatic determination of the extra soil volume required for settlement compensation.
- **Vertical drains**
  Input of strip drains, columns and sand walls, based on real project parameters and layout. Practical options for enforced dewatering. Automatic conversion to model parameters.
- **Consolidation period**
  Easy determination of the consolidation period for different vertical drain configurations.
- **Safety**
  Determination of the minimum period required for safe and stable construction, with the aid of coupled D-Geo Stability.
- **Settlement stress**
  Output of settlement, stress components and water head components along verticals and along time, as a result from staged construction and other types of loading (2D/3D).
- **Temporary preloading and dewatering**
  Analysis of the effect of temporary preloading and/or enforced dewatering on settlements and pore pressures.
- **Bandwidth**
  Output of total bandwidth and residual settlements.
- **Fit for settlement plate**
  Settlement plate fit (automatic or manual), affecting settlements and bandwidth.
- **Horizontal deformation**
  Output of approximate horizontal deformation along verticals.

D-SETTLEMENT comes as a standard module, which can be extended further with other modules to fit more advanced applications:

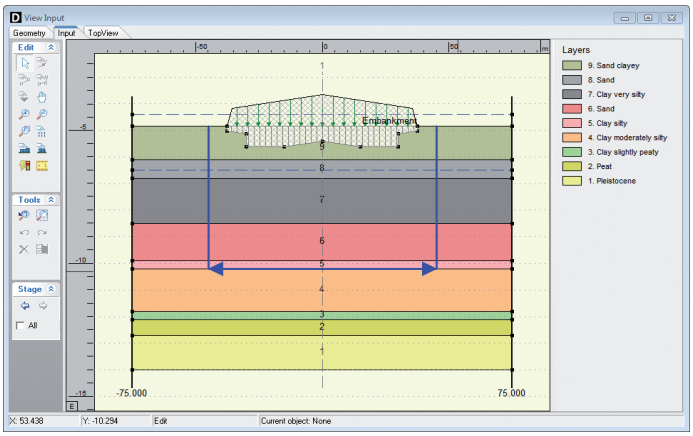
- D-SETTLEMENT Standard module (1D)
- 2D Geometry module
- Darcy module
- Vertical Drains module
- Fit for Settlement Plate module
- Reliability Analyses module
- Horizontal Deformations module.

Standard module (1D)

The standard module is intended for 1D settlement analyses. It allows input of straightforward projects and provides tabulated and graphical output of results both on-screen and in a report. Some specific features include:

Geometry and loading definition

- Direct import of geometry from other Deltares systems tools.
- Manual input of layers, time dependent piezometric levels and time dependent soil raise via interactive two-dimensional drawing, or via data entry in specific forms.
- A complete choice of additional uniform, two-dimensional and three-dimensional loading types, with different shapes.
- Entry of material properties via forms, or direct import from a central project database.

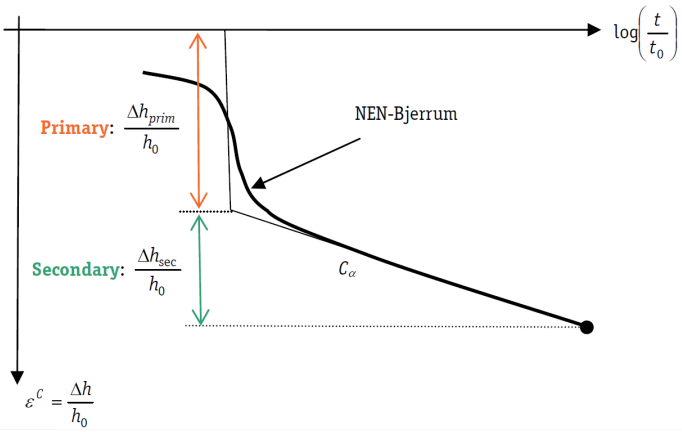


Geometry and loading

Soil models with common parameters

D-SETTLEMENT calculates the transient 1D settlement along user defined verticals, with one of the following three soil models:

- NEN-Bjerrum supports the common compression index Cc, swelling/recompression index Cr and coefficient of secondary compression Cα. The model and its parameters are based on a small strain assumption. The underlying isotache formulation is suited for staged loading, unloading and reloading. The concept was already introduced by Bjerrum in 1968. It implies that the creep rate increases by loading and reduces by unloading and by time.
- The Isotache natural strain (a,b,c) model is an extension to NEN-Bjerrum, by application of a natural strain description. Natural strain improves predictions in case of large strains.
- Koppejan represents the traditional Dutch model, applicable for staged loading.



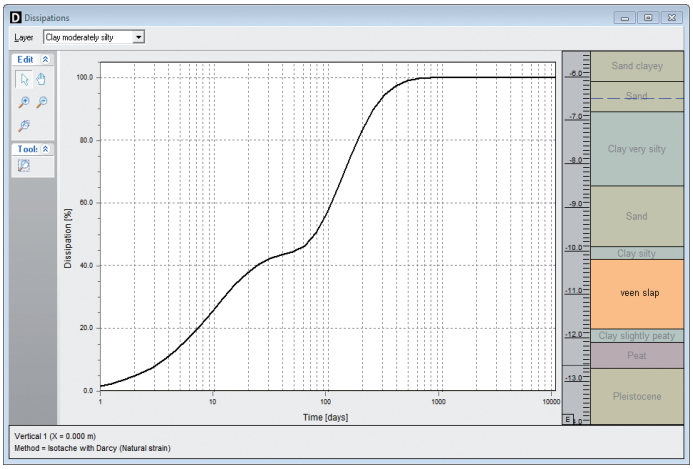
NEN-Bjerrum model

Consolidation

The base modules (1D-2D) includes the quick and approximate Terzaghi consolidation model. The input parameter is the common vertical consolidation coefficient. The model multiplies the drained settlement prediction with a so-called “degree of consolidation”. The latter follows from a theoretical elastic solution.

Output

After calculation, D-SETTLEMENT offers direct access to graphs of relevant results. All data behind these graphs can also be copied to



Output of dissipation graph

the clipboard, for instance for use in spreadsheets. Input, warnings and numerical results are furthermore printed in the report. Examples of available graphs are:

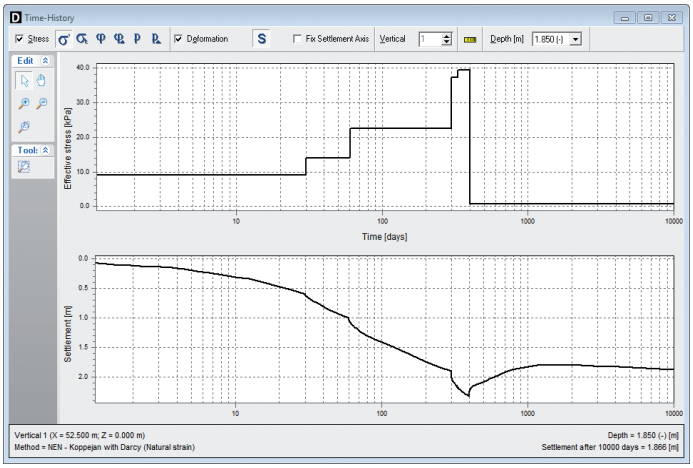
- graphs of the settlements and different stress and head components along time and along verticals
- residual settlement versus times at different starting measurements
- bandwidth indication in the settlement prediction
- dissipation graphs per layer, showing the degree of consolidation versus time.

2D Geometry module

The basic 1D module supports quick input and settlement prediction for uniformly loaded soil columns. The 2D module supports settlement by different loading types along verticals in full 2D geometries.

Darcy module

The accurate Darcy module is available for improved consolidation and submerging modelling. This model calculates the coupled development of excess pore pressure and effective stress numerically in time. Since D-Settlement Version 8.2, Darcy supports the same input as the Terzaghi model. Gradual submerging of initially dry soil is taken into account since then also. A semi-analytical spatial integration maximizes the speed and robustness.



Output of excess head versus time

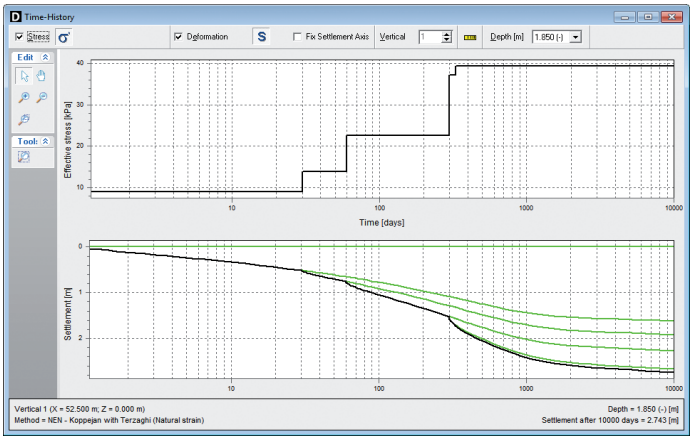
Vertical Drains module

D-Settlement calculates average heads, based on an assumed distribution between drains. This method extends in fact the classical Barron-Carillo method. Supported drain types are wicks, columns and sand screens, with direct input of their dimensions, spacing and range. Special features are enforced dewatering, supporting methods like Menard consolidation, IFCO, BeauDrain, etc. All drain types can be combined with both consolidation models.

Installation of wick drains

Fit for Settlement Plate module

D-Settlement offers a module to fit predicted settlements on measurements during construction. Such a fit can be used to improve the settlement prognosis for the remainder, as well as to update the soil properties. D-Settlement uses five practical fit factors for this purpose. One can opt either for a robust automatic procedure or for manual adaptation, with the aid of graphical support.



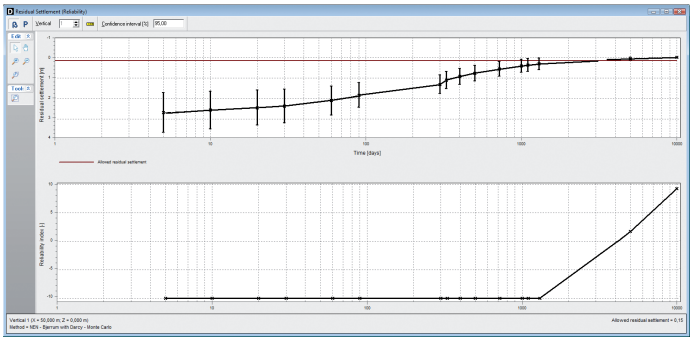
Output of effective stress and settlement versus time

Reliability Analyses module

Actual settlements will deviate from predictions, due to soil variability and additional uncertainty. D-Settlement can estimate the bandwidth in total and residual settlement during the design stage. D-Settlement can also update and reduce the bandwidth during the construction stage, after a fit on measurements.

- The crude Monte Carlo method determines the bandwidth in total and residual settlements, including the exceedance probability of the allowed residual settlement.
- The First Order Second Moment (FOSM) method is a quick alternative to approximate the bandwidth in total settlements.
- The iterative First Order Residual Moment (FORM) method is an alternative to approximate the exceedance probability of the allowed residual settlement.

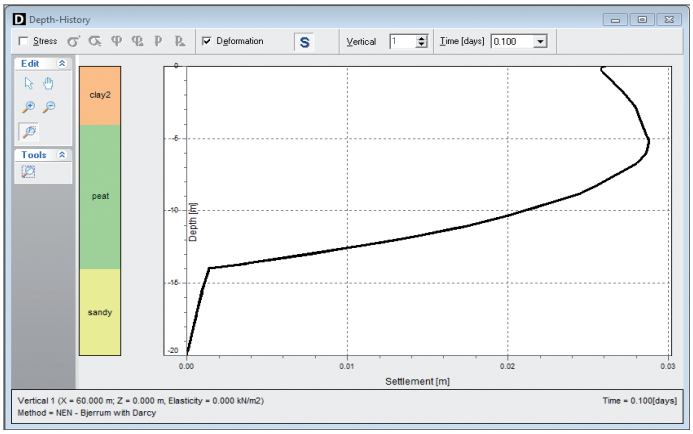
Resulting from a reliability analysis is also a graphical overview of the time dependent sensitivity of settlements, for variation of uncertain soil parameters.



Settlements with bandwidth, before and after the fit

Horizontal Deformations module

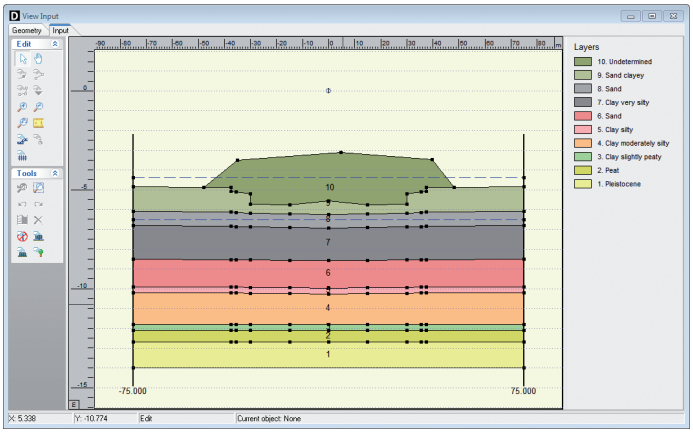
D-Settlement can estimate horizontal deformations in user-defined verticals, using an elastic solution for a single incompressible layer. The equivalent elastic stiffness of this layer is an input value.



Output of horizontal deformations

Interaction with other Deltares systems tools

D-Settlement is part of the Deltares systems product suite. Therefore, D-Settlement can import soil parameters from a central project database. D-Settlement can also share its (deformed) geometry with other Deltares systems programs. Finally, D-Settlement can directly generate input for the D-Geo Stability program, including excess pore pressures and deformed geometry.



Direct export to D-Geo Stability

Support

Deltares systems tools are supported by Deltares. A group of 70 people in software development ensures continuous research and development. Support is provided by the developers and if necessary by the appropriate Deltares experts. These experts can provide consultancy backup as well.

On-line software (VMware)

All popular geotechnical Deltares simulation products are available over the internet via our Online Software service (Software as a Service (SaaS)). An internet connection and subscription is sufficient for worldwide access. Billing is according to the actual use and subscription costs per quarter.

Deltares systems

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