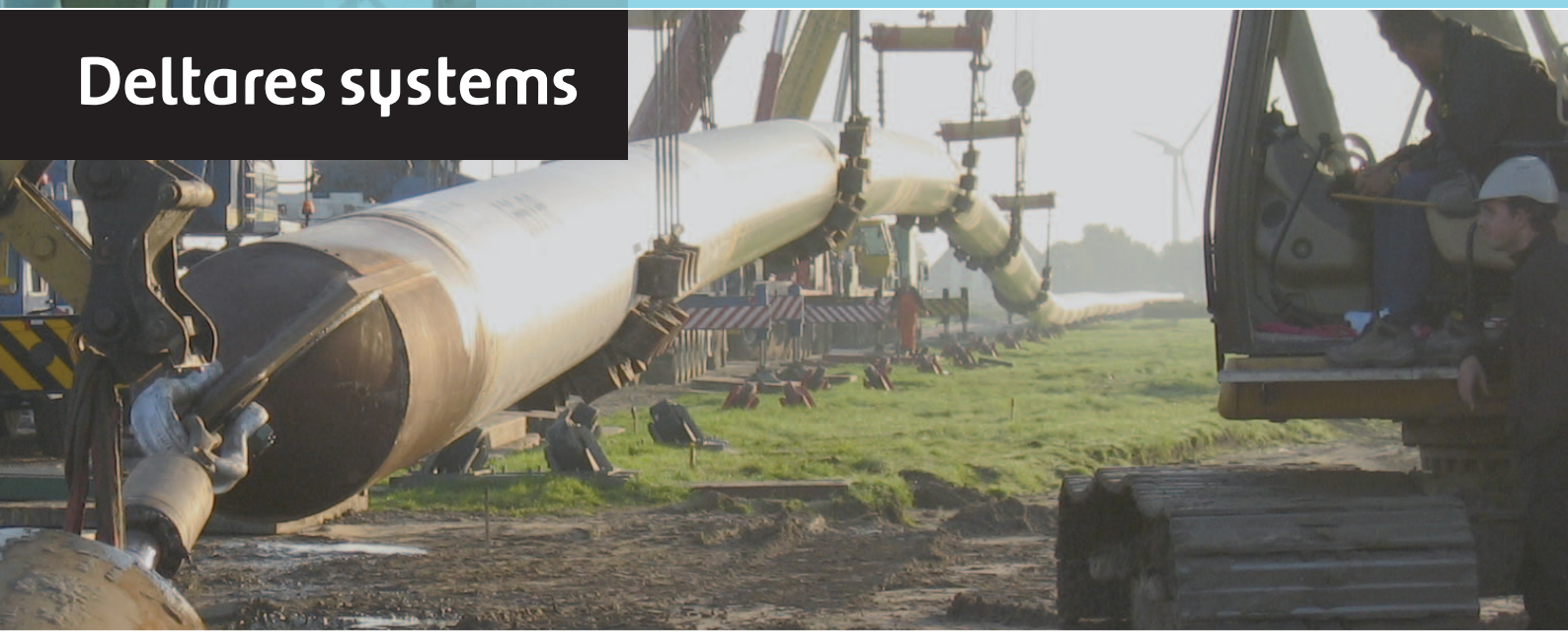
Design of pipeline installation

D-Geo Pipeline

Deltares systems



Deltares

Enabling Delta Life

Design of pipeline installation

D-Geo Pipeline

Deltares systems

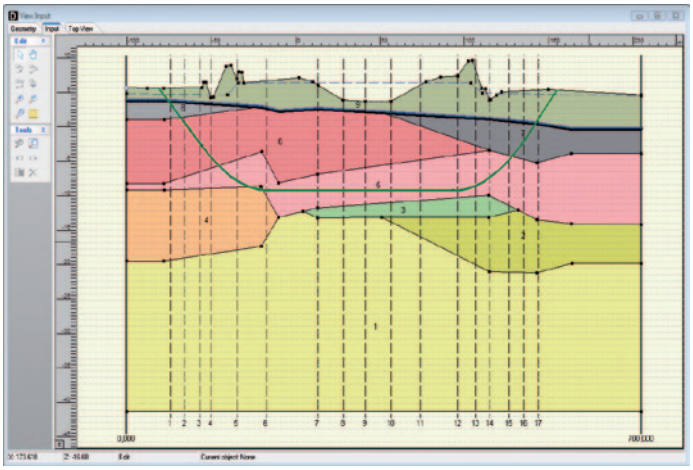
Pipelines are an important part of the underground infrastructure. They are the lifelines of our modern society. The successful operation of a pipeline system on the long term, however, is largely determined by the quality of the engineering works prior to the installation of the pipeline.

From time immemorial, pipelines have been installed in trenches. After excavation of the trench the pipeline is installed on the bottom of the trench and is subsequently covered by the excavated soil. Since the 1970s, Deltares (formerly known as GeoDelft) has been involved in the development and execution of trenchless technologies. Trenchless techniques provide a logical alternative when pipelines need to cross roads, railways, dikes, wetlands, rivers and other structures that have to remain intact. These techniques minimize the impact of installation activities in densely populated and economically sensitive areas. Previous releases of D-Geo Pipeline were named MDrill. MDrill was one of the first design codes for Horizontal Directional Drilling (HDD). MDrill was the result of years of research. Since the release of the first version in 1995, the design code has regularly been updated with new knowledge. Recently, two modules have been added to take into account the installation of pipelines using micro tunnelling and the installation of pipelines in trenches.

General

The program D-Geo Pipeline provides tools for the design of a pipeline installation in a trench and trenchless installation, using the micro tunnelling technique or the Horizontal Directional Drilling (HDD) technique. D-Geo Pipeline allows the user to minimize the risks during and after installation.

- **Geometry and 3D pipeline configuration**
  The graphical user interface allows an easy and fast input of the soil layers. The upper soil layers can be designated as load for settlement calculation purposes. The three dimensional pipeline configuration can be entered by a fast tabular input.



2D cross section

- **Arching**
  In case of trenchless installation, D-Geo Pipeline applies a reduced neutral soil load to incorporate the effect of arching. The amount of reduction depends on the installation method, the depth of the pipeline, diameter and the soil properties.

- **Pipe stress analysis for horizontal directional drilling installation**
  D-Geo Pipeline calculates the stresses in the pipeline during the installation stages in both axial and tangential direction. In a comprehensive report a stress verification is given for each pipeline material used.

- **Advanced calculation of settlements**
  Vertical displacement of soil below the pipeline that occurs after installation is an important factor in assessing the stresses in the pipeline. Pipeline settlement may be entered manually if the vertical settlements are available. For more accurate results, D-Geo Pipeline can use the D-Settlement computer program without additional input.

- **Advanced pipeline stress analysis**
  For advanced pipe stress analyses special programs need to be used. These programs need an advanced set of soil mechanical parameters, provided by D-Geo Pipeline. The programs will generate a complete spring model around the pipeline for further analyses. The soil mechanical parameters provided by D-Geo Pipeline are:
  - neutral, passive and reduced vertical soil load
  - vertical and horizontal modulus of sub grade reaction
  - ultimate vertical and horizontal bearing capacity
  - neutral horizontal soil load
  - vertical displacement
  - maximum axial friction
  - friction displacement.

D-Geo Pipeline comes as a standard module, which can be extended further with other modules to fit two other applications related to pipeline installation:

- D-Geo Pipeline Standard module (Horizontal Directional Drilling)
- Micro Tunnelling module
- Trench module.

Standard module (Horizontal Directional Drilling)

D-Geo Pipeline enables the fast design of a pipeline configuration, installed using the Horizontal Directional Drilling (HDD) technique. In HDD three installation stages are considered: Pilot drilling; reaming the initial pilot borehole and pulling back the pipeline. The initial borehole is called a pilot hole. The diameter of this pilot hole is enlarged using a reamer. Depending on the required final borehole diameter, the borehole can be enlarged in several steps using reamers of increasing diameters. Finally, the pipeline is pulled into the borehole.

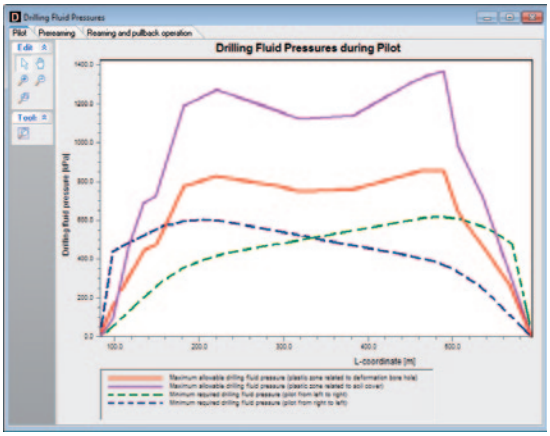
Barrel reamer and Fly cutter

Features

- Advanced input of the ground water pressure distribution.
- Drained and undrained behaviour of soil layers.
- Graphical output of calculated drilling fluid pressures.
- Library with steel and polyethylene pipelines.
- Standard calculation scheme for bundled pipelines.
- Calculation of settlement of the soil layers below the pipeline.
- Standard pipe stress analysis.

Drilling fluid pressures

The minimal required drilling fluid pressure is the pressure necessary for an effective return flow, capable of transporting cut soil particles towards the surface. The upper boundary of the allowable drilling fluid pressure indicates the pressure at which a blow-out is likely to occur. The lower boundary indicates the pressure at which fractures around the borehole are expected. Both minimum and maximum allowable drilling fluid pressure depend on depth and soil properties.



Drilling fluid graph

Drilling fluid pressures are calculated along the entire borehole and visualized in a graph showing both the upper and lower boundary. Drilling fluid pressures can be calculated for all installation stages (pilot, reaming and pull back).

Pipeline material

D-Geo Pipeline is capable of dealing with pipelines made of different materials. For steel and polyethylene a database containing the material data is available. The database enables a quick re-calculation for alternative material types and dimensions.

Pull back force calculation

D-Geo Pipeline calculates the pulling force on the pipeline that is required to pull the pipeline into the prereamed borehole. The pull back force is based on buoyancy control and consideration of the soil-pipeline interaction in the bends of the drilling line.

Pipeline stress analysis

Soil mechanical parameters are used for a pipeline stress analysis. The standard pipeline stress analysis by D-Geo Pipeline is based on a limited set of parameters. D-Geo Pipeline calculates the stresses in the pipeline during the installation stages in both axial and tangential direction. In a comprehensive report a stress verification is given for each pipeline material used. The calculated stresses are compared with the allowable stresses according the Dutch pipeline code (NEN 3650). The pipeline stress report contains:

- used input data
- calculated axial, tangential and combined stresses for all installation stages
- verification of the pipe stresses
- check on pipeline deflection
- check on implosion for polyethylene pipelines.

Micro Tunnelling module

Micro tunnelling is the technique which uses a tunnelling machine to remove the soil. Micro tunnelling usually starts horizontal at a certain level below the surface. Start and reception shafts are created for the micro tunnelling machine. In the start shaft a jacking frame and micro tunnelling machine are installed in front of the pipe sections. The jacks push the pipe elements section by section ahead towards the reception shaft. As the length of the advancing micro tunnel increases, the friction forces will increase. Lubrication fluid may be applied to reduce the friction. Very often, drilling fluid is used for soil removal and face stabilization at the front of the micro tunnelling machine.

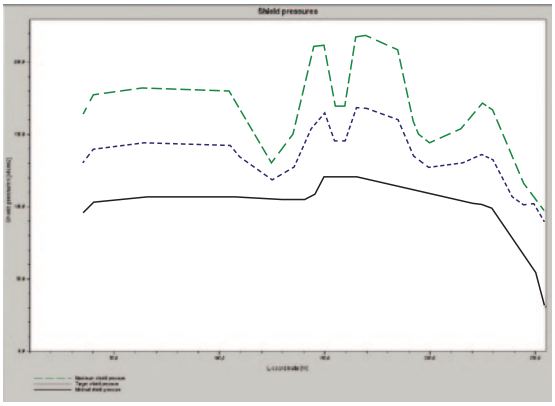
Features

- Drained and undrained behaviour of soil layers.
- Graphical output of calculated face support pressures, trust forces and subsidence through.
- Calculation of settlement of the soil layers below the pipeline.

Hydraulic jacks in the start shaft

Face support pressures

The micro tunnelling machine changes the stress conditions in the soil. The deviations from the original stress conditions are largely determined by the size of the overcut and the applied shield. Small deviations from the original conditions are acceptable as long as the stability of soil adjacent to the micro tunnelling machine is maintained. A relatively low face support pressure may lead to collapse in front of the shield, which in turn may lead to subsidence of the surface or to settlement of soil layers below a construction or pipeline. A relatively high face support pressure can lead to a blow out of drilling fluid or may lead to surface heave.



Maximum, neutral and minimum face support pressure

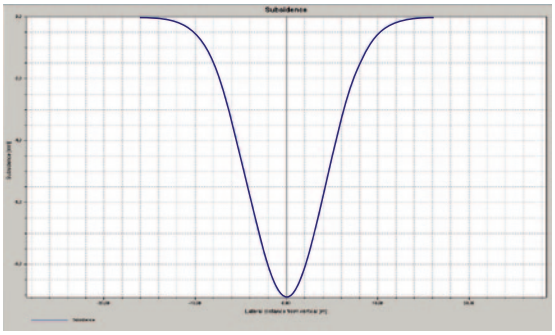
While drilling, the shield pressures have to be kept between certain limits. To prevent the possibility of collapse of the soil in front of the micro tunnelling shield, causing subsidence, the soil at the front is kept stable by maintaining a minimal face pressure. Depending on the soil type the minimal support pressure can be calculated using Jansecez and Steiner theory, or Broms and Bennermark theory. A maximum support pressure should not be exceeded to prevent uplift of the soil above the micro tunnelling machine or a blow out of drilling fluid towards the surface. The support pressure, the target pressure during drilling, should be in between the two limits. At the neutral pressure, the face support pressure is in equilibrium with the current horizontal soil pressure.

Thrust force

The micro tunnelling machine is at the front of the advancing pipe sections. As the length of the advancing micro tunnel increases, the friction forces along the micro tunnelling machine and the pipe segments rises. Lubrication fluid may be applied to reduce the friction. D-Geo Pipeline compares the predicted thrust force with the maximum allowable thrust force.

Surface subsidence

During the micro tunnelling drilling process the volume of removed soil is generally larger than the volume of the micro tunnel or pipeline (overcut). The volume difference will lead to soil movement



Subsidence trough

towards the borehole, which in turn will lead to surface subsidence. The magnitude of the subsidence (trough) is calculated and graphically shown by D-Geo Pipeline.

Trench module

The majority of the underground pipelines are installed in a trench. After excavation of the trench the pipeline is installed at the bottom of the trench and subsequently covered by the excavated soil. The interaction between the pipe and the condition of the soil material, which is placed back in the trench plays an important role in the engineering of the pipe. The compaction of the fill leads to differential settlement of the fill above the pipe and adjacent to the pipe.

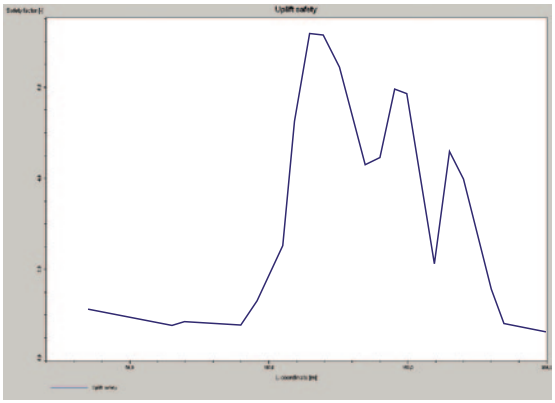
Features

- Upheaval and uplift check.
- Graphical output of the calculated uplift safety factor; upheaval safety.
- Calculation of settlement of the soil layers below the pipeline.

Installation of a pipeline into a trench

Uplift safety

Pipeline installation in wet soft soil environments may lead to buoyant behaviour of the pipeline. In case of superficial installation the soil cover above the pipeline may be insufficient to withstand the buoyant force of an empty pipeline. D-Geo Pipeline provides an Uplift check and Uplift safety factor chart.



Uplift safety factor chart

Interaction with other Deltares systems tools

D-Geo Pipeline interacts with other Deltares systems tools for settlement analysis, seepage analyses, central project and database storage:

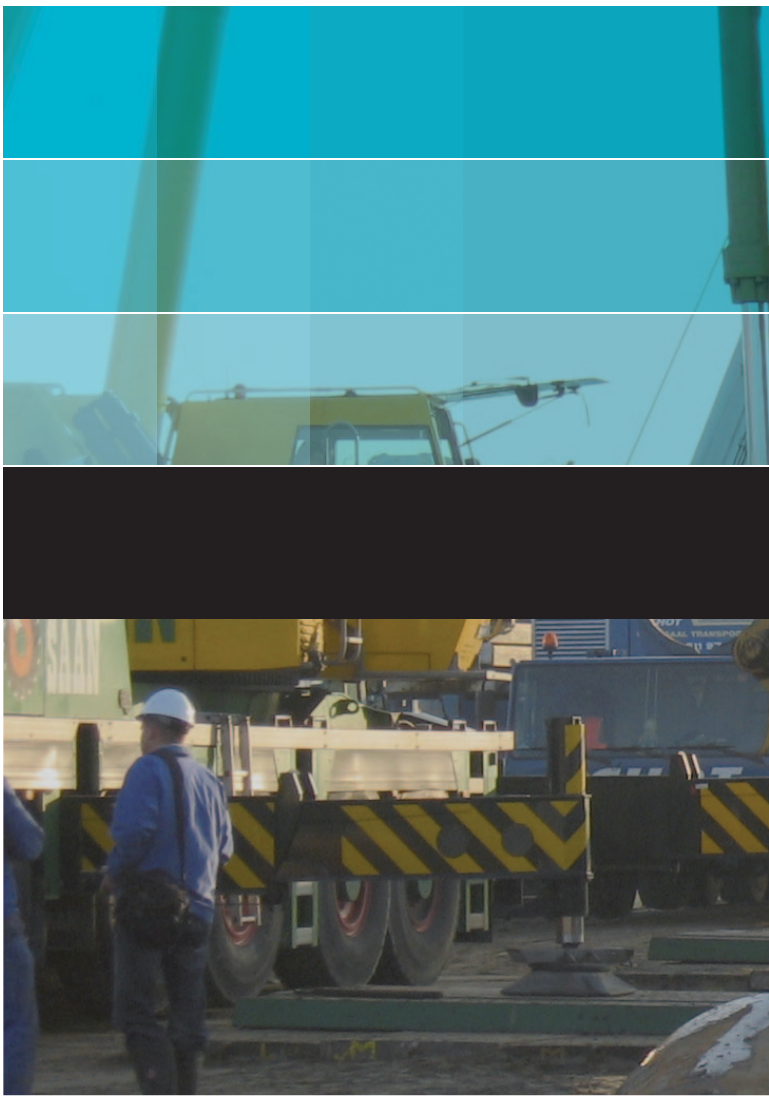
- D-Settlement for analyses and import of settled geometry
- D-Geo Stability for slope stability analysis
- Scia Pipeline for advanced structural analysis of pipeline behaviour.

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 (Citrix)

Besides purchased software, Deltares systems tools are available as an on-line service. The input can be created over the internet. Heavy duty calculation servers at Deltares guarantee quick analysis, while results are presented on-line. Users can view and print results as well as locally store project files. Once connected, clients will be charged by the hour.



Deltares systems

PO Box 177
2600 MH Delft
Rotterdamseweg 185
2629 HD Delft
The Netherlands

T +31 (0)88 335 79 09
F +31 (0)88 335 81 11

info@deltaressystems.com
www.deltaressystems.com