

CPT based foundation engineering

D-FOUNDATIONS

Deltares systems



Deltares systems

In the 1930s, Deltares (formerly known as GeoDelft) started the development of the Cone Penetration Test (CPT). In twenty years time this has evolved into the electrical cone, for which several national and international patents were granted. CPT testing is the standard soil test in The Netherlands, as it is accurate, fast and cost efficient. Since then it is impossible to imagine soil investigations in soft soil countries without the "Dutch Cone" test.

CPT tests measure cone resistance, as well as skin friction along the friction sleeve near the cone. These properties are ideal for the design of piled foundations, where both pile base resistance and pile shaft resistance are important.

Based on CPT test results, calculation techniques and design codes have been developed for the design of piled foundations in The Netherlands and Belgium. Since 1990, Deltares has been involved in the development of foundation design software. This has resulted in design and verification software for bearing piles, tension piles and shallow foundations. Previous releases of D-FOUNDATIONS were called MFoundation.

General

D-FOUNDATIONS follows the Eurocode 7 and the Dutch and Belgium National Annexes. First D-FOUNDATIONS is used to create and optimize a design. In this process, automatic optimization options assist the user to efficiently create and fine-tune a design. Once the design is finished D-FOUNDATIONS can perform a design code check resulting in a detailed report for the given situation. The ability to overrule and redefine various design code parameters allows D-FOUNDATIONS to be used by engineers for specialized calculations using user defined foundation types and factors. Some specific features in D-FOUNDATIONS are:

- **Soil data definition**

D-FOUNDATIONS requires input data from Cone Penetration Tests (CPT). Importing CPT data is possible in several formats, including the Geotechnical Exchange Format (GEF) and the format used by the Database Ondergrond Vlaanderen (DOV). Besides using GEF-files, CPT's can be imported directly from the Dutch DINO database by TNO. The automatic CPT interpretation tool provides soil-type dependent proposals, including design code based parameter proposals.

- **Preliminary design of piles**

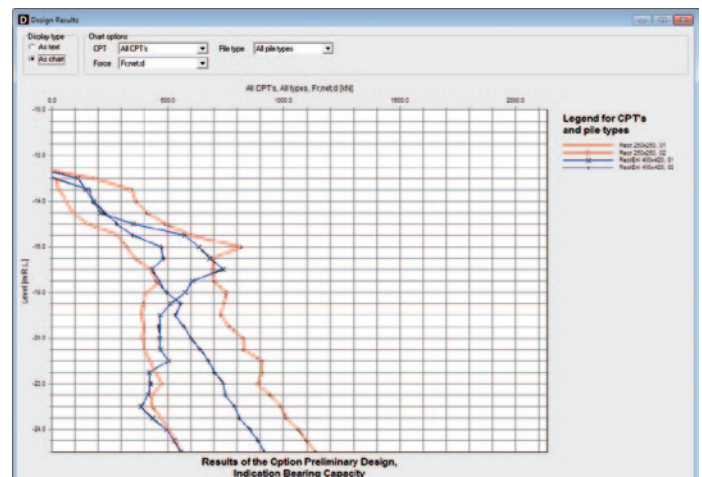
D-FOUNDATIONS provides simultaneous results of bearing capacity and required length for different pile types and different soil conditions.

- **Pile group interaction**

In calculations, the effect of pile group interaction on settlement is included as well as on bearing capacity for the selected pile type and pile plan.

- **Design of shallow foundations**

Foundation dimensions can be optimized. In addition, the required width for strip foundations and the capacity and stability of shallow foundations can be checked.



Bearing capacity versus depth for several pile types and CPT's

- **Code-based verification**

A complete verification report can be generated in Dutch and English.

- **Standard parameters**

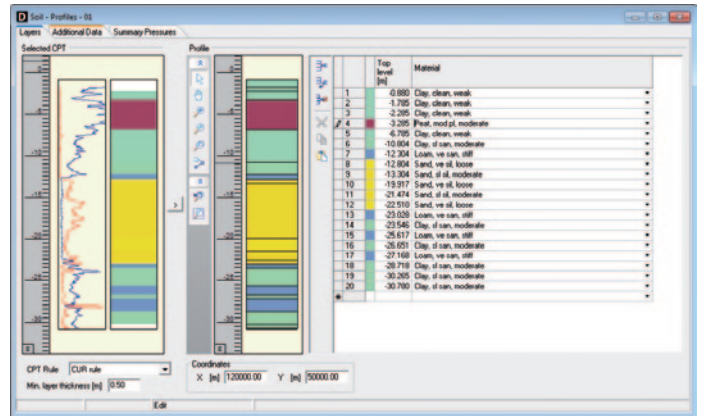
All standard parameters provided by Eurocode 7 (such as soil parameters and pile type parameters) are incorporated within D-FOUNDATIONS for easy and fast selection.

D-FOUNDATIONS comes as a standard module (Bearing piles), which can be extended further with other modules to fit other applications:

- **D-FOUNDATIONS Standard module (Bearing piles EC7-NL)**
- **Shallow Foundations module (EC7-NL)**
- **Tension Piles module (EC7-NL)**
- **Bearing Piles module (EC7-B)**
- **Feasibility module.**

CPT interpretation

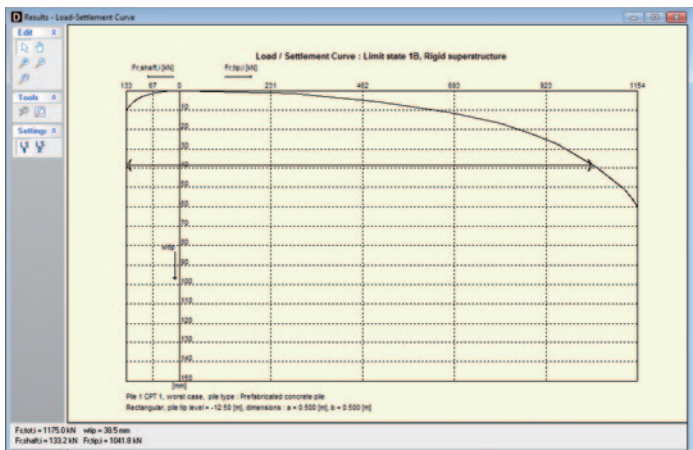
The automatic CPT interpretation uses the relation between cone resistance and skin friction using standard interpretation rules such as the well-known Robinson (CUR) rule. The user can specify the layer thickness to be distinguished. After the interpretation the proposed soil profile can be edited by the user. I.e. layers can be changed, added, removed or changed in thickness graphically. If desired, users can specify their own interpretation rule by specifying the relation between the cone resistance and skin friction. For each rule, the user can specify the soil types to be recognized. One can use the soil type preset by D-FOUNDATIONS, according to the table of standard soil types as specified in the Eurocode 7, or specify their own soil types table.



CPT interpretation window

Standard module (Bearing piles EC7-NL)

The standard module is intended for the design and verification of bearing piles. In short terms it allows for the input of projects, the analysis, and it provides tabulated and graphical output of results both on-screen and in a report. The output is available in Dutch and English. The bearing piles module is used to first determine the bearing capacity with depth for a number of preferred piles.

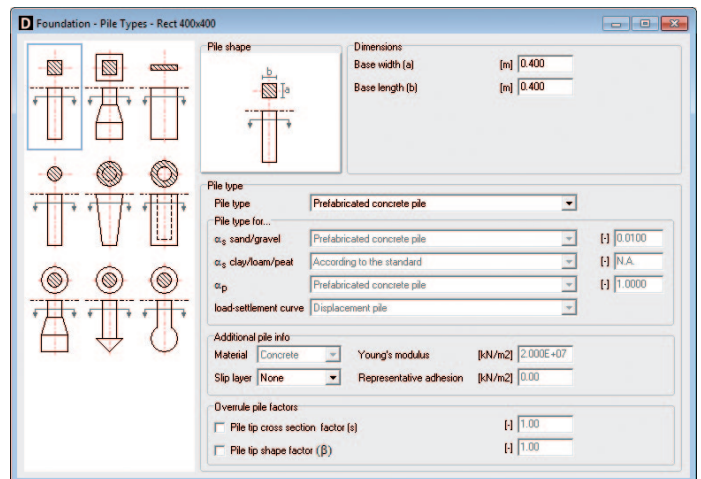


Load settlement curve for bearing piles

Once the bearing capacity is determined, the user can choose the most appropriate pile. After the preliminary design, the entire pile plan is entered and can be checked according to the design code. The result of this verification will show if the design is according to the standard and will also provide the user with the calculated settlements. The program provides fast options for re-calculation, using different pile types and fine-tuning of the pile plan. In this manner a cost efficient design can easily be obtained. Some specific features of the standard module include:

Pile library

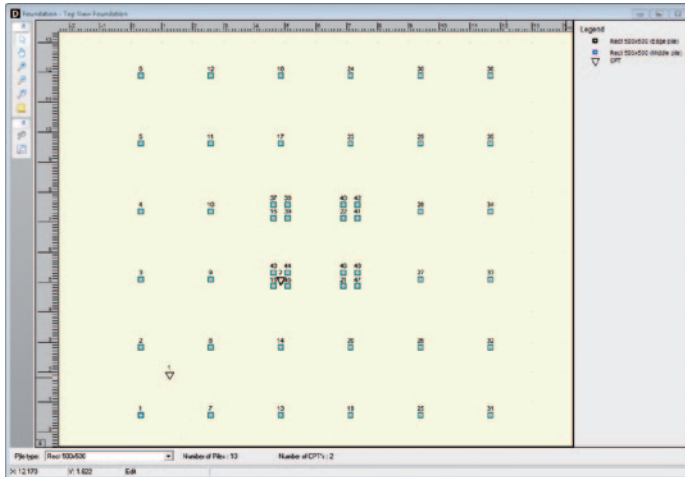
A pile library containing most standard piles provides the default parameters according to the design code. This includes α_p , the pile factor for the pile point and α_s , the pile factor for shaft friction, the pile stiffness and the pile adhesion. Users can also specify their own pile types and properties.



The pile library window

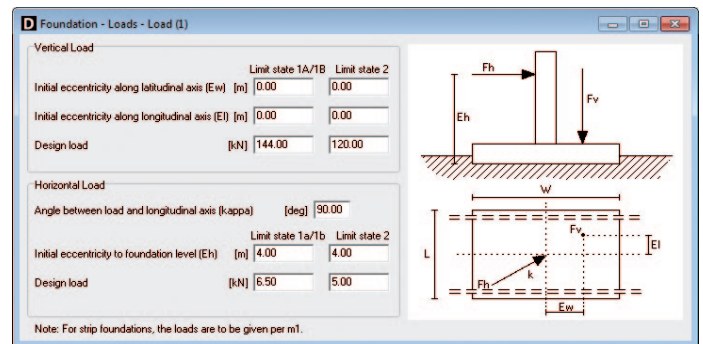
Pile grid generator

The pile grid generator eases the input of complex pile plans for equally spaced as well as non structured pile groups.



Generated pile group after using pile grid generator

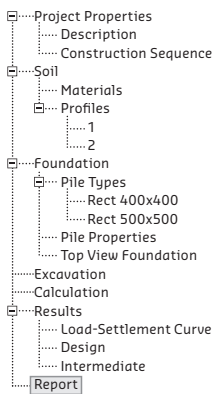
- automatic optimization of foundation size for given loads
- maximum bearing capacity for a given foundation
- verification of the foundation according to design code
- check on punch through for foundations on non-cohesive layers located above a cohesive layer
- check on tip-over stability
- check on bearing capacity if a slope is nearby
- check on squeezing effects.



Loading input for shallow foundations

Tree view

D-FOUNDATIONS uses a tree view that contains all menu-items relevant to a design/verification calculation. The user can navigate through these items manually, or use a wizard that fills in the required input for a standard pile design calculation.



Tree view

Shallow Foundations module (EC7-NL)

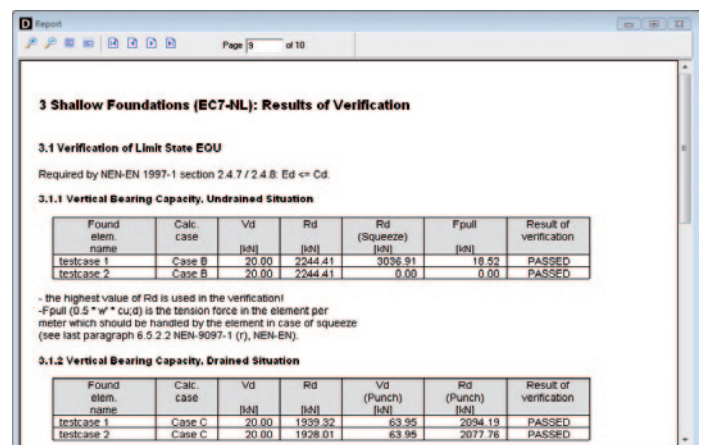
This module allows for the design of strip footings, as well as square or circular footings. The verification is based on the Eurocode 7 design code for shallow foundations, and the Dutch National Annex. The Shallow foundations module takes into account:

- horizontal and vertical loads
- load spread
- eccentricity of loads
- interaction between footings

Tension Piles module (EC7-NL)

For some constructions a foundation capable of dealing with uplift forces is needed. A foundation on tension piles may offer a more economical alternative to constructions that counter the uplift forces by ballast. The tension pile module is used to determine the pile length needed according to the Eurocode 7. D-FOUNDATIONS determines the tensile capacity and required length for each pile in a user defined pile group for different pile types and selected CPT's. The Tension Piles module takes into account:

- reduction of cone resistance due to excavation
- safety factors for design
- effects of pile installation
- reduction of stresses due to tension forces in pile groups
- pile weight and weight of soil body being pulled.



Results are presented on-screen and as printed reports

Bearing Piles module (EC7-B)

This module is similar to the base module of D-FOUNDATIONS for bearing piles, however, in this case the Belgium National Annex of the Eurocode 7 has been used. The Belgium Annex for bearing piles supports all three models available in D-FOUNDATIONS:

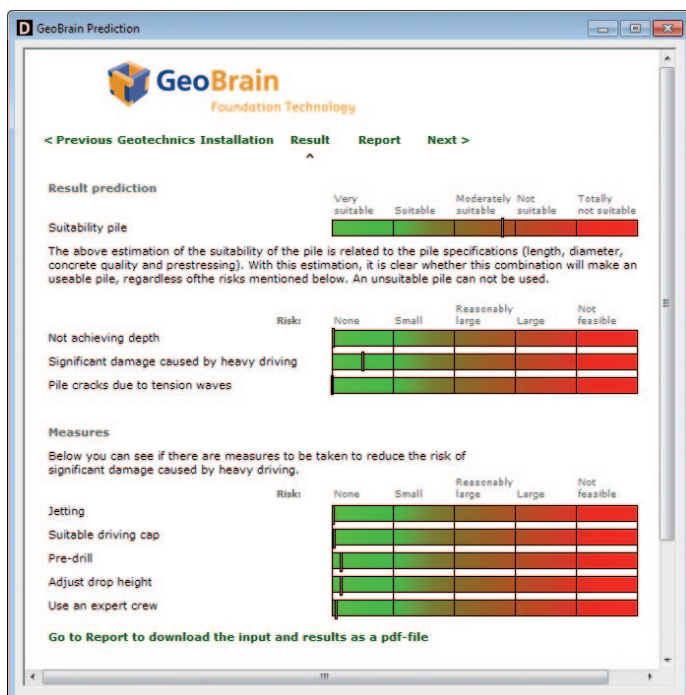
- method “de Beer”
- method “Van Impe/de Beer”
- method NEN.

The bearing capacity for the pile tip, q_{bp} , is calculated with one of the three above methods. D-FOUNDATIONS also supports rules that incorporate shaft bearing capacity, q_s . Finally, the construction design value R_{cd} is calculated, incorporating the safety philosophy of the Eurocode 7.

The Bearing piles module for the Belgian method supports the input of mechanical CPT's, electric CPT's and CPT's that can be downloaded free of charge from the DOV (Databank Ondergrond Vlaanderen).

Feasibility module

During the design of a piled foundation, the foundation is checked according to guidelines like the Eurocode. In practice, this does not guarantee that the project is feasible. This may depend on many other local factors, among which the equipment used during construction. For this purpose, the use of the Feasibility module helps the user to evaluate the feasibility of their project by comparison with experiences.



D-FOUNDATIONS Feasibility module

GeoBrain Foundation technics experiences

In 2002, GeoDelft started a project called GeoBrain which aim was to develop a prediction model for the feasibility of foundation works. Hundreds of project experiences concerning the driving of sheet pile walls and piles were therefore received for study. The Feasibility module provides access to these experiences. These may help the users to predict the feasibility of their projects.

GeoBrain Foundation technics predictions

The designed piles can also be checked using the GeoBrain prediction model. D-FOUNDATIONS will transfer the information over the internet to the GeoBrain predictions model. Results of GeoBrain are represented and pre-cautions for improvement are suggested.

Interaction with other Deltares systems tools

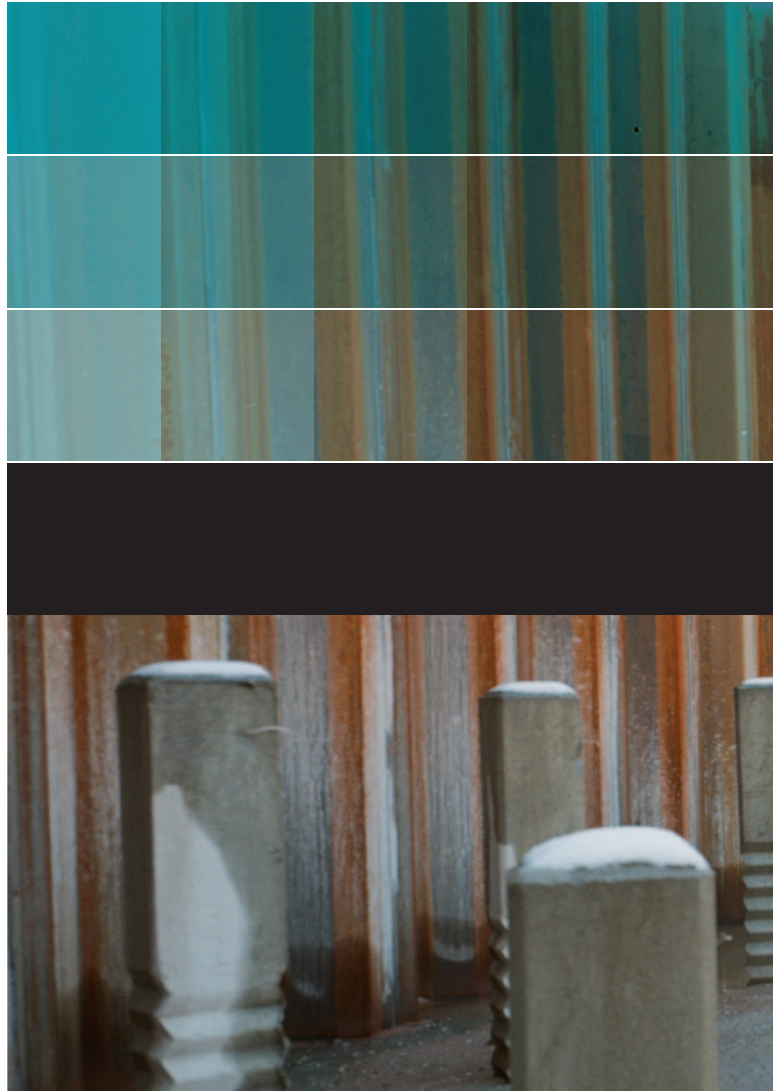
D-FOUNDATIONS requires the input of digitized CPT's which are now widely available. In some situations CPT's only exist on paper. The GEFPlotTool by Deltares is available for digitizing of electric and mechanical CPT's and to convert them to the Geotechnical Exchange Format (GEF) standard. For a full 3D analysis of piles and pile groups including pile interaction under vertical as well as horizontal loading, Deltares systems provides the D-PILE GROUP program. D-PILE GROUP follows the American Petroleum Institute (API) standard. Please refer to the D-PILE GROUP page for additional information.

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.



Photo's by: BeeldbankVenW.nl, Rijkswaterstaat.

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