PLAXIS

PLAXFLOW - Version 1.4

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PREFACE

PLAXFLOW is one of the PLAXIS products. PLAXIS is a range of finite element programs which are used worldwide for geotechnical engineering and design. The development of PLAXIS began in 1987 at Delft University of Technology as an initiative of the Dutch Ministry of Public Works and Water Management (Rijkswaterstaat). The initial purpose was to develop an easy-to-use 2D finite element code for the analysis of river embankments on the soft soils of the lowlands of Holland. In subsequent years, PLAXIS was extended to cover most other areas of geotechnical engineering. Because of continuously growing activities, the PLAXIS company (PLAXIS bv) was founded in 1993. In 1998, the first PLAXIS 2D deformation and stress analysis program for Windows was released. In the mean time a calculation kernel for 3D finite element calculations was developed which resulted in the release of the PLAXIS 3D Tunnel program in 2001. The recent PLAXIS 2D Version 8 was released in 2002. This version included a new steady-state Groundwater flow calculation kernel. The current software package PLAXFLOW is the stand-alone version of this Groundwater flow program including transient flow, unsaturated behaviour and time-dependent boundary conditions. PLAXFLOW is compatible with PLAXIS Version 8 for deformation and stability analysis, which was released at the same time as PLAXFLOW.

Main goals and objectives: In 1999 the Road and Hydraulic Engineering division of Rijkswaterstaat took the initiative for the development of a new Groundwater flow program, compatible with the 2D deformation and stability analysis software. The main goal was to improve the analysis software for the evaluation of river dike stability in the case of time-dependent groundwater flow during high water on the Dutch rivers. For this project a cooperation between Rijkswaterstaat, GeoDelft and PLAXIS was started. The first result of this cooperation was the steady-state version of the new Groundwater flow calculation kernel, as available in PLAXIS Version 8. We are very proud to release now the transient version of the full Groundwater flow program, PLAXFLOW, which can be used as a stand-alone program or in combination with PLAXIS Version 8. The combination of PLAXIS Version 8 and PLAXFLOW will enable you to solve a wide range of steady-state and transient groundwater flow problems, in combination with deformation and/or stress analysis and stability.

CUR consortium: Research and development of the PLAXIS software is supported by the Centre for Civil Engineering Research and Codes (CUR). A consortium of more than 30 European companies contribute financially to these developments and the CUR committee checks the efficiency and quality of the resulting software products. The CUR consortium provides a valuable link with engineering practice. Future developments are discussed within the CUR consortium and feedback is provided after new releases of the code.

Delft Cluster: The research required to develop the PLAXFLOW program was performed in the framework of the Delft Cluster programme. The Delft Cluster is a civil engineering research programme in The Netherlands with financial support from the Ministry of Economic Affairs.

Scientific network: The development of PLAXIS and PLAXFLOW would not be possible without world-wide research at universities and research institutes. To ensure that the high technical standard of PLAXIS is maintained, the development team is in contact with a large network of researchers in the field of geo-mechanics and numerical methods. Direct support is obtained from a series of research centres:

Delft University of Technology (NL)	Prof. F. Molenkamp
Institut für Geotechnik, Uni Stuttgart (D)	Prof. P.A. Vermeer
BundesAnstalt für Wasserbau (D)	Dr. M. Heibaum, Dr. R. Schwab
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University of Colorado at Boulder (USA)	Prof. S. Sture
Massachusetts Institute of Technology (USA)	Prof. A.J. Whittle
University of California at Berkeley (USA)	Prof. J.M. Pestana
Norwegian Univ. of Science and Tech (N)	Prof. S. Nordal
Norwegian Geotechnical Institute (N)	Dr. L. Andresen
National University of Singapore	Prof. H. Tan

The editor

Disclaimer:

PLAXFLOW is a finite element program for groundwater flow applications in which models are used to simulate the (un)saturated steady-state and transient flow in porous media. The PLAXFLOW code and its soil models have been developed with great care. Although a lot of testing and validation have been performed, it cannot be guaranteed that the PLAXFLOW code is free of errors. Moreover, the simulation of geotechnical problems by means of the finite element method implicitly involves some inevitable numerical and modelling errors. The accuracy at which reality is approximated depends highly on the expertise of the user regarding the modelling of the problem, the understanding of the soil models and their limitations, the selection of model parameters, and the ability to judge the reliability of the computational results. Hence, PLAXFLOW may only be used by professionals that possess the aforementioned expertise. The user must be aware of his/her responsibility when he/she uses the computational results for hydraulic or geotechnical design purposes. The PLAXIS organisation cannot be held responsible for design errors that are based on the output of PLAXFLOW calculations.

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PLAXIS VERSIONS, COURSES AND USER SERVICES

Update Versions and new releases of PLAXIS, containing various new features, are generally released annually. In addition, courses and user meetings are organised on a regular basis. Registered users receive detailed information about new developments and other PLAXIS activities. Valuable user information is provided by means of the PLAXIS bulletin and the Internet site *http://www.plaxis.nl*.

2D Professional Version: A large range of geotechnical problems may be analysed using this high capacity version. It is possible to use extensive 2D finite element meshes. The Professional Version is supplied as an extended package, including static elastoplastic deformation, advanced soil models, consolidation, updated mesh and steady-state groundwater flow.

2D Dynamics module: The PLAXIS Dynamics module is an add-on module to the PLAXIS 2D Professional Version. This module may be used to analyse vibrations in the soil and their influence on nearby structures. Excess pore pressures can be analysed. Liquefaction, however, is not included in this version, but the intention is to include this feature in future versions.

PLAXFLOW: The PLAXIS Groundwater flow program is an independent program for the analysis of steady-state and transient groundwater flow. PLAXFLOW incorporates sophisticated models for saturated/unsaturated groundwater flow, using the well-known "Van Genuchten" relations between pore pressure, saturation and permeability. PLAXFLOW is numerically stable and provides state-of-the-art facilities to incorporate time-dependant boundary conditions. It also enables you to combine results with the PLAXIS 2D professional version for deformation and stability analysis.

3D Tunnel Program: This program is especially designed for the analysis of tunnel projects, but it also enables the analysis of a larger range of other geotechnical problems. 3D finite element meshes consisting of thousands of elements can be generated. The 3D Tunnel Program is supplied as an extended package, including static elastoplastic deformation and advanced soil models.

3D Foundation Program: This program is designed for the analysis of raft foundations, but it also enables the analysis of pile-raft foundations and offshore foundations. Large 3D finite element meshes can be generated. The 3D Foundation Program is supplied as an extended package, including static elastoplastic deformation and advanced soil models.

Demo Version: A Demo Version of PLAXIS Version 8, PLAXIS 3D FOUNDATION and PLAXIS 3D TUNNEL is available for interested persons who wish to learn about the program features and capabilities before ordering the Educational Version or the Professional Version. The Demo Version is based on the pre- and postprocessor of the Professional Version, but user-defined geometries cannot be stored and calculations cannot be actually performed. The postprocessor can be evaluated on the basis of the tutorial examples that are installed in the examples directory.

Educational Version: For universities and education centres, an Educational Version of the listed PLAXIS programs is available at a reduced price.

Courses on Computational Geotechnics: Courses dealing with both theoretical and practical aspects of computer modelling in geotechnical engineering are given on a regular basis in several countries, with support from the scientific network. In these courses, applications exercises and case studies are included during which participants have the opportunity to carry out various types of computer analyses. Although PLAXIS is intensively used, the courses are not primarily intended to teach the details of this particular computer program. The main aim of these courses is to teach finite element modelling in geotechnical engineering, with direct applications to practical problems.

Magazine: An international magazine, issued twice a year, is provided to all registered PLAXIS users. This magazine contains descriptions of practical projects in which PLAXIS has been used, backgrounds on the use of advanced soil models, information on new developments, hints for optimised usage of the program and a diary of activities.

Internet site: In addition to the information provided in the magazine, the internet site *http://www.plaxis.nl* contains more general information about PLAXIS, including information on courses and meetings, answers to frequently asked questions and a discussion group for users.

User support: Limited free technical support is provided by e-mail. A professional helpdesk is available for clients who wish to obtain prompt and extensive technical and scientific support. This support is provided on the basis of a support contract.

For more information on products and users services, contact:

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SHORT REVIEW OF FEATURES

PLAXFLOW is a finite element package intended for two-dimensional transient and steady-state analysis of saturated and unsaturated groundwater flow problems in geotechnical engineering and hydrology. Groundwater flow applications require advanced models for the simulation of the unsaturated, time-dependent and anisotropic behaviour of soils. PLAXFLOW is equipped with features to deal with various aspects of complex geotechnical flow problems. A brief summary of the important features of the program is presented below.

Graphical input of geometry models: The input of soil layers, structures, construction stages and boundary conditions is based on convenient CAD drawing procedures, which allows for a detailed modelling of the geometry cross-section. From this geometry model, a 2D finite element mesh is easily generated.

Automatic mesh generation: PLAXFLOW allows for automatic generation of unstructured 2D finite element meshes composed of 3-node triangular elements, with options for global and local mesh refinement. For compatibility with the PLAXIS deformation program, 6-node and 15-node elements can also be chosen.

Screens: Screen elements are used to simulate an impermeable screen. An active screen is fully impermeable (separation of pore pressure degrees-of-freedom of node pairs). An inactive screen is fully permeable (coupling of pore pressure degrees-of-freedom of node pairs).

Wells: Wells are used to prescribe points inside the geometry model where a specific discharge is subtracted from (source) or added to (sink) the soil.

Drains: Drains are used to prescribe lines inside the geometry model where pore pressures are set to zero.

Tunnels: The PLAXFLOW program offers a convenient option to create circular and non-circular tunnels using arcs and lines.

Water Level: General groundwater heads or pore pressures and external water pressures can be conveniently generated on the basis of water levels. Groundwater heads and pore pressures can also be specified directly in individual boundary lines.

Closed flow boundary: A closed flow boundary is an object that can be placed at the boundary of the geometry model to ensure that flow across that boundary will not occur.

Precipitation: Precipitation is a vertical infiltration that can be used to simulate weather conditions. Infiltration is a conditional inflow, which can also be specified directly on individual boundary lines.

Inflow and outflow: These conditions can be used to specify a recharge or discharge directly on individual boundary lines.

Material database: Material properties for soil are entered in data sets, which are collected in the project database. Material data sets from the projects database may be assigned to individual soil layers.

Van Genuchten model: Soil can be modelled at several levels of sophistication. Clearly, the number of model parameters increases with the level of sophistication. The Van Genuchten model is a well-known and widely accepted model to simulate unsaturated soil behaviour. This model is one of the models that are available in PLAXFLOW.

Predefined data sets: Various types of soil can be conveniently selected on the basis of common soil classification systems (Hypres, USDA, Staring). Predefined data sets for the Van Genuchten and the Approximate Van Genuchten models are available for all types of soil.

User-defined models: Experts on groundwater flow modelling may enter all parameters of the Van Genuchten model manually or specify user-defined relationships between groundwater head, permeability and saturation.

Steady-state and transient flow: Multiple calculation phases may be created in which different sets of boundary conditions can be specified. The groundwater flow calculation kernel allows for steady-state and transient groundwater flow calculations.

Time-dependent conditions: PLAXFLOW allows for conditions that are gradually changing in time. Time-dependent conditions can be defined by a linear or harmonic function or by means of an input table.

Output features: The PLAXFLOW postprocessor has enhanced graphical features for displaying computational results, such as distributions of the groundwater head, pore pressure, degree of saturation and Darcy flux. Values of these quantities can be obtained from the output tables. Plots and tables can be send to output devices or to the Windows® clipboard to export them to other software.

Cross-sections: The cross-section option can be used to create graphs for pressures, heads, and flow velocities in any desired cross-section of the geometry.

Curves: Curves can be drawn of selected points in the geometry and of cross-sections. These curves visualise the development of the groundwater head, pore pressure, degree of saturation or Darcy flux during the various calculation phases, which provides valuable insight in the groundwater flow process.

Animations: Video animations can be created for all graphical output quantities.

HARDWARE SPECIFICATIONS

System requirements: The PLAXFLOW program runs on Pentium PC's using Windows®NT 4.0 with at least Service Pack 4, Windows® 2000 or Windows® XP Professional (32 bits) as the operating system.

Hard disk: To install the PLAXFLOW package, at least 60 Mb of hard disk space must be available. In addition, a minimum workspace of 500 Mb is recommended, but for large projects more disk space may be required.

Random Access Memory (RAM): The minimum recommended amount of RAM installed in the computer is 512 Mb in all Windows® environments. The use of extra memory in addition to the minimum requirements results in a faster operation of the program and/or a larger number of elements that can be used in finite element models.

Video modes: The PLAXFLOW program requires a minimum screen resolution of 800 x 600 pixels and a 256 colour palette. However, it is advisable to use a screen resolution of at least 1024 x 768 pixels and a 16 bit colour palette.

Mouse: A graphical pointing device (mouse) with two or three buttons is required. A 'wheel mouse' is not required, but can be useful to view tables of output data.

Output devices: Graphical and tabulated output can be printed on all modern types of laser or inkjet printers (including colour printers). Printing is fully controlled by the Windows® operating system. For more information on the installation of output devices reference should be made to the respective manuals.

PC network: A single version of PLAXFLOW may be installed on a PC network. However, single versions can only be run on one workstation at a time using a local hardlock key. A multiple licence network version is available upon special request. This requires the installation of a multiple licence hardlock key on the network server and additional network software. A network hardlock requires the TCP/IP protocol.

INSTALLATION

The PLAXFLOW package is installed by using an easy-to-use installation program. The program acts like a wizard and guides the user through the installation settings. During installation the files from the installation CD are decompressed and copied to the appropriate locations on the hard disk. At the end of the installation procedure, a new program group *PlaxFlow 1.x* is automatically created in the *Programs* sub-menu of the *Start* menu. The installation of PLAXFLOW does not affect other PLAXIS products. Installation under the various Windows® versions, as mentioned in the system requirements, is similar. Make sure that you have the *Administrator* rights to be able to update the Windows registry.

Program installation

- Insert the PLAXFLOW installation CD in the CD-ROM drive. Within 10-20 seconds an introduction screen should appear. If this is not the case, then:
  - Click the Windows® *Start* button and select *Run...* from the *Start* menu.
  - In the *Open* edit field type "R:\AUTORUN.EXE" (assuming that the installation is executed from CD-ROM drive "R").
  - Click the *OK* button to start the introduction screen.
- Choose the option *Install PLAXFLOW Version XX*.
- Follow the instructions on the screen.
- Before starting the PLAXFLOW program, make sure that the hardlock key is correctly installed.

Local Hardlock key installation

PLAXFLOW continuously checks for the presence of the hardlock key that is included in the package. This key must be inserted in a USB port of the computer. Alternatively, a parallel key is available. Normally a device driver for the hardlock key is installed during the setup. If, for some reason, the installation of the hardlock key driver fails the user can install it manually as described in the section troubleshooting on page xii.

Network Hardlock key installation

Alternatively it is possible to use a shared hardlock over the network. This needs a specical hardlock as well as a special driver to be installed which is not done automatically by the the setup. The document “network.pdf” that can be found on the PLAXIS Installation CD describes what procedure to follow in order to install the network hardlock key. Please note that a network hardlock key can be installed on any computer in the network with Windows® 2000, XP or 2003 as the operating system.

PROGRAM UNINSTALL AND REINSTALL

Should you wish to uninstall or reinstall PLAXFLOW you can either use the Windows' *Add/Remove* programs utility from the *Control Panel* or re-run the installation from the PLAXFLOW Installation CD. You can now choose whether to remove the program from your computer, repair a currently installed version or modify the currently installed version.

TROUBLESHOOTING

In exceptional cases the installation program fails to install the PLAXFLOW package. Some possible error messages during the execution of the program are:

- The program starts with the message "*No Hardlock found.*" and closes immediately.
- The program starts with a message related to the dynamic link library HLVDD.DLL.

Additionally the following problems may occur using Windows 2000:

- The mesh generator fails to generate a mesh though all the possible solutions have been applied.
- The calculation hangs directly after starting. In the bottom left corner of the calculation window the status of the calculation shows "Profile…".

The appropriate actions to be taken on these messages are described below:

No Hardlock found

For some reason the automatic hardlock installation has failed. In this case, the user has to install the hardlock drivers manually.

Manual hardlock key driver installation:

- Open a Command Prompt box and go to the sub-directory "Hardlock" of the directory where the PLAXFLOW package was installed (by default "C:\Program Files\PlaxFlow 1.x").
- If a PLAXIS hardlock key was installed before, it should be de-installed before installing the new key. Therefore type the command: "HLDINST -remove".
- To install the new hardlock, type the command: "HLDINST -install".
- All options of the manual hardlock installation program can be viewed by typing the command "HLDINST -help".

The new hardlock key drivers are downwards compatible, which means that they can also be used successfully in combination with old PLAXIS versions.

The program starts with a message related to the dynamic link library HLVDD.DLL

The program finds an old hardlock key driver before it finds the newly installed driver. Most likely there is still a hardlock key driver of PLAXIS version 7.x on the system.

The best solution would be to manually remove all files called HLVDD.DLL from your computer and manually reinstall the hardlock key driver as described in the previous trouble shooting topic.

Windows 2000: Mesh generation fails or calculation hangs directly after starting

Both problems are related to the Windows' temporary directory stored in the TEMP environment variable. By default, under Windows 2000, this TEMP variable contains a rather long path ("C:\Documents and Settings\<username>\Local Settings\Temp" for the case where Windows has been installed on drive "C") causing the problem.

The solution is to set the TEMP variable to a shorter, existing, path. To do this:

- Go to the Windows *Start* Menu and successively select *Settings*, *Control Panel* and *System*.
- In the *System Properties* window that has now appeared choose the last tab sheet called *Advanced*.
- From this tab sheet choose the middle option *Environment variables*
- In the *Environment variables* window choose from the uppermost list the variable called TEMP and click the *Edit* button in order to change its value.
- Set the TEMP variable's value to, for example, "C:\TEMP".
- Close all windows.
- Make sure the newly defined temporary directory exists. If this is not the case, then create the directory using the Windows Explorer.

Note that the above procedure may have to be repeated after installing a Windows Service Pack.