# PLAXIS

CONNECT Edition V20.04

## General Information Manual



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# 1 Preface

PLAXIS is a finite element program, developed for the analysis of deformation, stability and groundwater flow in geotechnical engineering. It is a part of the PLAXIS product range, a suite of finite element programs that is 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 formed in 1993. As of 2018, PLAXIS is part of Bentley Systems, Incorporated, a US-based company specialised in software for planning, design and maintenance of infrastructural projects.

In 1998, the first PLAXIS 2D for Windows was released. In the meantime a calculation kernel for 3D finite element calculations was developed which resulted in the release of the 3DTunnel program in 2001. 3DFoundation was the second three-dimensional PLAXIS program, and was developed in cooperation with TNO. The 3DFoundation program was released in 2004. However, in neither 3DTunnel nor 3DFoundation it was possible to define arbitrary 3D geometries, because of their geometrical limitations. PLAXIS 3D is a full three-dimensional finite element program which combines an easy-to-use interface with full 3D modelling facilities. The first PLAXIS 3D program was released in 2010.

Goals and objectives: PLAXIS is intended to provide a tool for practical analysis to be used by geotechnical engineers who are not necessarily numerical specialists. Quite often practising engineers consider non-linear finite element computations cumbersome and time-consuming. The PLAXIS research and development team has addressed this issue by designing robust and theoretically sound computational procedures, which are encapsulated in a logical and easy-to-use shell. As a result, many geotechnical engineers world-wide have adopted the product and are using it for engineering and design purposes.

Memberships: The PLAXIS company and its employees are members of various institutions in civil engineering, geo-science and computational methods throughout the world. The PLAXIS company is a member of NAFEMS, a non-profit organisation with the goal to stimulate the use of the finite element method in various types of engineering.

Scientific network: The development of the PLAXIS products would not be possible without worldwide research at universities and research institutes. To ensure that the high technical standard of PLAXIS is maintained and that new technology is adopted, the development team is in contact with a large network of researchers in the field of geo-engineering and numerical methods.

The Editors gratefully acknowledge the direct support from different researchers and research centres:

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# Important warning and disclaimer

**Warning:** PLAXIS is a finite element program for geotechnical applications in which soil models are used to simulate the soil behaviour. The PLAXIS 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 PLAXIS 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, PLAXIS 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 geotechnical design purposes. The PLAXIS organization cannot be held responsible or liable for design errors that are based on the output of PLAXIS calculations.

# 2 PLAXIS Products and Services

## Products

Update versions and new releases of PLAXIS, containing various new features, are released frequently. In addition, courses and user meetings are organised on a regular basis. Registered users receive detailed information about new developments and other activities. Valuable user information is provided on the Bentley website and Bentley communities.

### *PLAXIS 2D*

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

### *PLAXIS 3D*

PLAXIS 3D is a geotechnical finite element program with a full 3D pre-processor that allows CAD objects to be imported and further processed within a geotechnical context. The program is supplied as an extended package, including static elastoplastic deformation, advanced soil models, stability analysis, consolidation, safety analysis, updated mesh analysis and steady-state groundwater flow.

### *PLAXIS MoDeTo*

PLAXIS MoDeTo is a software package for the analysis and design of monopiles as foundation elements for offshore wind turbines, under lateral loading conditions. PLAXIS MoDeTo can be used as a stand-alone tool for the rule-based design method and in connection with PLAXIS 3D for the numerical-based design method, as defined in the PISA research project. In the latter case, soil reaction curves, used in the one-dimensional finite element kernel of PLAXIS MoDeTo, are derived and calibrated from the results of a series of 3D finite element calculations performed in PLAXIS 3D.

### *Dynamics*

Dynamics is an add-on module to PLAXIS 2D and PLAXIS 3D. This module may be used to analyse vibrations in the soil and their influence on nearby structures as well as for geotechnical earthquake analysis. Excess pore pressures can be analysed. Liquefaction can be analysed by using one of the available liquefaction models (UBC3D-PLM or PM4Sand). The latter is available as user-defined soil model upon request. Besides short-term (undrained) dynamic analysis, the module includes dynamics with simultaneous consolidation of excess pore

pressures. Dynamic calculations can also be executed taking large deformation effects (updated mesh) into account.

### *PlaxFlow*

PlaxFlow is an add-on module to PLAXIS 2D and PLAXIS 3D. This module may be used for the analysis of fully coupled flow deformation analysis, steady-state and transient groundwater flow. The module incorporates sophisticated models for saturated / unsaturated groundwater flow, using the well-known *Van Genuchten* relations between pore pressure, saturation and permeability. It provides state-of-the-art facilities to incorporate time-dependent boundary conditions. The Barcelona Basic model for unsaturated soil behaviour is available as a user-defined soil model upon request.

### *Thermal*

Thermal is an add-on module to PLAXIS 2D. This module may be used for the analysis of fully coupled thermo-hydro-mechanical analysis, steady-state and transient thermal flow.

## Tools

### *2D to 3D Converter Tool*

The PLAXIS 2D to 3D Converter tool takes the 2D model geometry and soil properties and will convert this as an extruded model in PLAXIS 3D(Click here for further infomation) .

### *ISM*

**Note:** This feature is provided as a Technical Preview .

Bentley's Integrated Structural Model (ISM) is a technology for sharing structural engineering project information among structural modeling, analysis, design, drafting, and detailing applications. ISM is similar to Building Information Modeling (BIM), but focuses on the information that is important in the design, construction, and modification of the load bearing components of buildings, bridges, and other structures.

This feature is only available for PLAXIS 3D.

### *PLAXIS Coupling Tool*

**Note:** This feature is provided as a Technical Preview

The PLAXIS Coupling Tool enables you to integrate PLAXIS with an external structural FEM package (STAAD.Pro).

# Services

## *Geotechnical SELECT* GSE

Geotechnical SELECT is an additional subscription system on top of the professional software licenses. Geotechnical SELECT subscribers benefit from the latest releases of their PLAXIS software maintenance and support from PLAXIS technical experts. In addition, some features of PLAXIS programs are only available to Geotechnical SELECT subscribers. These features are noted with the icon GSE in the software. An overview of these features and more information about Geotechnical SELECT are available on our website within Bentley communities.

## *User Support*

Priority technical support is provided to Geotechnical SELECT users . A professional help desk is available on Service Request Manager for clients who wish to obtain prompt and extensive technical and scientific support.

## *PLAXIS Demo*

An introductory version of PLAXIS software is available for interested persons who wish to learn about the program features and capabilities before ordering the software. The PLAXIS Demo is based on PLAXIS software but there is a limited number of material sets and calculation phases. In addition, it is not possible to copy or print. A Tutorial Manual with examples specifically generated for the PLAXIS Demo is included. For further information and to request a copy of the Demo please contact sales@plaxis.com.

## *PLAXIS Academy*

Under the PLAXIS Academy educational program several courses, trainings, seminars, webinars and workshops are organized through out the year at different locations all over the world.

| | |
|---|---|
| *PLAXIS Courses* | PLAXIS Courses consist of a mixture of lectures and hands-on computer analyses making the courses more than just a software training. The aim of both teaching and exercises is to concentrate on the use and background of advanced methods in geotechnical engineering. The principle of PLAXIS Courses is that they will give ongoing education and knowledge transfer for which the use of the PLAXIS software is only a tool to explain the topics learned. There are two levels of courses, Standard and Advanced. The Standard Courses are meant for those who have little or no experience with PLAXIS and focuses on the engineering aspects of the use of finite element method. The Advanced Courses on the other hand assume a certain level of experience and therefore go deeper into the theoretical background. |
| *PLAXIS Trainings* | The PLAXIS Trainings focus on developing knowledge on the use of PLAXIS Software. This is considered the main topic and any technical lecture is just to support and illustrate the use of the software. Under PLAXIS Trainings we distinguish between a PLAXIS Training (multi-day), a PLAXIS Workshop (1-day) or PLAXIS Seminar (without any hands-on training with the software). |

## *Website*

Bentley website is the main sources of information about the latest news, events, products and services of PLAXIS products. Besides this information Bentley communities contains and extensive WIKI with a collection of bulletins, publications, models and much more. Visit the site on a regular basis to stay in contact with PLAXIS.

For more information on products and user's services, contact:

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# 3 Short review of features

PLAXIS is a finite element package intended for the two-dimensional or three-dimensional analysis of deformation, stability, dynamics and groundwater flow in geotechnical engineering. Geotechnical applications require advanced constitutive models for the simulation of the non-linear, time-dependent and anisotropic behaviour of soils and/or rock. In addition, since soil is a multi-phase material, special procedures are required to deal with pore pressures and (partial) saturation in the soil. Although the modelling of the soil itself is an important issue, many geotechnical projects involve the modelling of structures and the interaction between the structures and the soil. PLAXIS is equipped with features to deal with various aspects of complex geotechnical structures. A brief summary of the important features of all PLAXIS programs is given below.

## Graphical input of geometry models

The input of soil data, structures, construction stages, loads and boundary conditions is based on convenient CAD drawing procedures, which allows for a detailed modelling of the geometry. From this geometry model, a finite element mesh is easily generated.

## Design approaches 

A coherent set of partial factors for loads and model parameters can be defined according to the applicable Ultimate Limit State design method (e.g. Eurocode 7 or LRFD) and applied during calculations, in addition to the Serviceability Limit State calculations.

## Boreholes

Soil layers are defined by means of boreholes. Multiple boreholes can be placed in the geometry to define a non-horizontal soil stratigraphy or an inclined ground surface. PLAXIS automatically interpolates layer and ground surface positions in between the boreholes. Alternatively, imported top and bottom surfaces (e.g. parametric DXF, STEP) can be assigned to a borehole to characterize the soil stratigraphy (only 3D).

## Automatic mesh generation

PLAXIS allows for automatic generation of unstructured finite element meshes with options for global and local mesh refinement.

## High-order elements

Quadratic 6-node and 4$^{th}$ order 15-node triangular elements are available in PLAXIS 2D to model the deformations and stresses in the soil. Quadratic tetrahedral 10-node elements are available in PLAXIS 3D .

## Interfaces

Joint elements are available to model soil-structure interaction. For example, these elements may be used to simulate the thin zone of intensely shearing material at the contact between a tunnel lining and the surrounding soil. Values of interface friction angle and adhesion are generally not the same as the friction angle and cohesion of the surrounding soil.

## Plates

Plates (or shell elements) can be used to model thin structures in the ground with a significant flexural rigidity (bending stiffness). Their behaviour can be elastic or non-linear elastoplastic. Typical applications are floor plates, walls and tunnel linings.

## Beams

Beam elements can be used to model slender one-dimensional objects with a significant flexural rigidity. Their behaviour can be elastic or non-linear elastoplastic. Typical applications are walings, girders and structural columns.

## Anchors

Elastoplastic spring elements are used to model anchors and struts. The behaviour of these elements is defined using a normal stiffness and a maximum force. A special option exists for the analyses of prestressed ground anchors and excavation supports.

## Geogrids

Geogrids (or geotextiles) are often used in practice for the construction of reinforced embankments or soil retaining structures. These elements can be simulated in PLAXIS by the use of special tension elements. It is often convenient to combine these elements with interfaces to model the interaction with the surrounding soil. The behaviour of these elements is defined using a normal stiffness and a maximum tension force.

## Embedded beams

These special elements consist of beam elements with embedded interface elements to describe the interaction of a pile, rockbolt and grout body with the surrounding soil or rock at the skin and the tip of a pile. The embedded beam interface elements are considered to be elastoplastic. The failure behaviour of the embedded beam elements is defined by their bearing capacity.

## Ground anchors

These special elements consist of embedded beam elements (representing the grout body) and a node-to-node anchor. The behaviour of the anchor is defined using a normal stiffness and a maximum force. The embedded beam elements consist of beam elements with embedded interface elements to describe the interaction of the ground anchor with the soil. The embedded interface elements are considered to be elastoplastic. The failure behaviour of the ground anchors is defined by their bearing capacity. During calculations, a ground anchor may be prestressed.

## Tunnels GSE

The PLAXIS program offers a convenient option to create circular and non-circular tunnels using arcs and lines. Plates and interfaces may be used to model the tunnel lining and the interaction with the surrounding soil. Additional features such as loads or rock bolts may be defined at the tunnel contour. Fully isoparametric elements are used to model the curved boundaries within the mesh. Various methods have been implemented to analyse the deformations that occur as a result of various methods of tunnel construction (for example, deconfinement method).

## Loads

The program allows for various types of loads (point loads, line loads, surface loads [3D only]) that could be applied in the model. Different loads and load levels can be activated independently in each construction stage.

## Mohr-Coulomb model

This robust and simple non-linear model is based on soil parameters that are known in most practical situations. Not all non-linear features of soil behaviour are included in this model, however. The Mohr-Coulomb model may be used to compute realistic bearing capacities and collapse loads of footings, as well as other applications in which the failure behaviour of the soil plays a dominant role. It may also be used to calculate a safety factor using a "phi-c reduction" approach.

## Hoek-Brown model GSE

This model may be used to describe the stiffness and strength of intact and weathered rock formations. It is based on the well-known Hoek-Brown failure criterion with practical input parameters. As an alternative, the Joined Rock model may be used for stratified and jointed rock formations.

## Advanced soil models

As a general second-order model, an elastoplastic type of hyperbolic model is available, which is called the Hardening Soil model. This model allows for plastic compaction (cap hardening) as well as plastic shearing due to deviatoric loading (shear hardening). To account for the increased stiffness of soils at small strains, the Hardening Soil model with small-strain stiffness (HSsmall) is available. To analyse accurately the time-dependent and logarithmic compression behaviour of normally consolidated soft soils, a Creep model is available, which is referred to as the Soft Soil Creep model. To evaluate the liquefaction behaviour in dynamic application of sandy soils, the UBC3D-PLM and PM4Sand models are available. To simulate the time-dependent strength and stiffness of concrete and shotcrete structures, strain hardening-softening in compression and tension as well as creep and shrinkage, the Concrete model is available.

The above models are just some of the available models. A full list of models and more detailed information on these models can be found in the Material Models Manual.

## User-defined soil models GSE

A special feature in PLAXIS is the user-defined soil models option. This feature enables users to include self-programmed soil models in the calculations. This option is primarily of interest for researchers and scientists at universities and research institutes, but it may also be useful for practising engineers. An overview of existing

user-defined soil models is available on the Bentley Communities website . Some user-defined soil models have been developed and are supported by the PLAXIS team itself.

## Soil tests GSE

The soil test option in PLAXIS is a convenient procedure to check the behaviour of the selected soil material model with the given material parameters. After entering the model parameters, the user can quickly simulate several standard soil lab tests and compare the results against the results from actual laboratory tests. The *SoilTest* facility can be used to optimise model parameters such that a best fit is obtained between the model results and the results of real soil lab tests.

## Orthotropic structural behaviour

Structural behaviour may be defined as linear elastic material orthotropy. This applies to beams, plates, geogrids. Geometric orthotropy of plates with a particular profile can also be emulated to a certain extend.

## Steady state pore pressure

Complex pore pressure distributions may be generated on the basis of a combination of phreatic levels or direct input of water pressures. In PLAXIS a steady-state groundwater flow calculation can be performed as an alternative to calculate the pore pressure distribution in problems that involve steady state flow or seepage. Transient flow and fully coupled flow-deformation analysis are available in the PlaxFlow module.

## Excess pore pressures

PLAXIS distinguishes between drained and undrained soils to model permeable sands as well as almost impermeable clays. Excess pore pressures are computed during plastic calculations when undrained soil layers are subjected to loads. Undrained loading situations are often decisive for the stability of geotechnical structures.

## Automatic load stepping

The PLAXIS program runs in an automatic step size and automatic time step selection mode. This avoids the need for users to select suitable load increments for non-linear calculations and it guarantees an efficient and robust calculation process.

## Staged construction

This powerful PLAXIS feature enables a realistic simulation of construction and excavation processes by activating and deactivating clusters of elements, application of loads, changing of water pressure distributions, etc. This procedure allows for a realistic assessment of stresses and displacements as caused, for example, by soil excavation during an underground construction project.

## Consolidation analysis

The decay of excess pore pressures with time can be computed using a consolidation analysis. A consolidation analysis requires the input of permeability coefficients in the various soil layers. Geometry boundaries can be set open or closed for consolidation. Automatic time stepping procedures make the analysis robust and easy-to-use.

## Safety analysis

The factor of safety is usually defined as the ratio of the failure load to the working load. This definition may be suitable for foundation structures, but not for sheet-pile walls or embankments. For this latter type of structure it is more appropriate to use the soil mechanics definition of a safety factor, which is the ratio of the available shear strength to the minimum shear strength needed for equilibrium. PLAXIS can be used to compute this factor of safety using a "phi-c reduction" procedure.

## Dynamics analysis

The dynamic module enables the analysis of vibrations and strong motions in the ground. Special boundary conditions and post-processing facilities are available for ground response analysis, soil-structure interaction and deformation/stability analysis under earthquake loading conditions. A dynamic analysis with consolidation is available to allow for the simultaneous dissipation of excess pore pressures.

## Updated Lagrangian analysis

Using this option, the finite element mesh is continuously updated during the calculation. For some situations, a conventional small strain analysis may show a significant change of geometry. In these situations it is advisable to perform a more accurate Updated Lagrangian calculation, which is called *Updated Mesh* in PLAXIS.

## Scripting interface

PLAXIS provides an HTTP based API that provides additional flexibility and power to the existing command line. Moreover, the Python wrapper for the *PLAXIS HTTP REST API* hides the technicalities of dealing with the HTTP communications behind a comfortable object-oriented wrapper available directly from PLAXIS.

## Preview option

A convenient preview option is available to check model and calculation settings in a graphical 2D or 3D environment. Since calculations can be quite time consuming, it is important to check the model carefully before starting the calculation process.

## Presentation of results

The PLAXIS postprocessor has enhanced graphical features for displaying computational results. Exact values of displacements, stresses, strains and structural forces can be obtained from the output tables. Plots and tables can be sent to output devices or to the Windows® clipboard to export them to other software. They can also be exported to a file on your computer.

## Stress paths

A special tool is available for drawing load-displacement curves, stress paths and stress-strain diagrams. Particularly the visualization of stress paths provides a valuable insight into local soil behaviour and enables a detailed analysis of the results of a PLAXIS calculation.

## Sensitivity Analysis and Parameter Variation GSE

The Sensitivity Analysis and Parameter Variation is a tool available within PLAXIS to perform multiple PLAXIS calculations for a given PLAXIS model with different model parameters. Extensive description of this tool is available in the Reference Manual .

## Cyclic Accumulation and Optimisation tool GSE

The Cyclic Accumulation and Optimisation tool is used to determine the UDCAM-S model parameters. Extensive description of this tool is available in the Reference Manual.

# 4 First Time Installation

If you install PLAXIS for the first time, download the installer from PLAXIS software downloads at Bentley Communities. You will need to create an account and log in to access the download site.

## Software and Hardware Requirements

Please visit System Requirements on Bentley communities website to find the software and hardware requirements.

## Installation

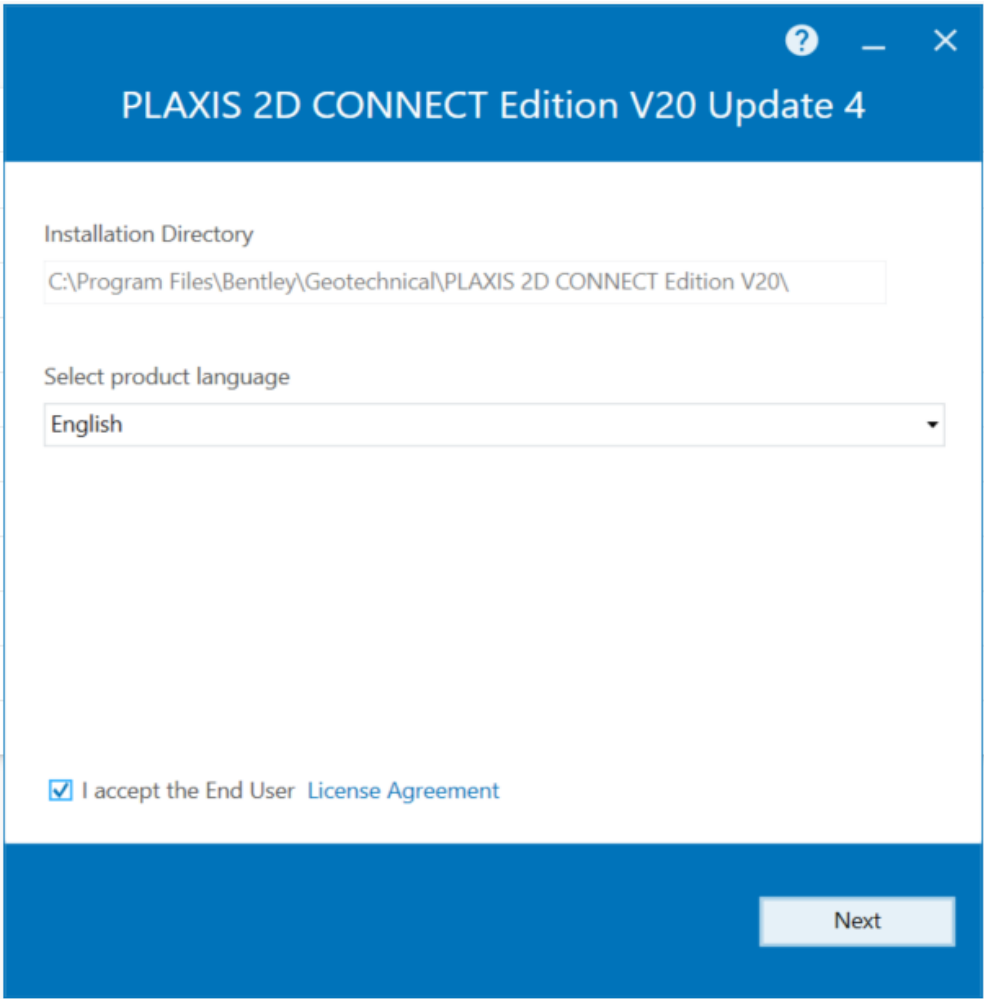
During installation the following software is installed:

- PLAXIS.
- CONNECTION Client.
- Manuals for PLAXIS .
- Python distribution.

To install PLAXIS:

1. Go to the Installer executable that you have downloaded and double-click the file.

   The PLAXIS Installation Wizard opens.




2. (Optional) To change the location where PLAXIS is installed, either:
   - Type a path in the *Installation Directory* field or
   - Click the *Browse* button (...) and browse to the folder you want to install PLAXIS
   - Click *Ok*
3. To select the installation language use the drop-down menu in *Select product language*
4. To read the End-User License Agreement (EULA), click the *License Agreement link.*

   The EULA opens in a web browser.

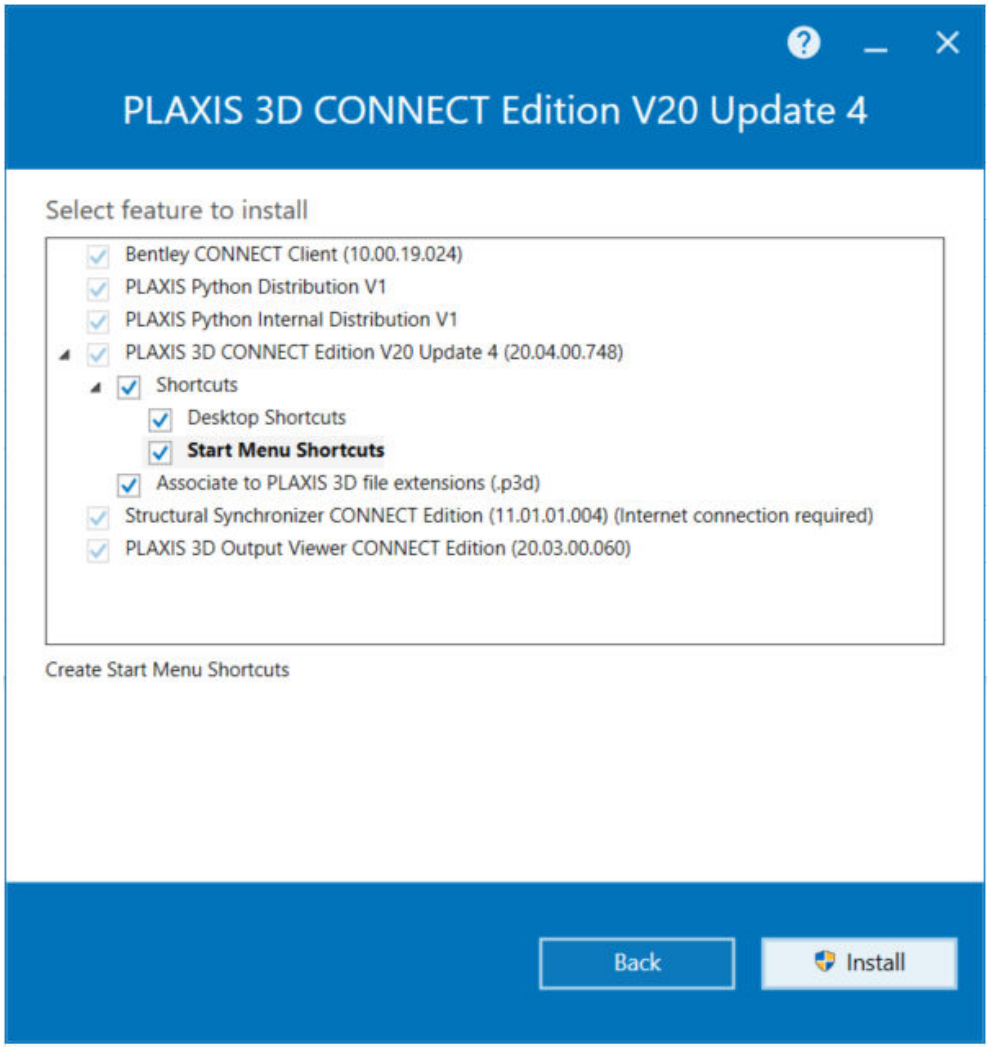
   - After reading the license agreement, check the *I accept the End User License Agreement* box to acknowledge that you understand and agree to the EULA.

     This step is required to install the software.
   - Click *Next*.

5. (Optional) Select the features which you want to install.
   a. On PLAXIS 2D:



**b.** On PLAXIS 3D:




6. Click *Install* to start the installation.

   **Note:** The installation requires administrator rights. If Windows prompts you with a User Account Control dialog, click *Yes* to proceed.

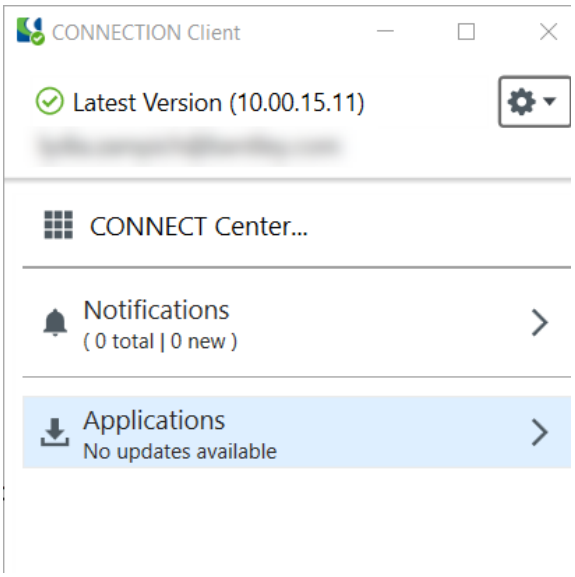
7. Once the installation has finished the Install Wizard will notify you.

   *>Installed PLAXIS CONNECT Edition V20 Update 4*

   - Click *Finish* to close the Wizard.

# Update install - Using CONNECTION Client

When PLAXIS is installed for the first time, the CONNECTION Client is installed as well:




When there are updates available for PLAXIS (or any other Bentley products), the CONNECTION Client will notify you. You can install the update by clicking the *Update* button in the CONNECTION Client.

You can use the CONNECTION Client also to browse for other available Bentley products by clicking *Applications*.

The CONNECTION Client can update itself, too. It is recommended to keep it up-to-date.

Sign into the CONNECTION Client and refer to its Help for information on managing notifications and installing application updates. For more information go to the link CONNECTION Client on the Bentley communities website.

# Uninstall

To uninstall the software from the system go the **Windows Start menu** > *Settings* > *Apps & features*. Click on PLAXIS and click the *Uninstall* button.

# 5 Subscription Entitlement Service

PLAXIS uses licencing through Subscription Entitlement Service. This service lets an administrator set usage limits and notifies the user when a usage limit (set by the administrator) is reached.

For specific information on Subscription Entitlement Service licensing, please click here for the latest information.

# 6 Troubleshooting

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

- Problems with OpenGL

The appropriate actions to be taken on the problems are described below.

## Problems with OpenGL

In case of problems with OpenGL make sure that the latest drivers for the graphics card have been installed. In addition, the settings of the graphics card can be changed via the windows dialog *Display Properties*, *tabsheet Settings*, button *Advanced*. This way the quality of the display can also be increased.

# 7 Acknowledgments

The Manuals of PLAXIS CONNECT Edition V20.04 by Bentley Systems were edited by:

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| With Cooperation of: | |
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