BI Dry 3.0 – A COMSOL® App for Simulating Concrete Drying

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[4] Lund University, Lund, Sweden

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- Setting Up a Model
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- Results
- Preferences
- Underlying COMSOL Model
- Access to Specific Functionality
- Conclusions

Introduction

Background and benefits of the software

Concrete Drying

- Moisture enhances concrete curing, but fast drying and low relative humidity (RH) are essential for flooring to prevent deterioration of flooring adhesive
- Drying is slow and can delay construction, resulting in premature floor installation and costly testing, disputes, or repairs
- Factors like temperature, wind, rain, construction type, and dimensions affect drying rates

Simulating Concrete Drying

- An effective way to predict concrete drying is through finite element-based simulations
- Setting up a finite element model requires expertise, but the process is simplified with a compiled COMSOL® app
  - Any contractor can leverage the power of COMSOL Multiphysics®
- By using simulations, contractors can choose the optimal concrete mix, minimizing environmental impact and reduce costs

Reductions & Savings

CO_2 Emission Reductions

- Decrease the amount of binder
- Use lower-grade concrete where applicable
- Incorporate binder combinations with slag, fly ash and other additions
- Select an optimal design

Cost Savings

- Accelerate construction timelines
- Prevent costly failures

Background

Longstanding Expertise

For decades, Heidelberg Materials has offered customers finite element-based software solutions

Launch of HETT^{22} in 2022 [1]

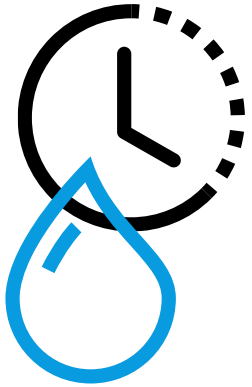
A COMSOL Multiphysics®-based tool, HETT^{22} was developed to simulate early-age temperature and strength development

Development of BI Dry 3.0

Following the success of HETT^{22}, Heidelberg Materials chose the same platform to support BI Dry 3.0, a software focused on simulating concrete drying

1. D. Ericsson et al., COMSOL Conference 2023 Munich
www.comsol.com/paper/hett22-a-comsol-app-to-accurately-simulate-plan-and-monitor-concrete-castings-122611

Differences between HETT^{22} and BI Dry



Timescale

While HETT^{22} and BI Dry share similarities, concrete drying in BI Dry spans months or years, unlike the shorter timescale of hours or days required for early-age strength development in HETT^{22}.

Modeling

Both HETT^{22} and BI Dry utilize the Maturity Method and the heat transfer equation. Additionally, BI Dry solves a convection-diffusion equation for moisture content, which is coupled with heat transfer.

Joint Efforts

Heidelberg Materials

Collaborative Development of HETT[22]

Created through a partnership between Deflexional AB, a COMSOL Certified Consultant, and Heidelberg Materials

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BI Dry 3.0 Development Team

Deflexional worked closely with concrete drying experts from Lund University and Heidelberg Materials

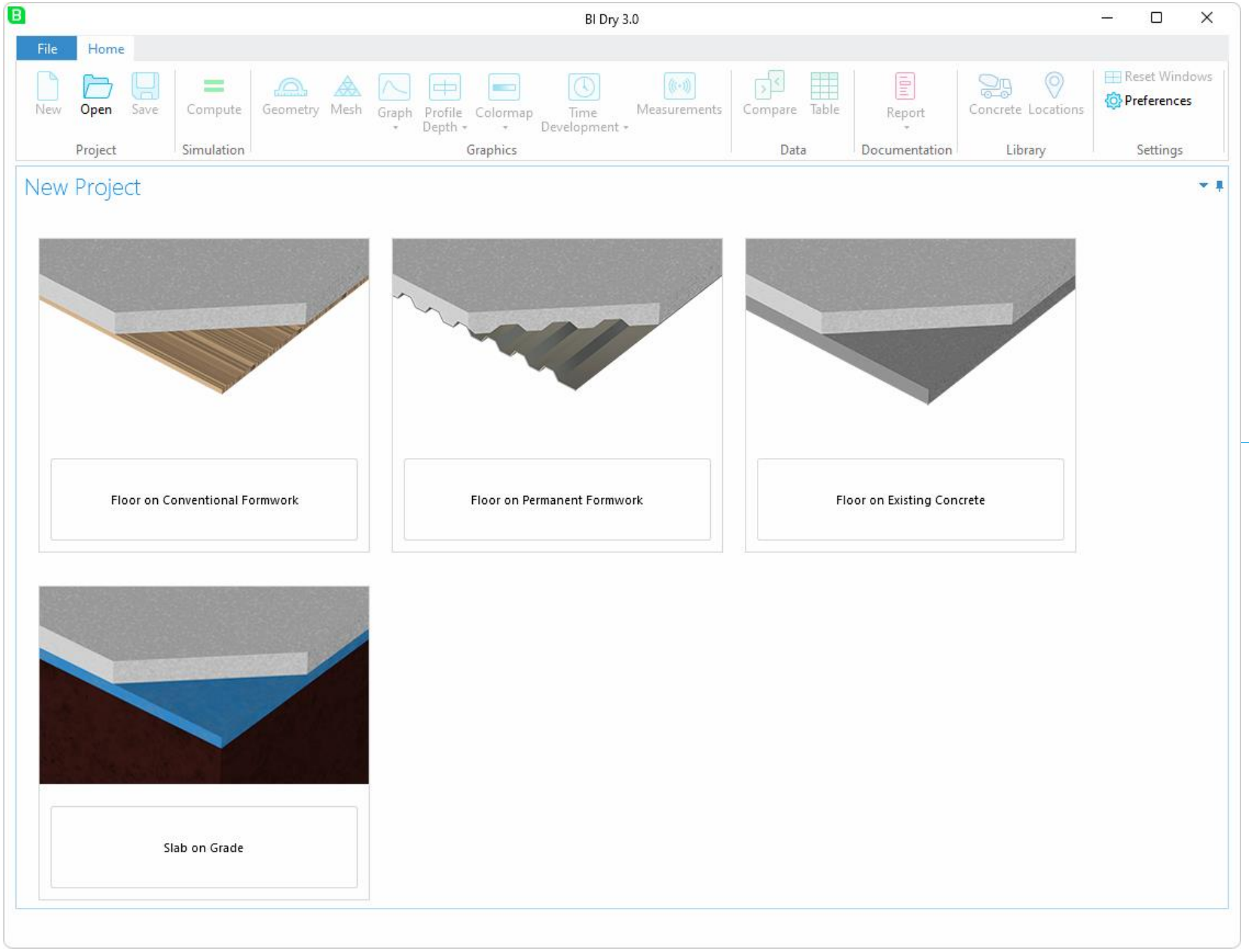
LUNDS UNIVERSITET

Project Success

The achievements of this project underscore the essential contributions and collaboration from all involved parties

Graphical User Interface

An intuitive interface enables contractors to perform advanced simulations with ease



Select construction scenario to start a new project

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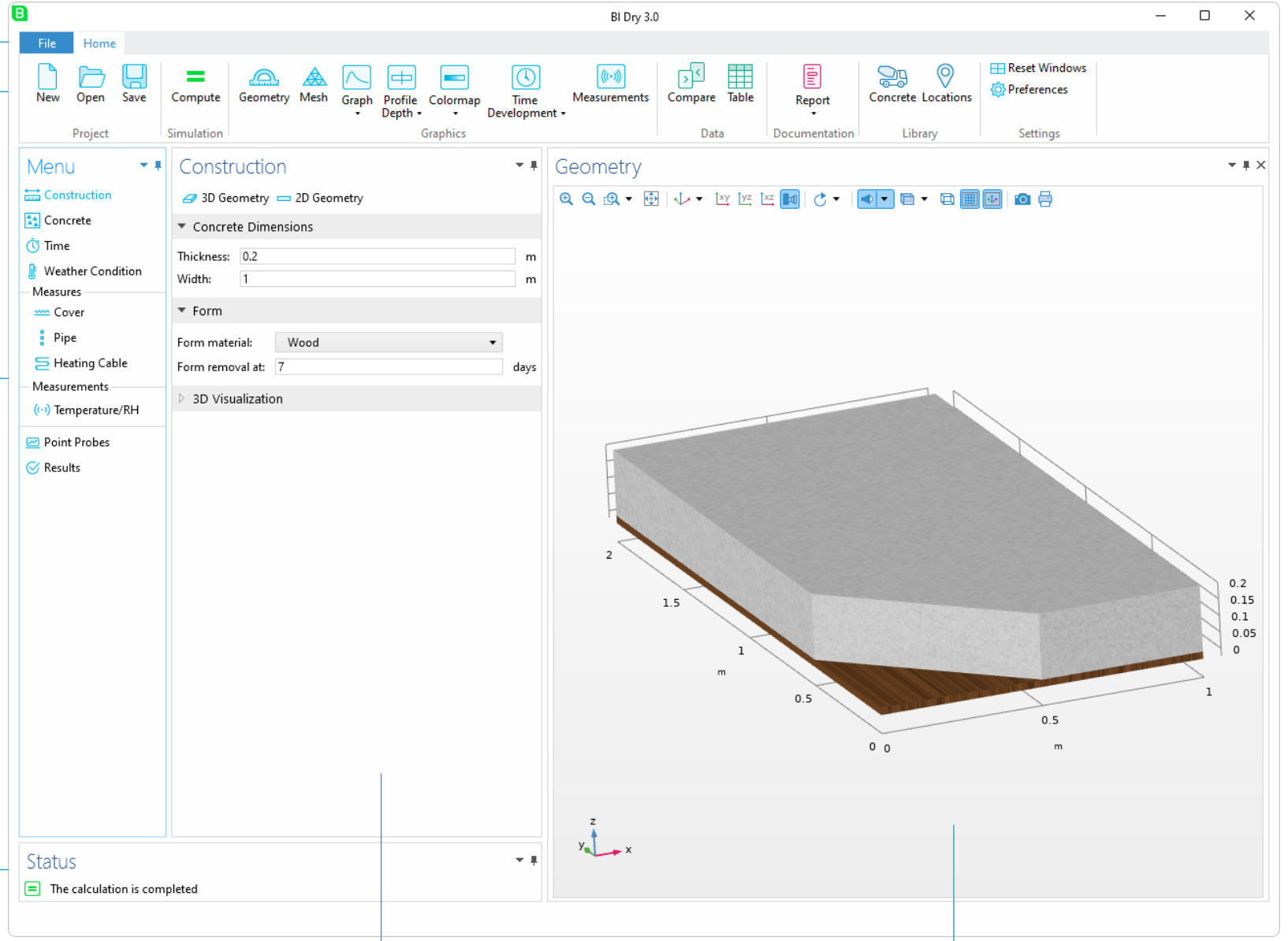
File Menu

Ribbon

Menu

Status



Settings

Graphics

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Ribbon

Compute

Results as numerical data

Standard libraries and user libraries

Settings

Create a new project, open, and save

Visualize geometry, mesh, graphs, 2D plots, and 3D plots

Microsoft® Word® and Microsoft® PowerPoint® reports

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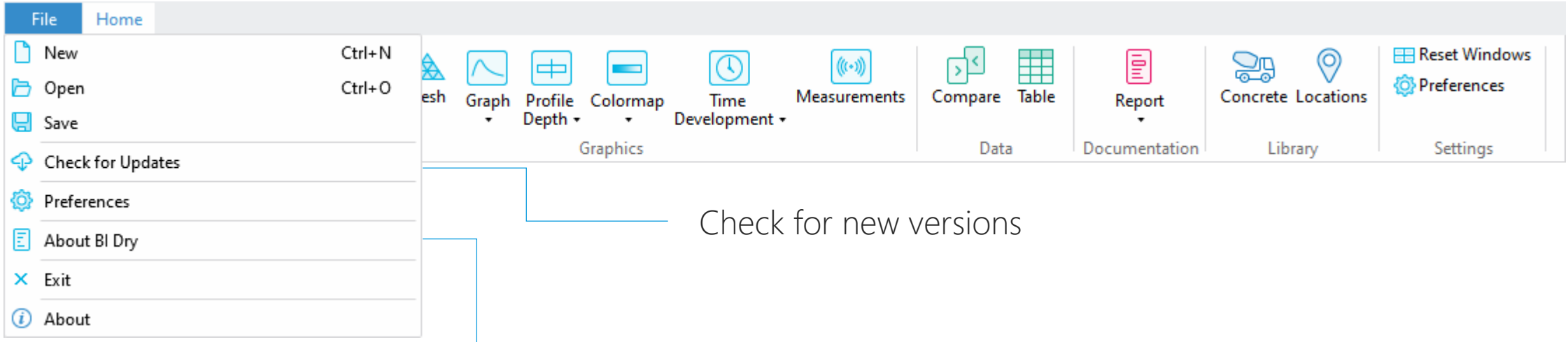
File Menu

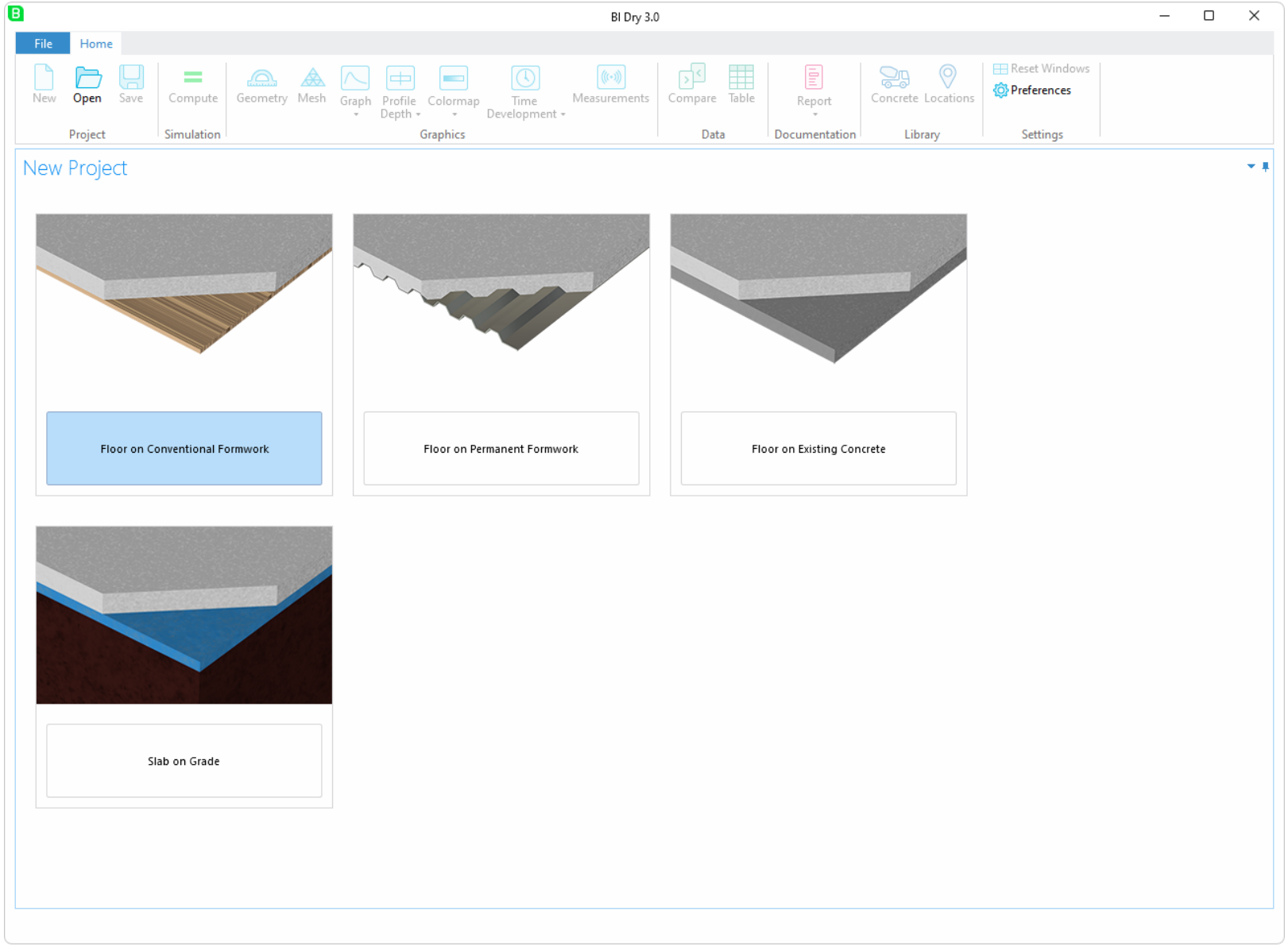

File
Home
New Ctrl+N
Open Ctrl+O
Save
Check for Updates
Preferences
About BI Dry
Exit
About
esh
Graph
Profile Depth
Colormap
Time Development
Measurements
Graphics
Compare
Table
Data
Report
Documentation
Concrete
Locations
Library
Reset Windows
Preferences
Settings
Check for new versions
License information

Setting Up a Model

Follow the left menu step-by-step from start to finish

New Project

- Select the construction scenario



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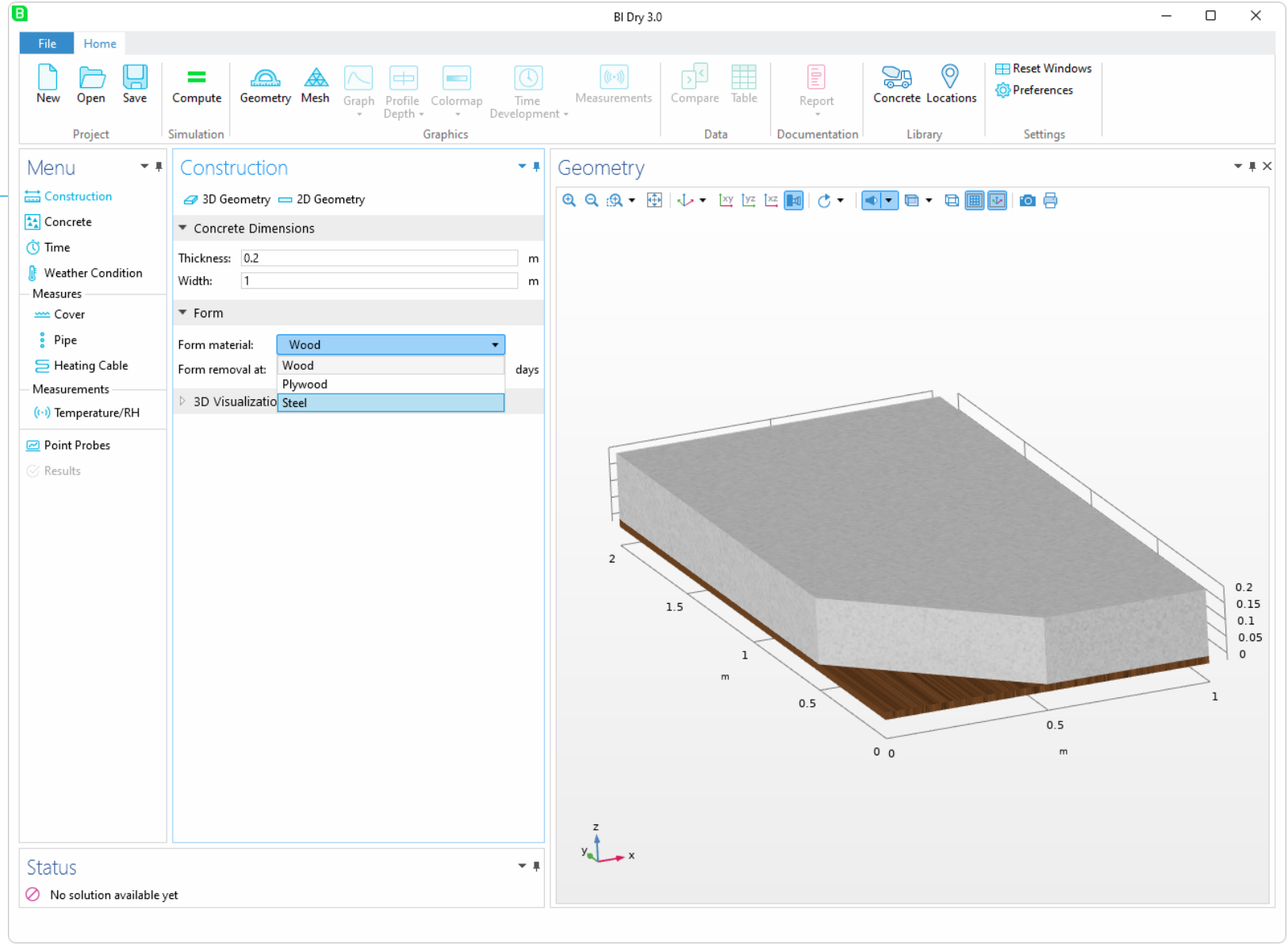
Menu

Construction

- Change dimensions and materials



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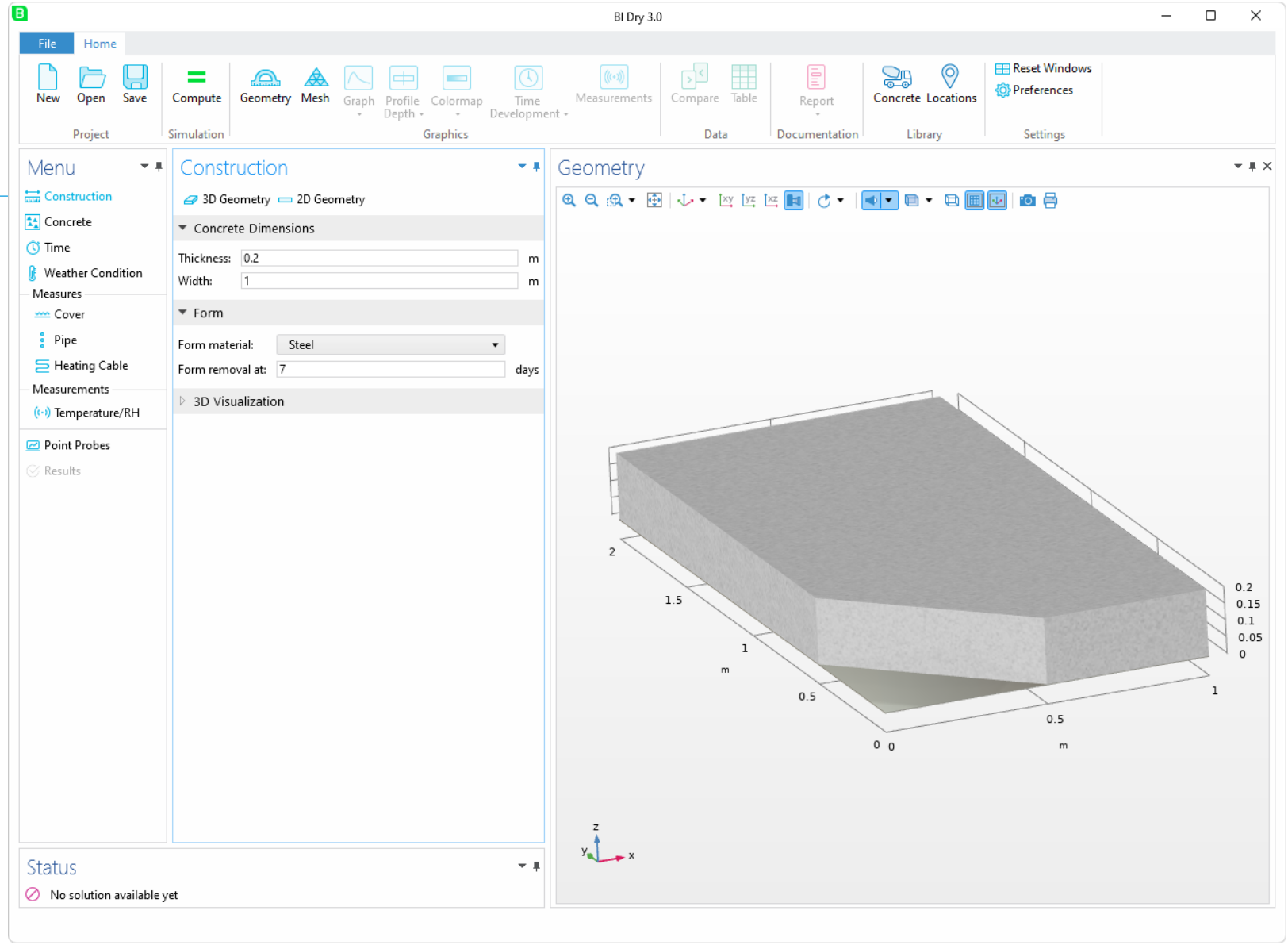
Menu

Construction

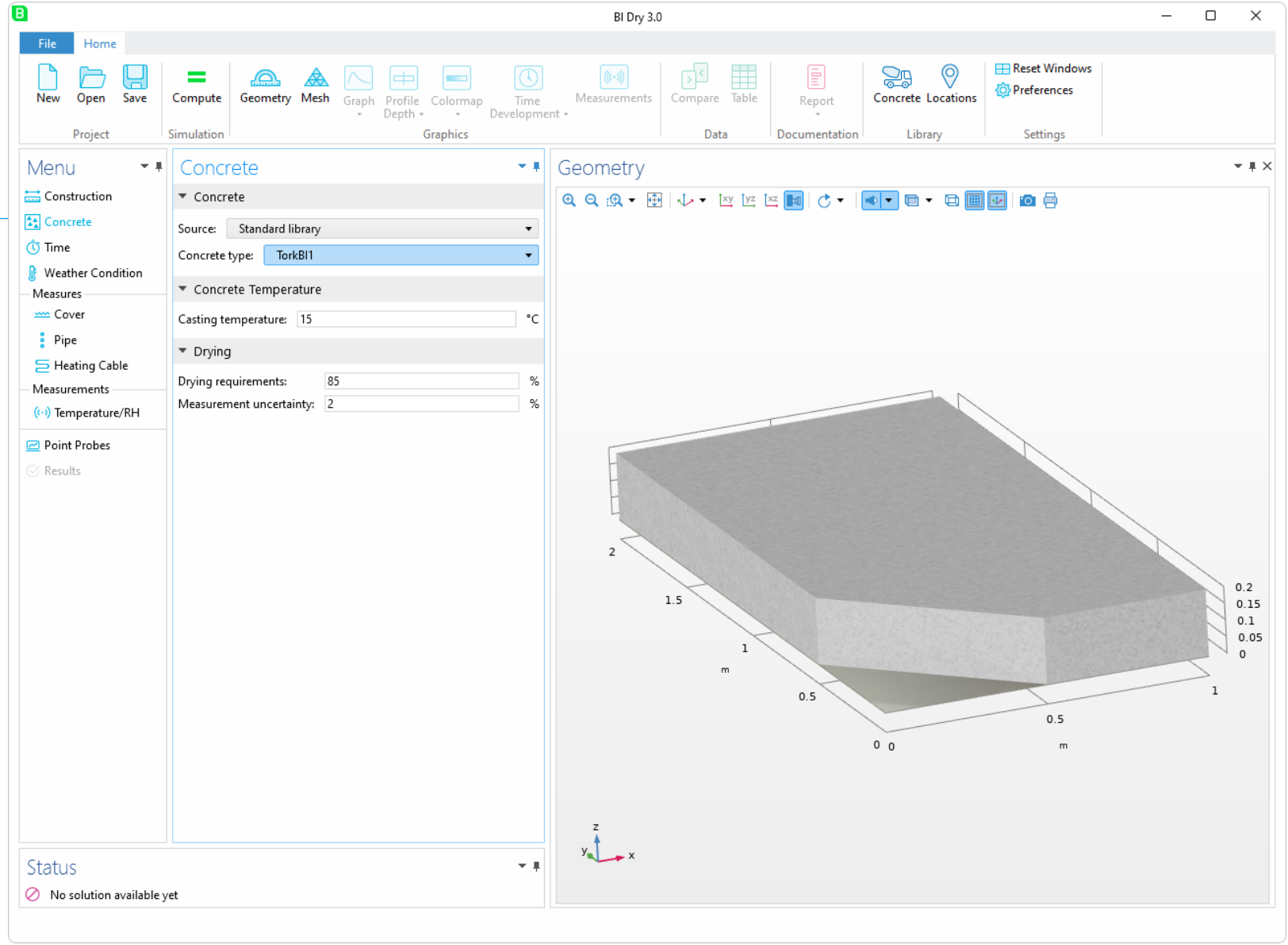
- Visualization in 3D of the construction and the materials



Menu

Concrete

- Set the concrete type and the casting temperature
- Define drying requirements



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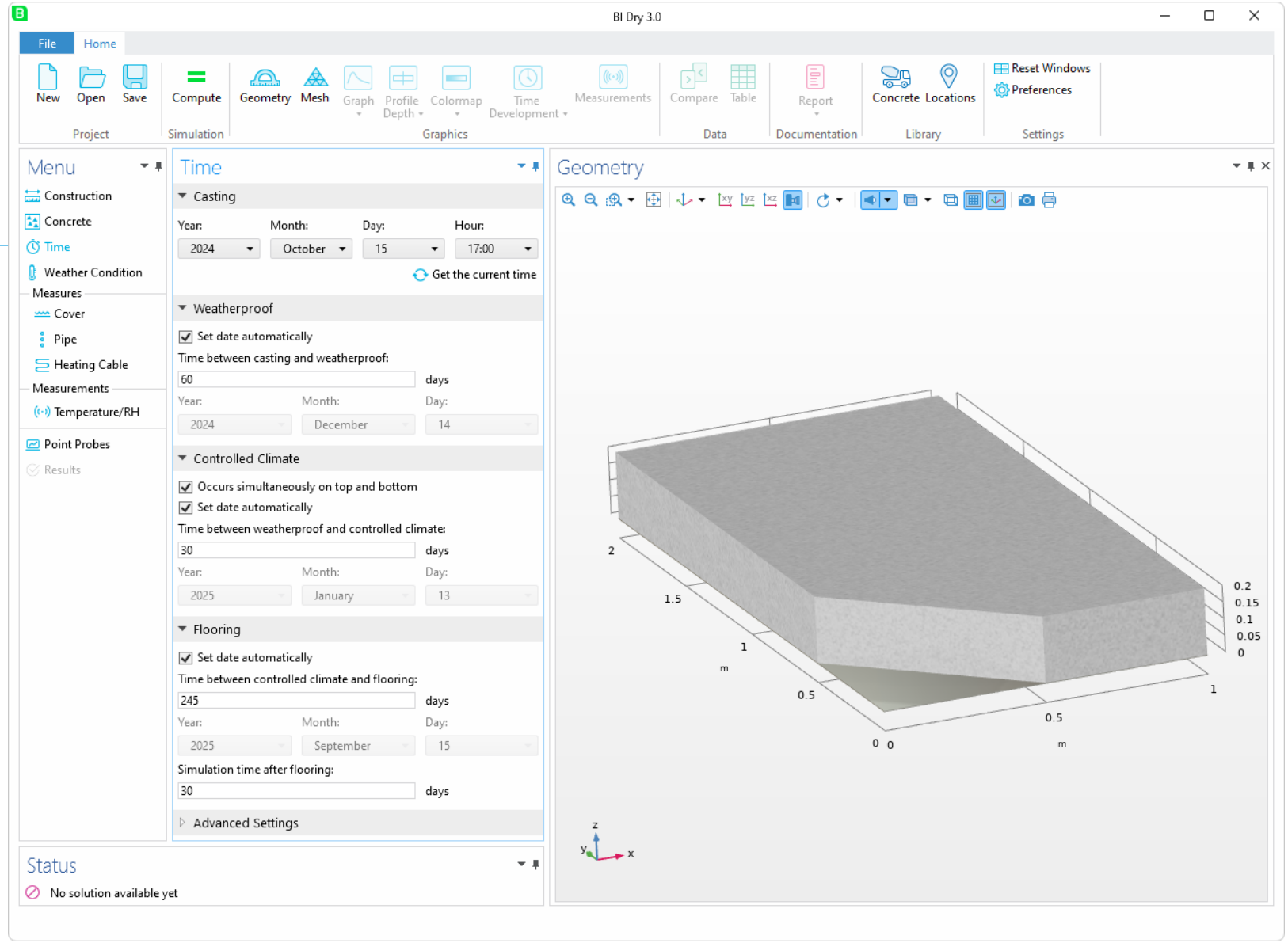
Menu

Time

- Set dates for the different events
- The time between the casting and the simulation time after flooring will be the total simulation time



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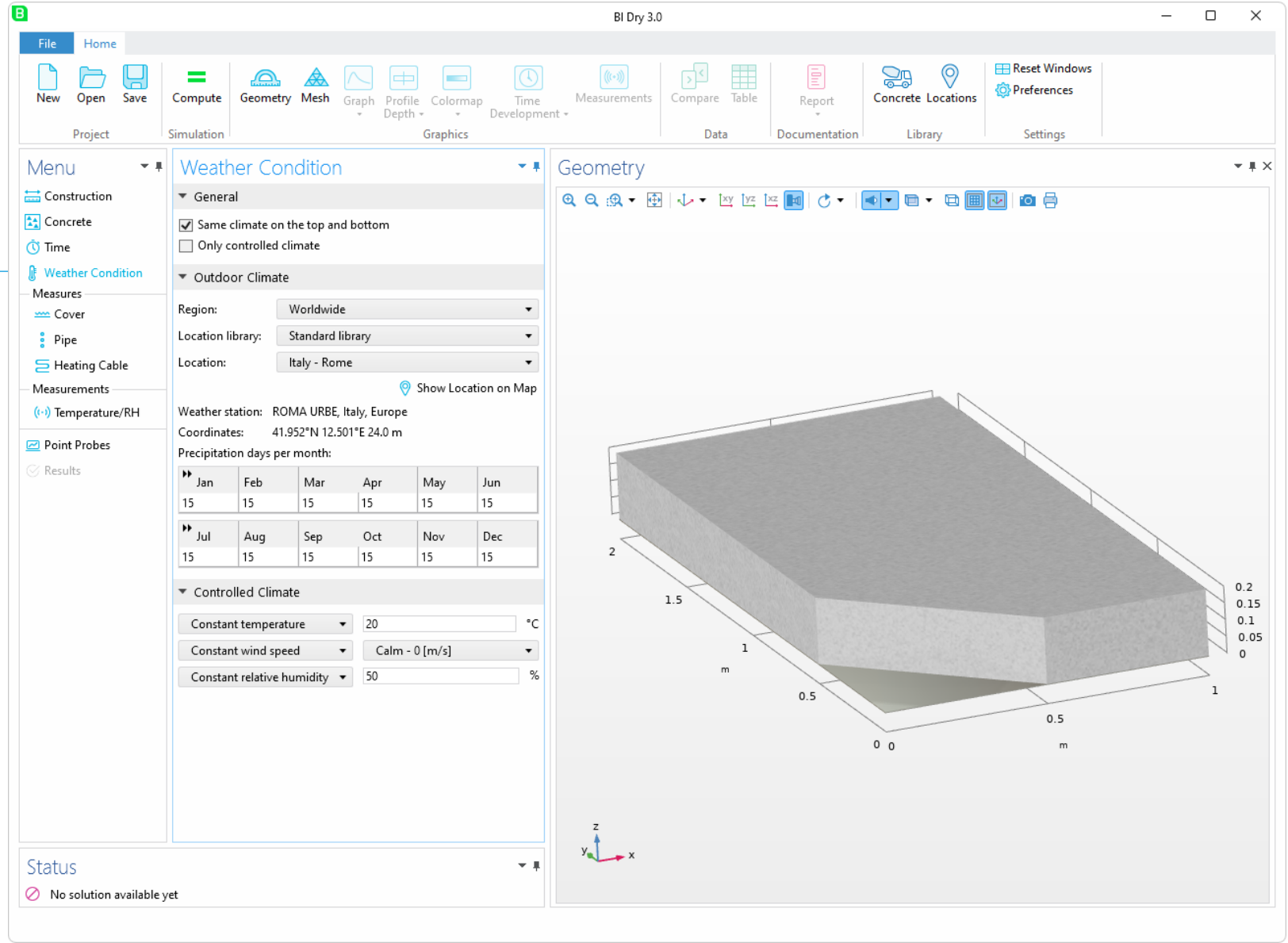
Menu

Weather Condition

- Temperature, wind, and RH comes from the ASHRAE 2021 database
- Precipitation days per month must be set manually for locations outside of Sweden
- For Sweden, precipitation data is sourced from SMHI



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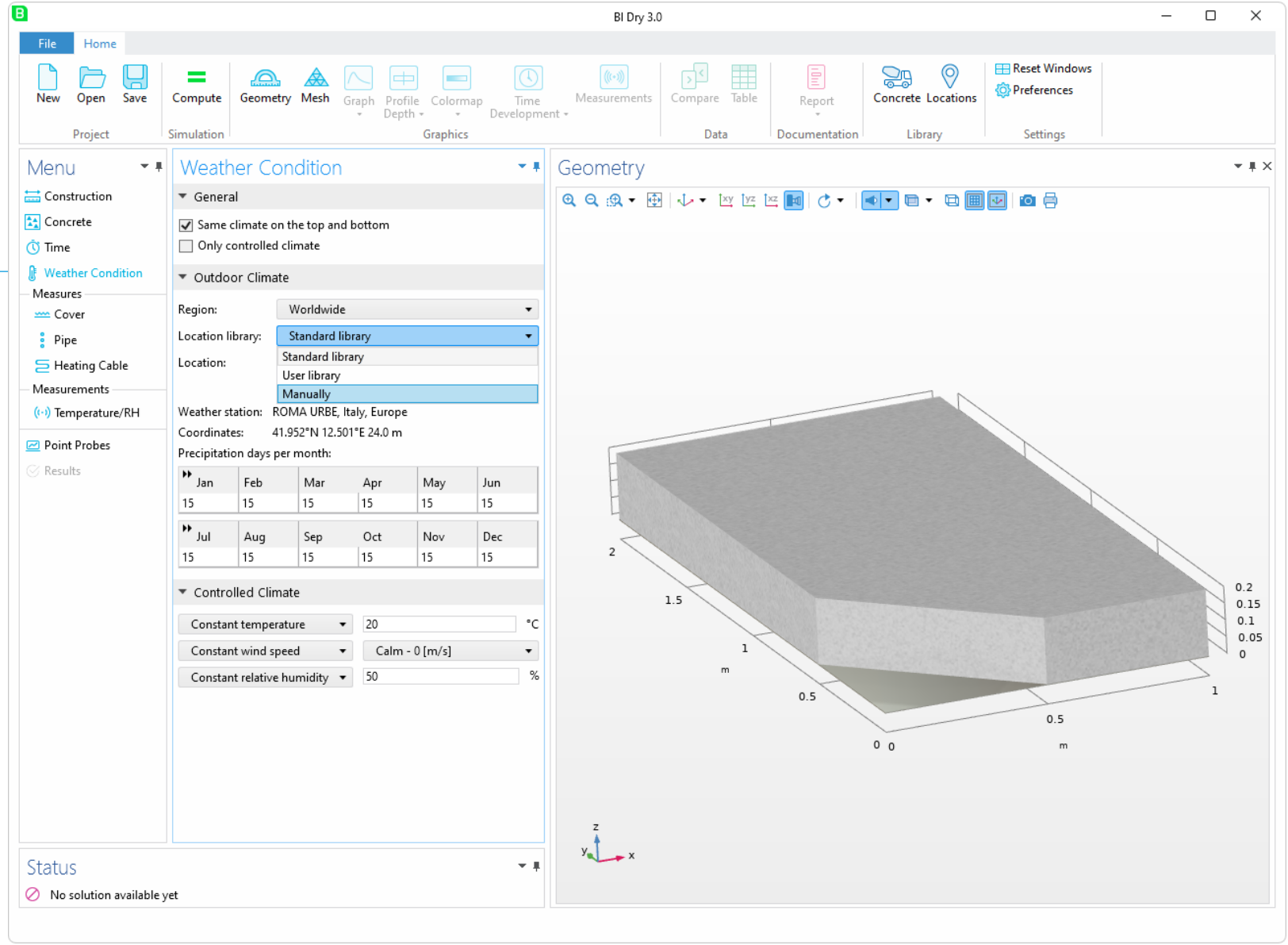
Menu

Weather Condition

- The Location Library makes it easy to re-use data for construction sites



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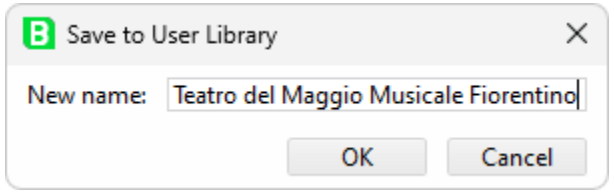
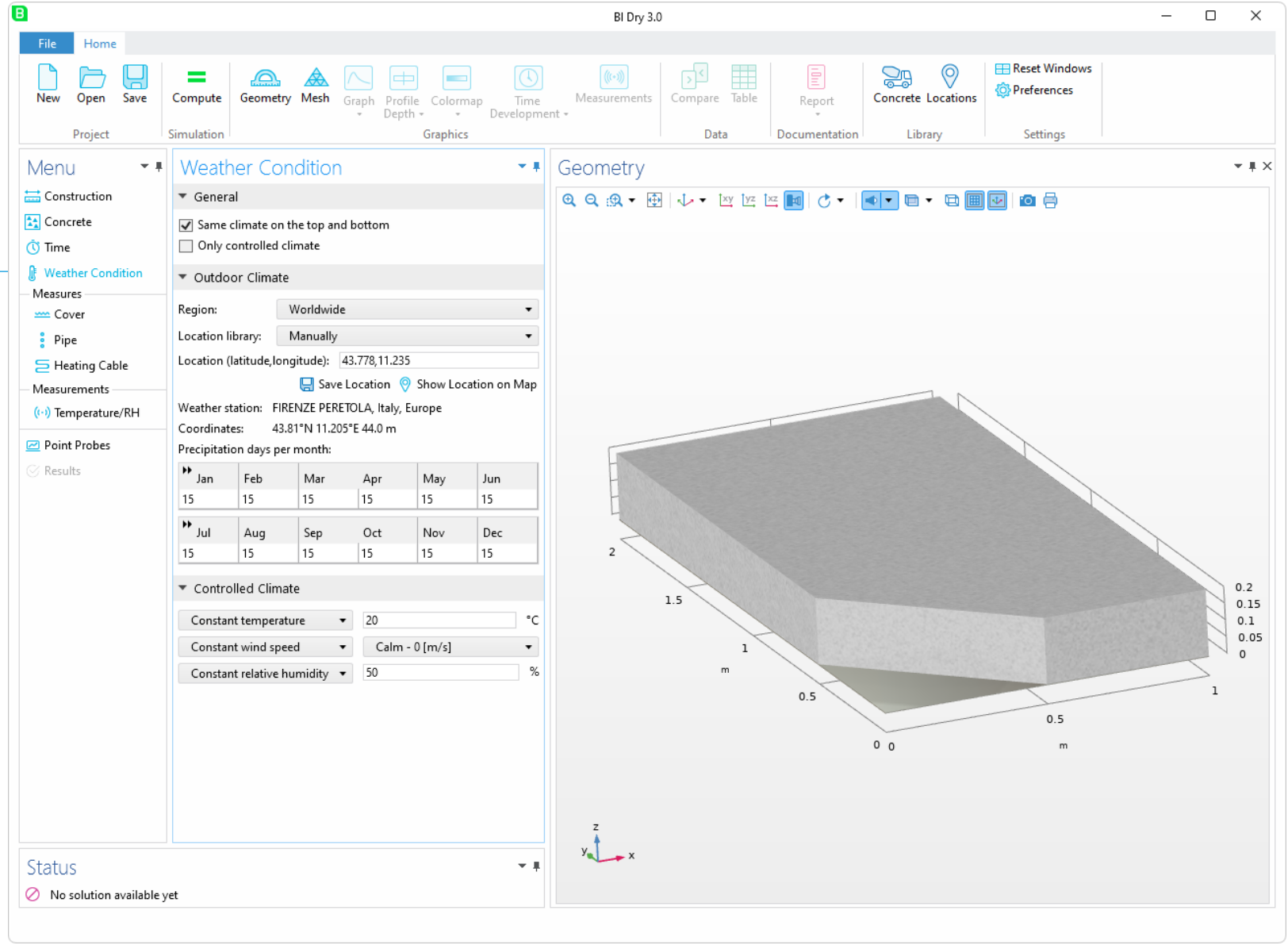
Menu

Weather Condition

- Enter the coordinates for Teatro del Maggio Musicale Fiorentino
- *Show Location on Map* opens Google Maps
- *Save Location* opens a new dialog to save the location:





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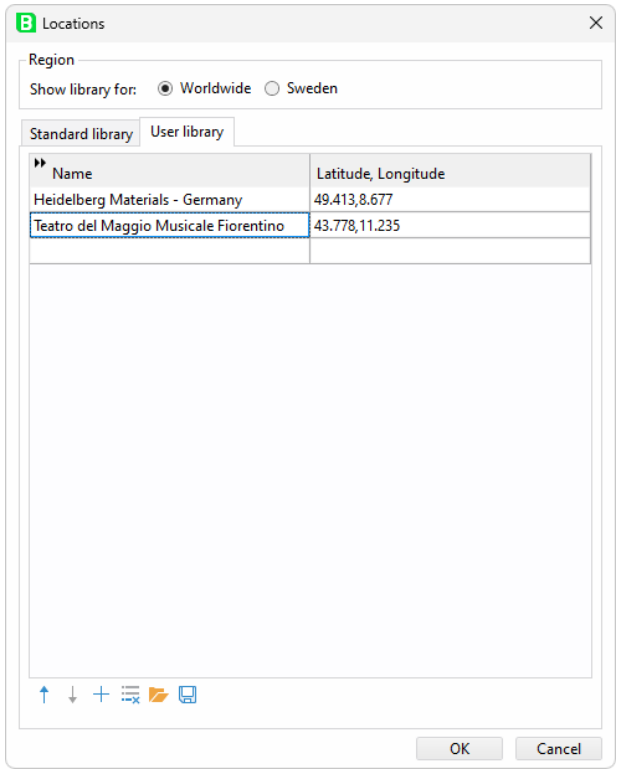
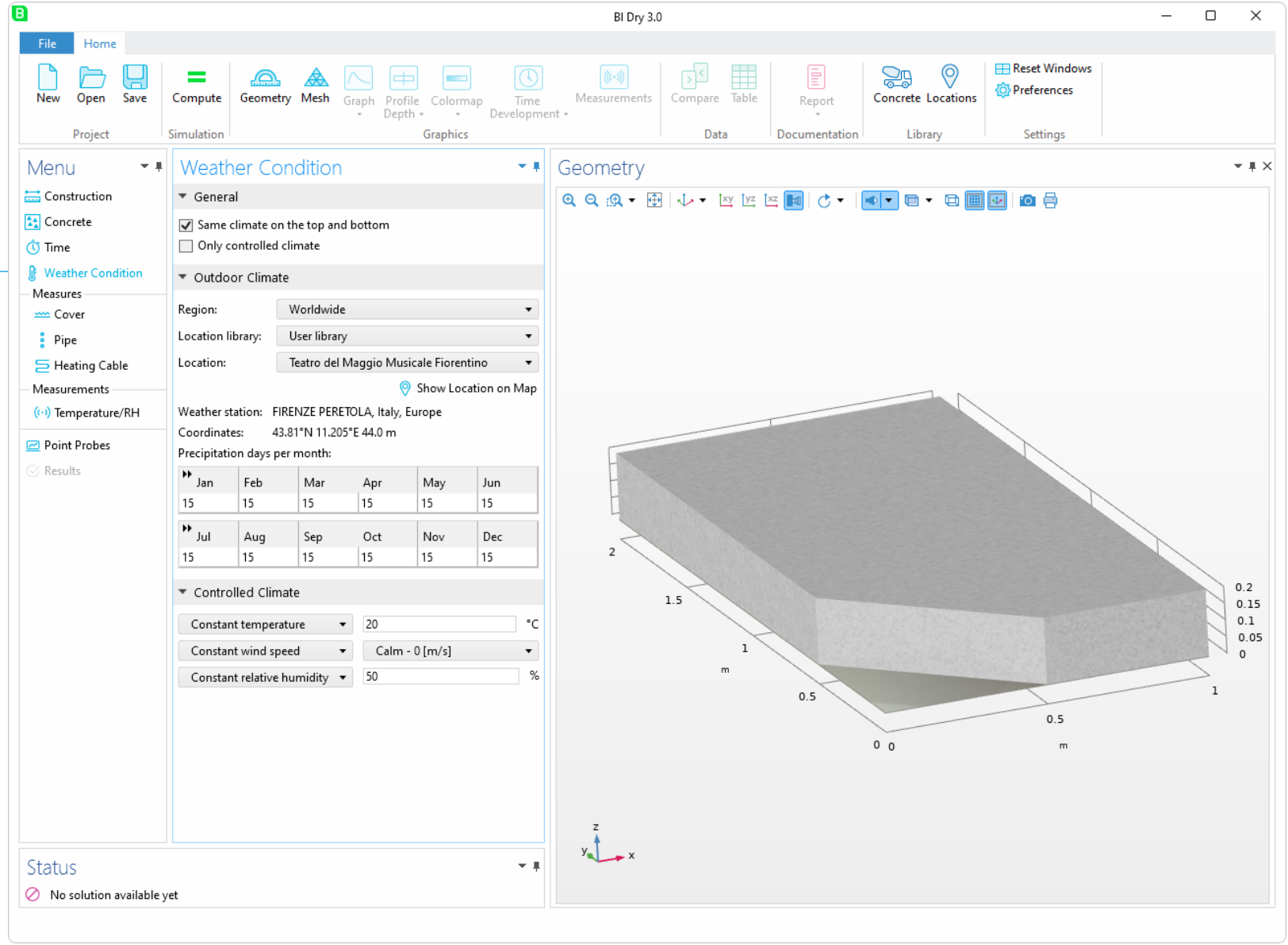
Menu

Weather Condition

- Locations are saved to the library





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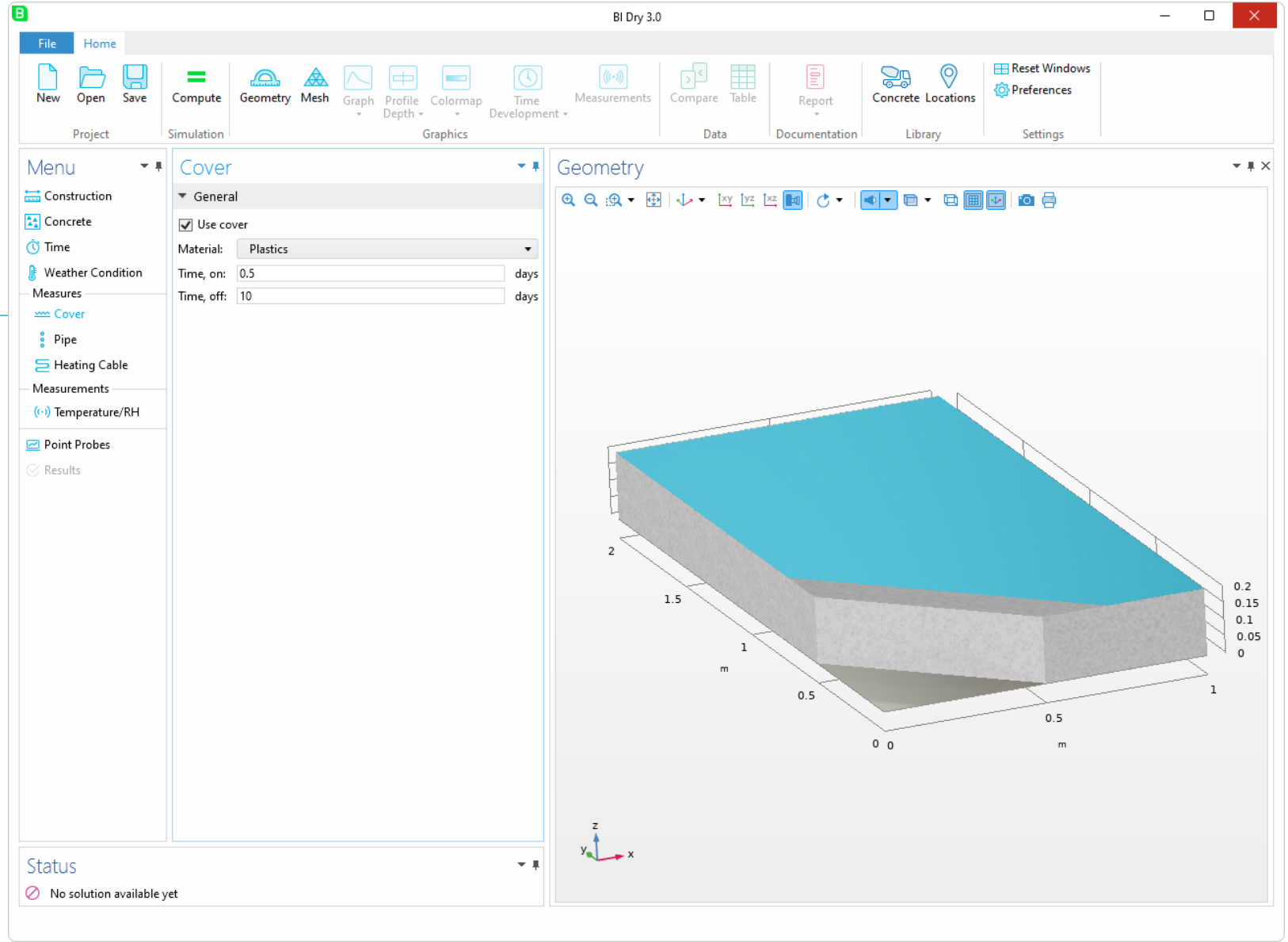
Menu

Cover

- Cover of different materials can be added
- Time for on/off condition



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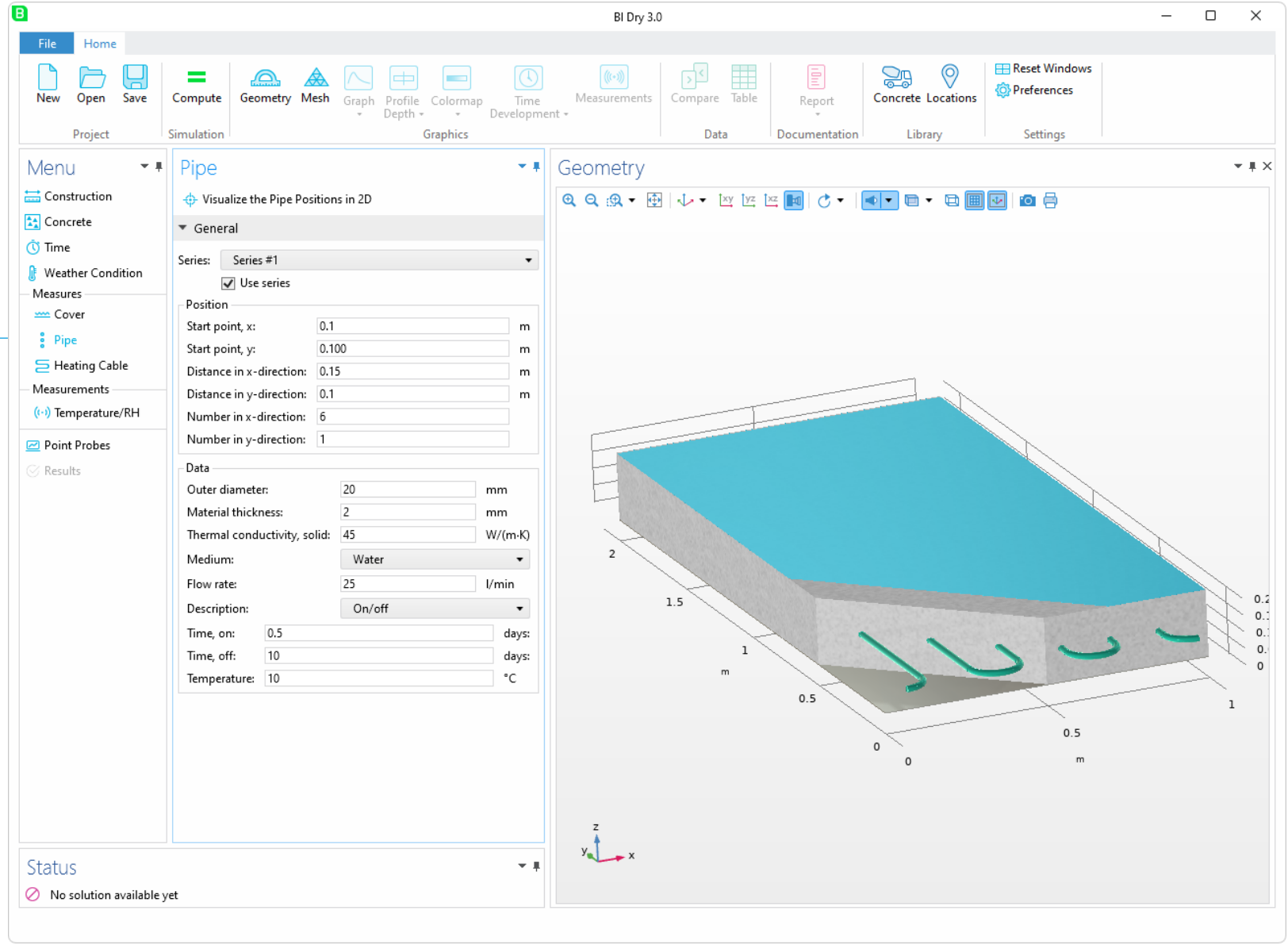
Menu

Pipe

- Pipes with fluid can cool or heat the concrete



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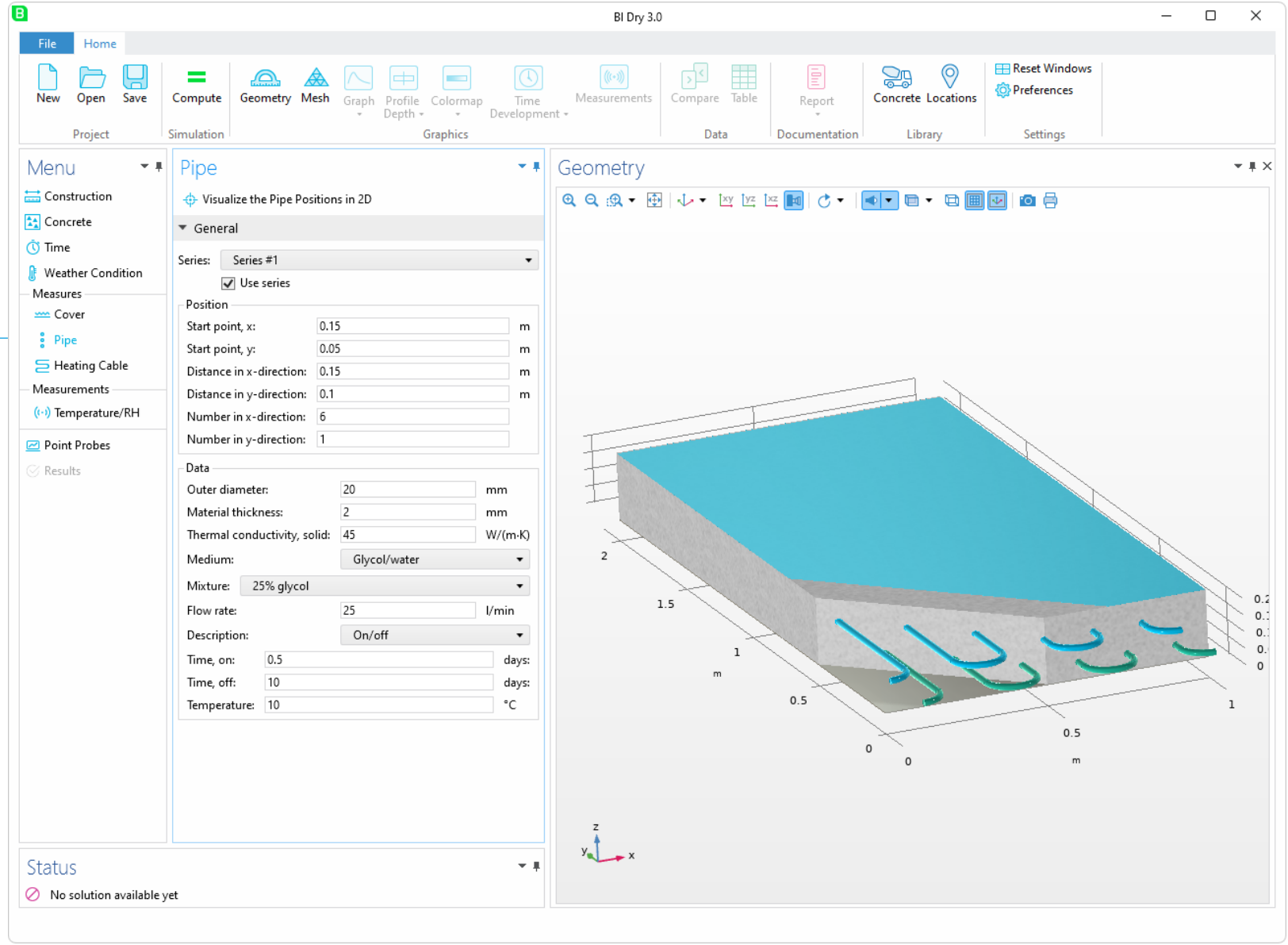
Menu

Pipe

- Can include several pipe series with different properties
- The pipe medium can be altered



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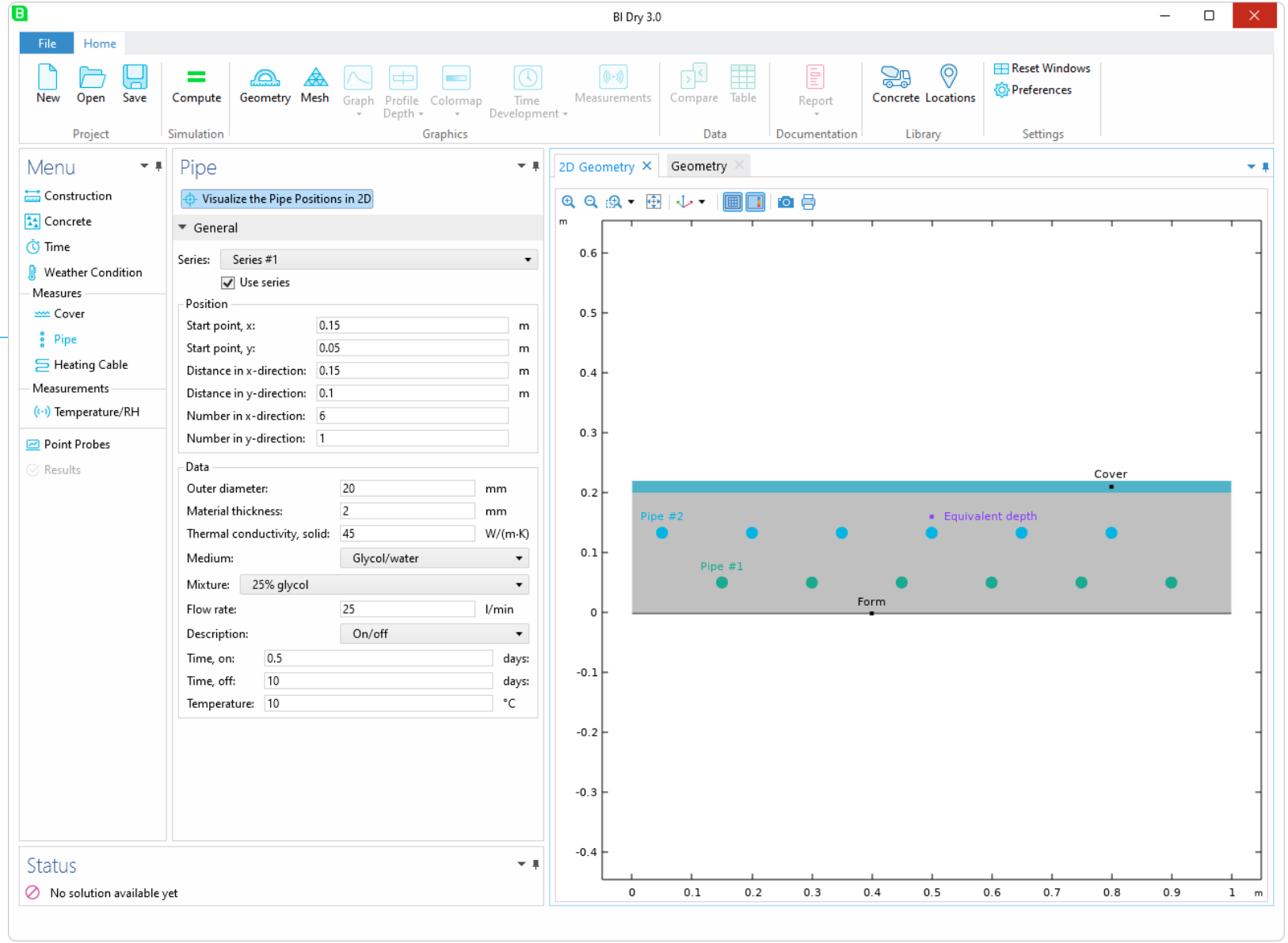
Menu

Pipe

- 2D visualization provides an easy-to-use interface for geometric dimensioning



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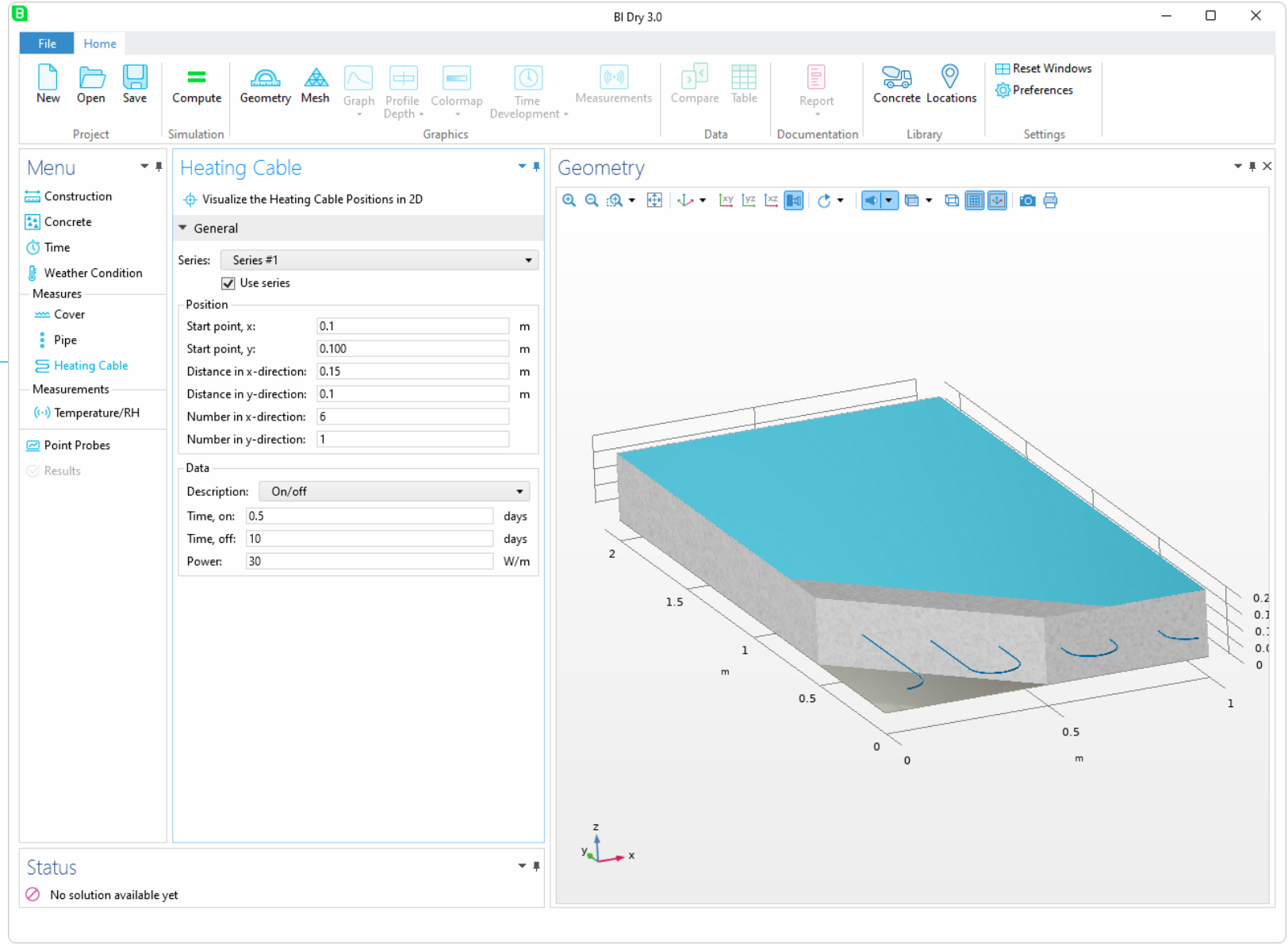
Menu

Heating Cable

- Heating cables can be arranged in a manner similar to pipe installation



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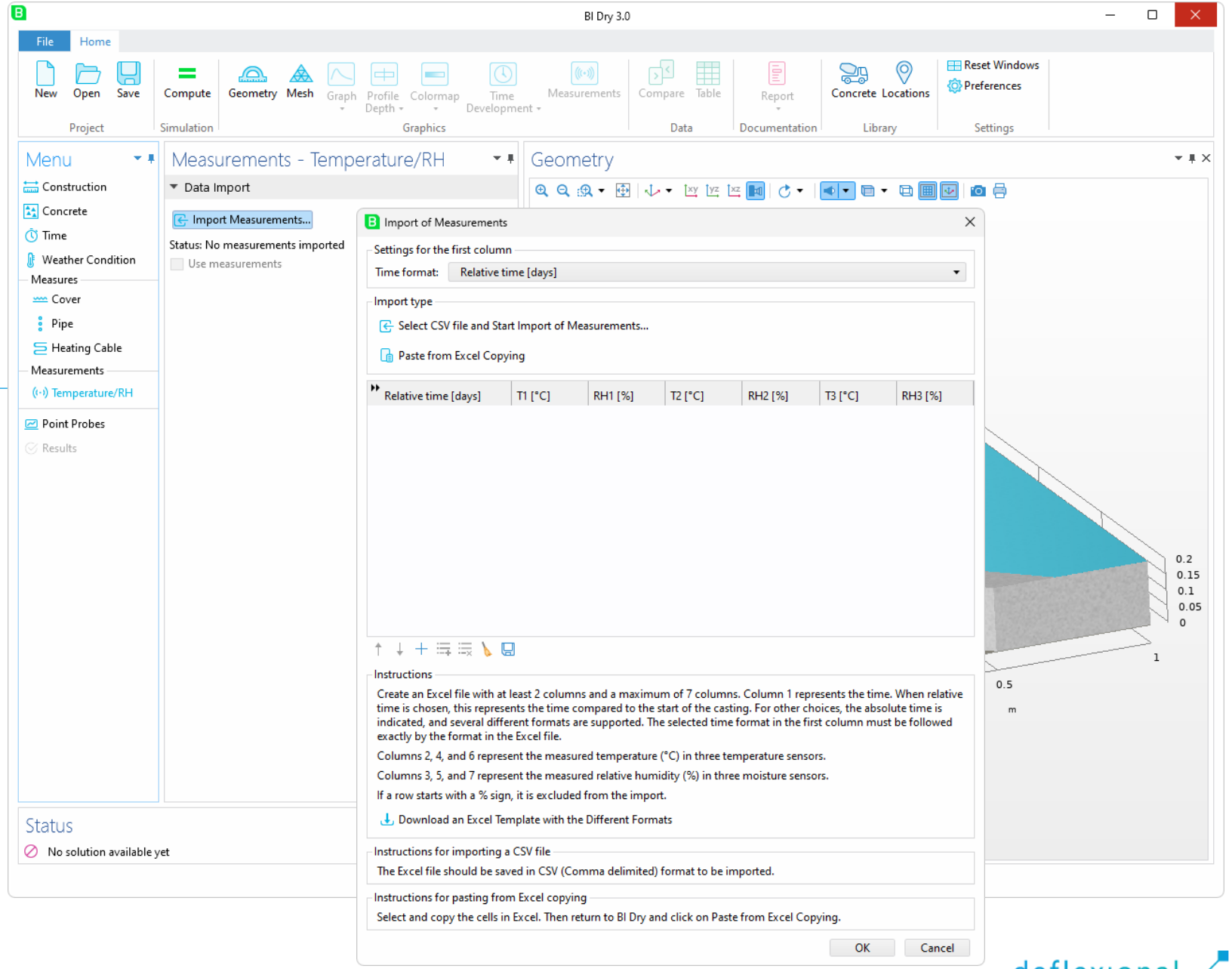
Menu

Measurements

- Add measurements to compare simulations with on-site sensor data
- Capable of handling large datasets efficiently
- Accepts local user settings in a comma-delimited format



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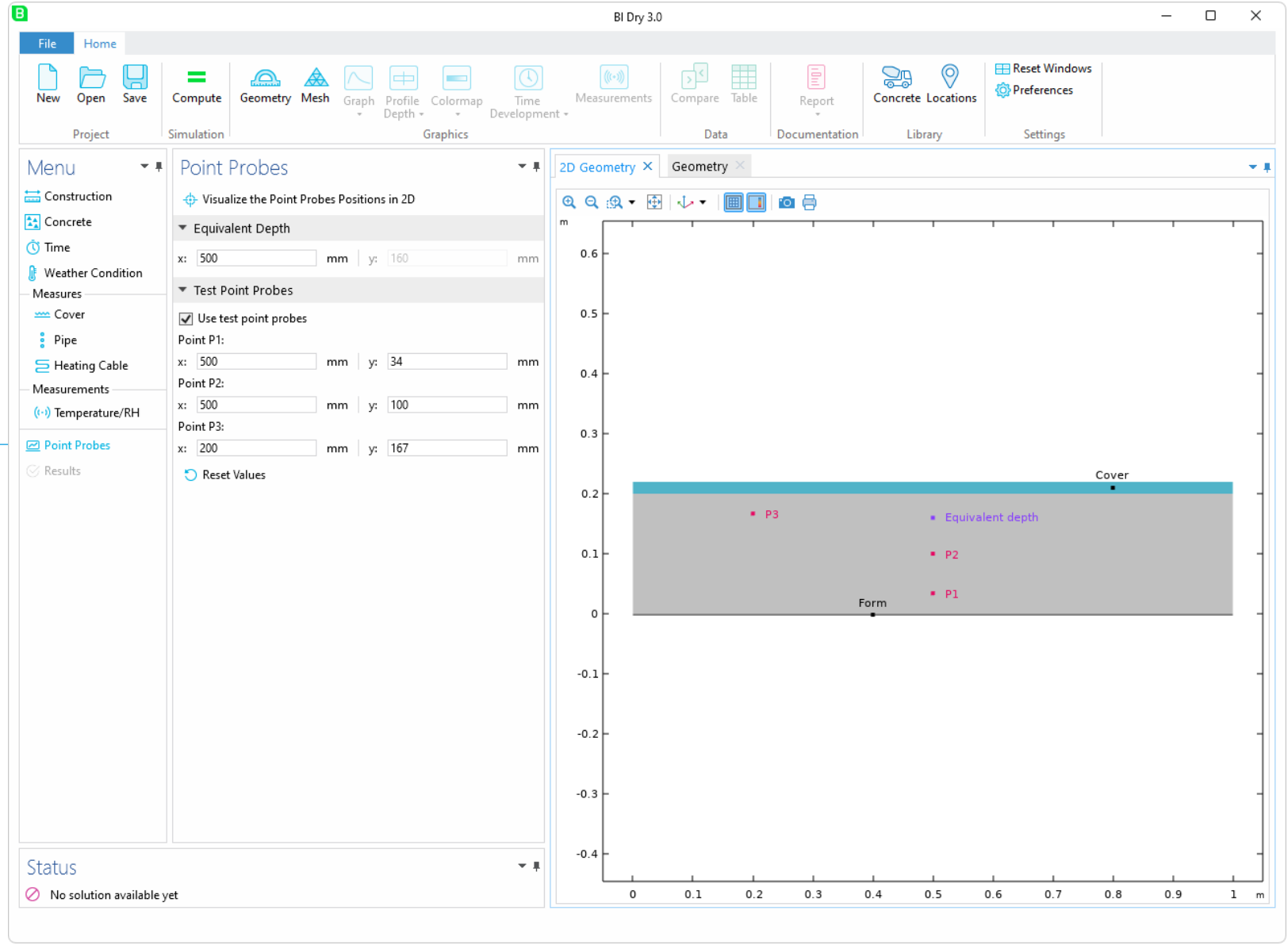
Menu

Point Probes

- Enables the visualization of output data at selected points
- The y-coordinate for the equivalent depth is fixed and cannot be edited, as it depends on the construction type
- The x-coordinate is crucial when using pipes or heating cables



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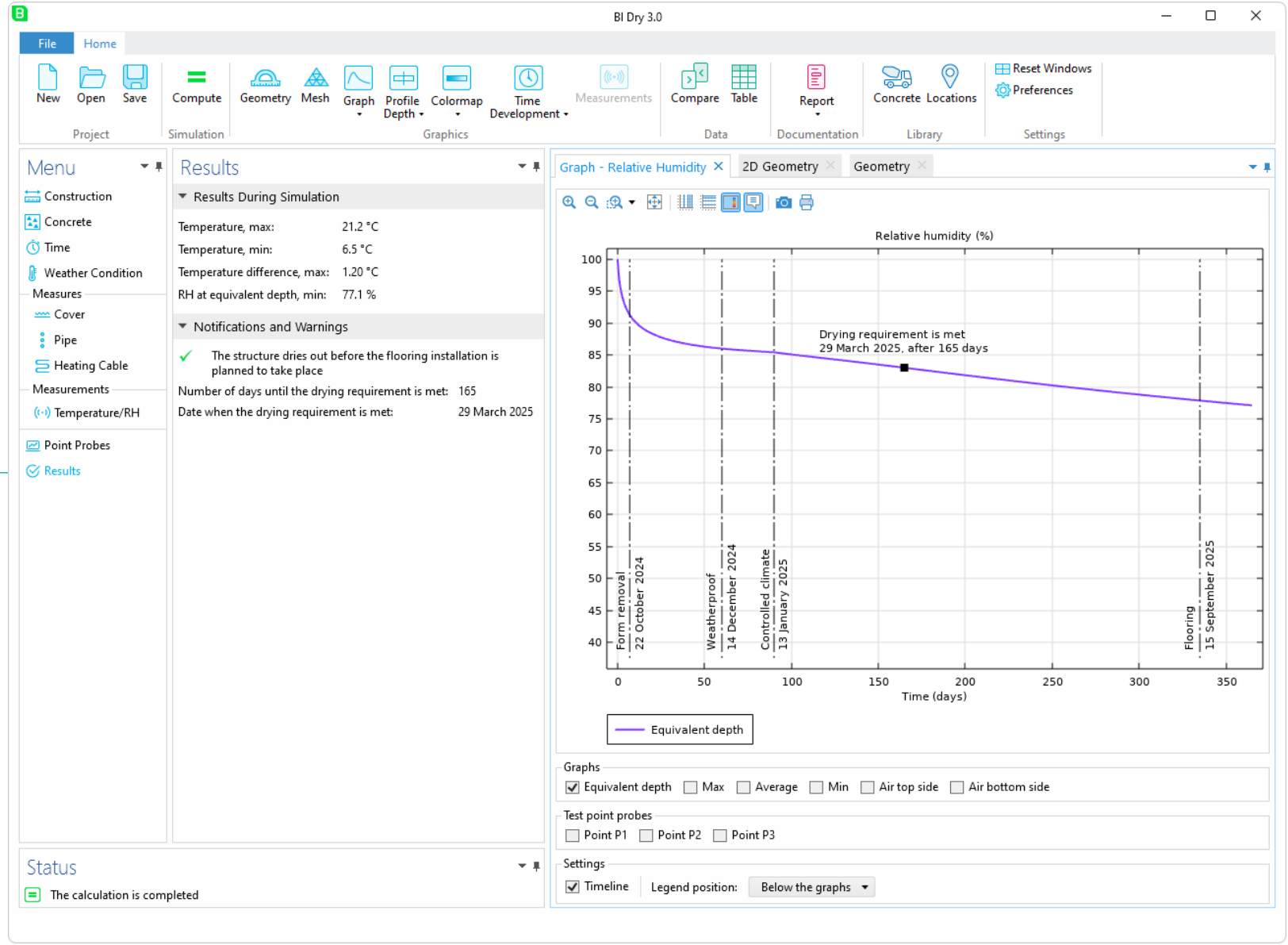
Menu

Results

- Notifications and warnings
- Date when drying requirement is met



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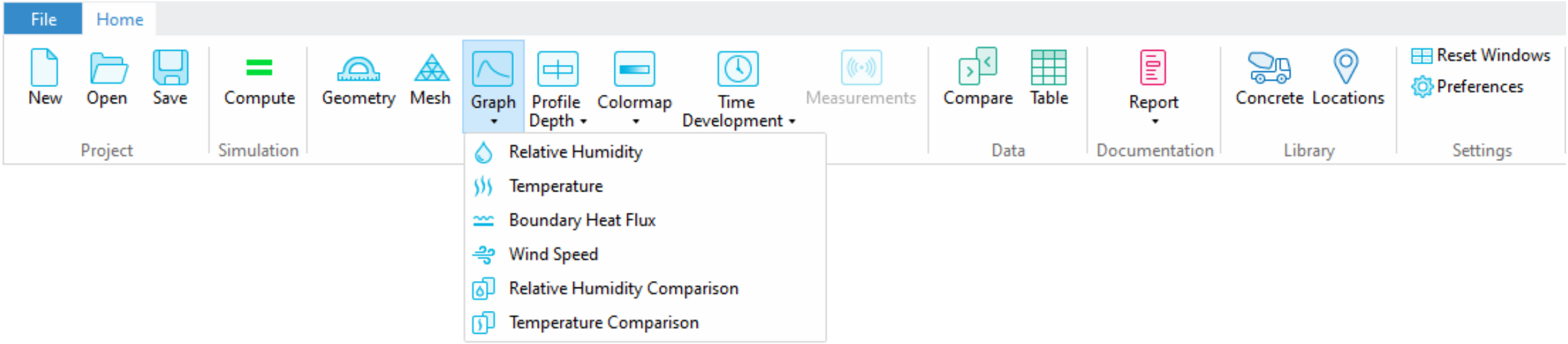
Graphics

Results visualization

Graphics

Graph Menu

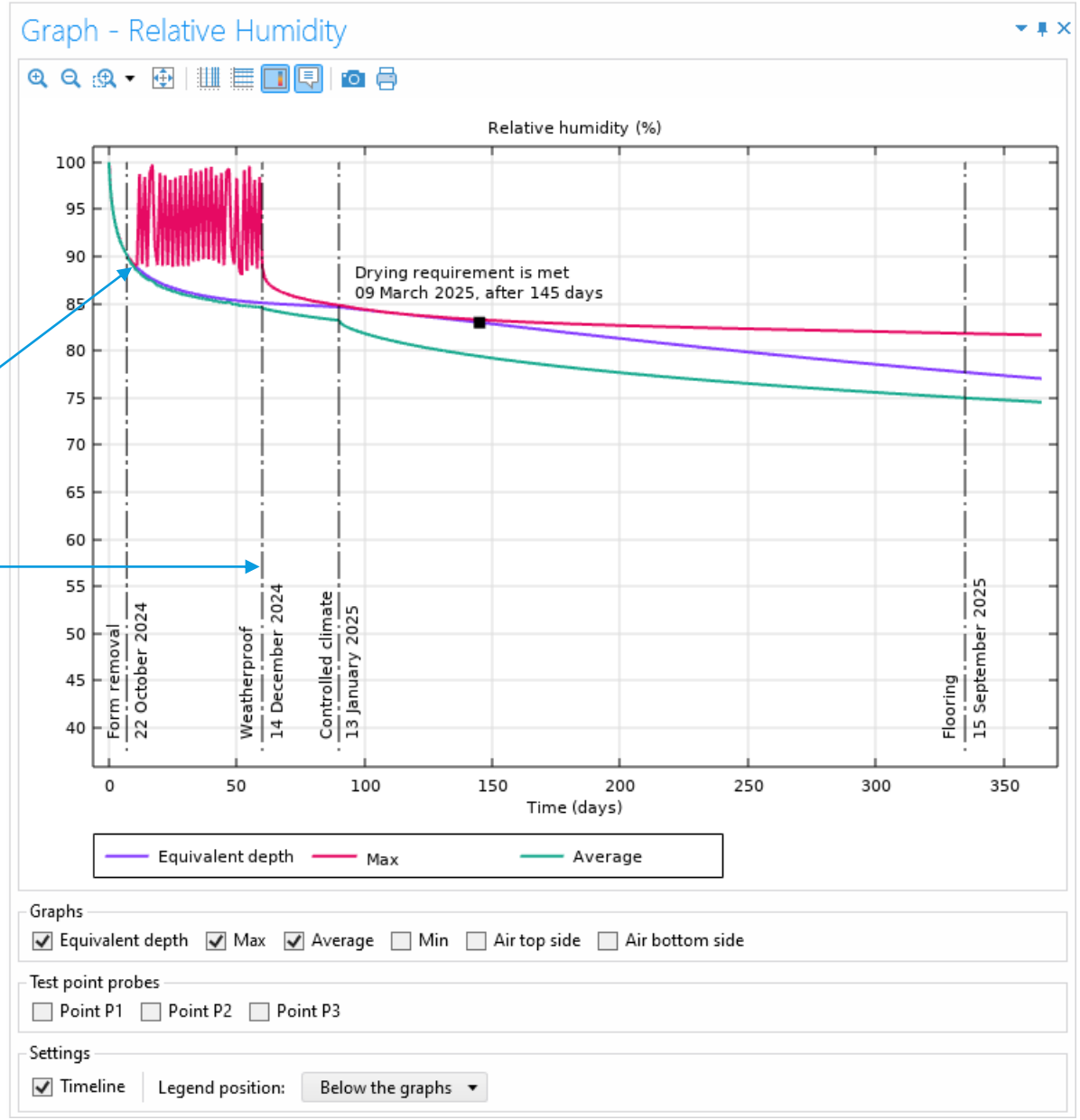


Graphics

Graph - Relative Humidity

Cover removed

Weatherproof

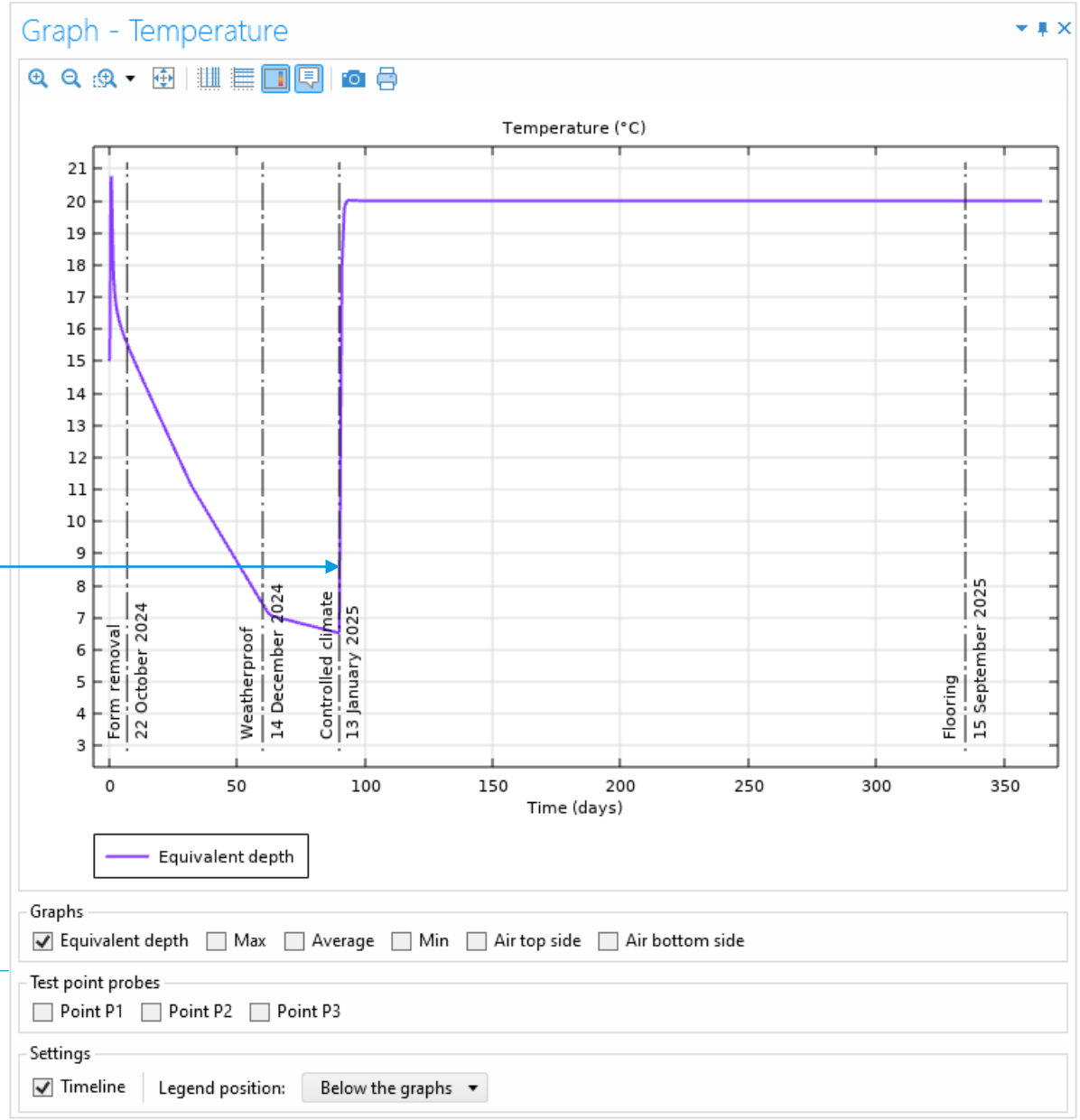


Graphics

Graph - Temperature

Controlled climate

Select graphs



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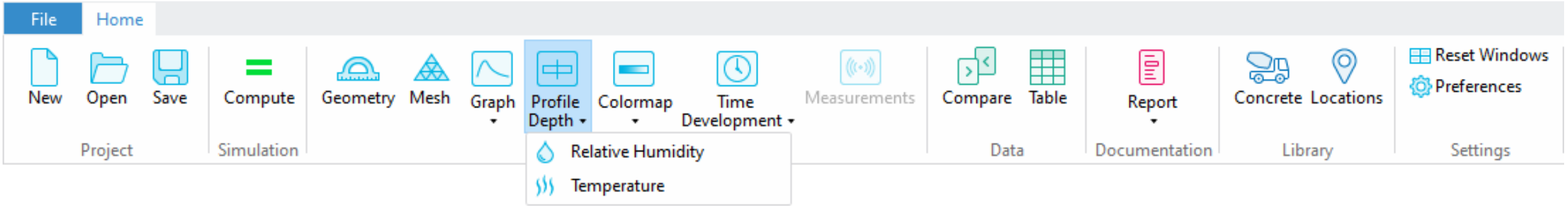
Graphics

Profile Depth Menu



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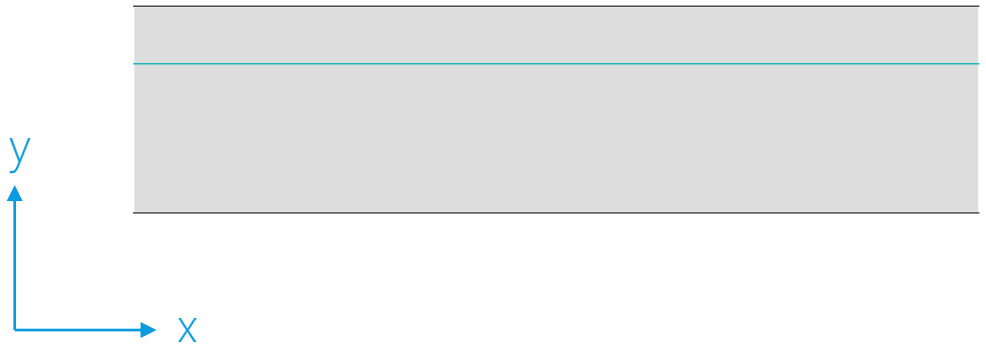
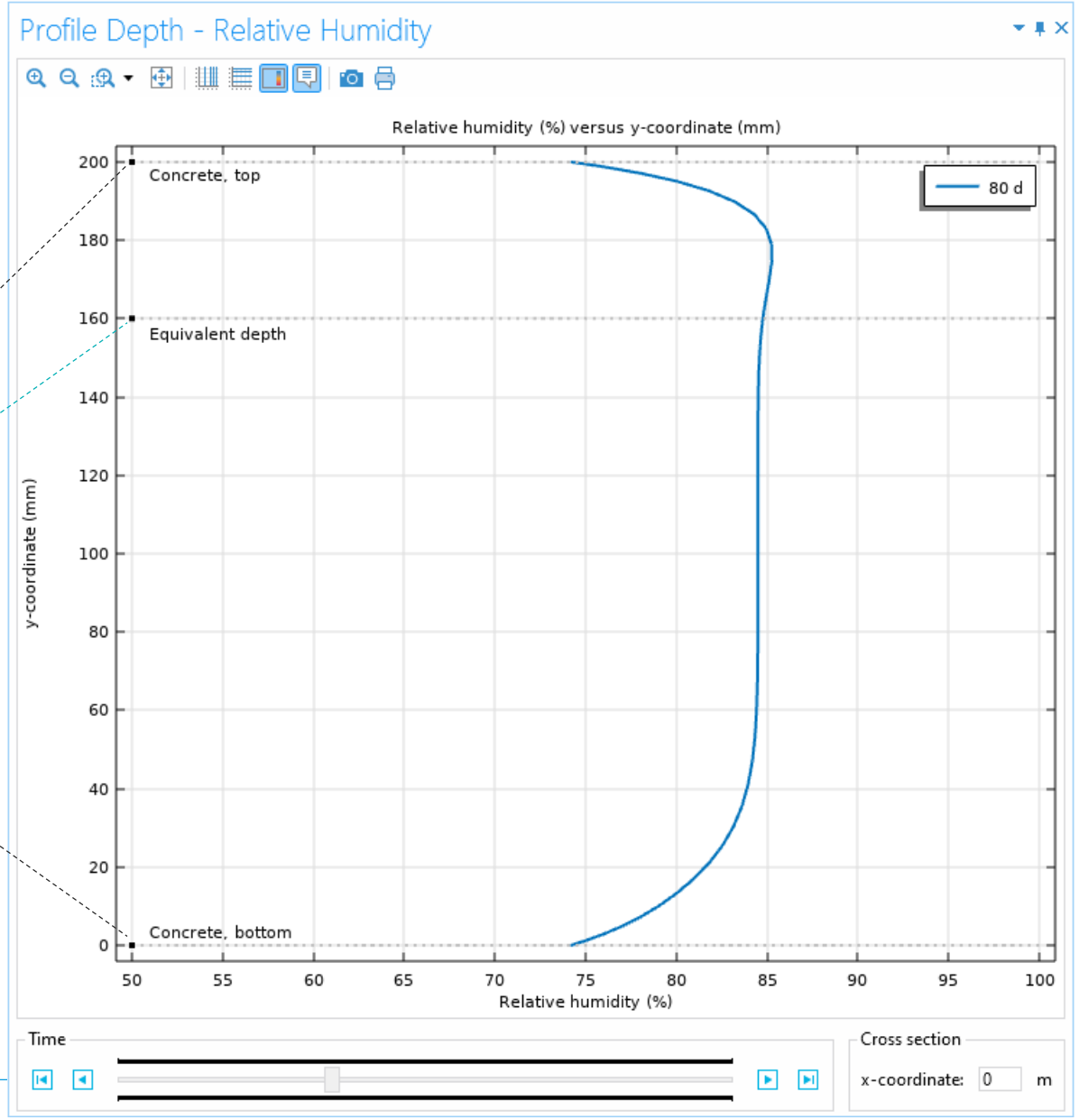
Graphics

Profile Depth – Relative Humidity

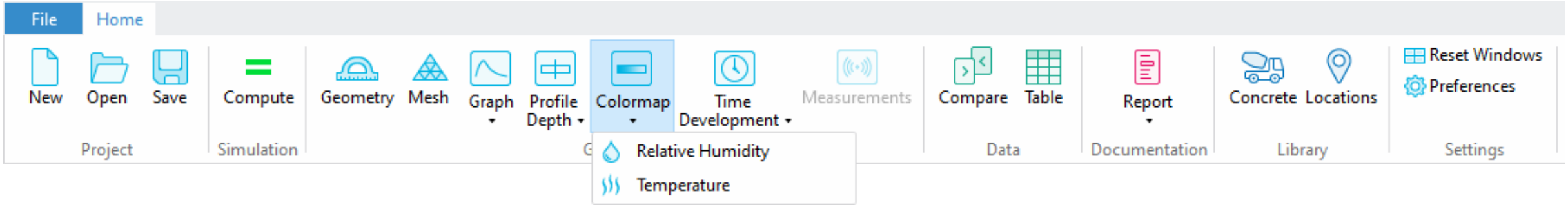




Drag slider to change time step

Graphics

Colormap Menu



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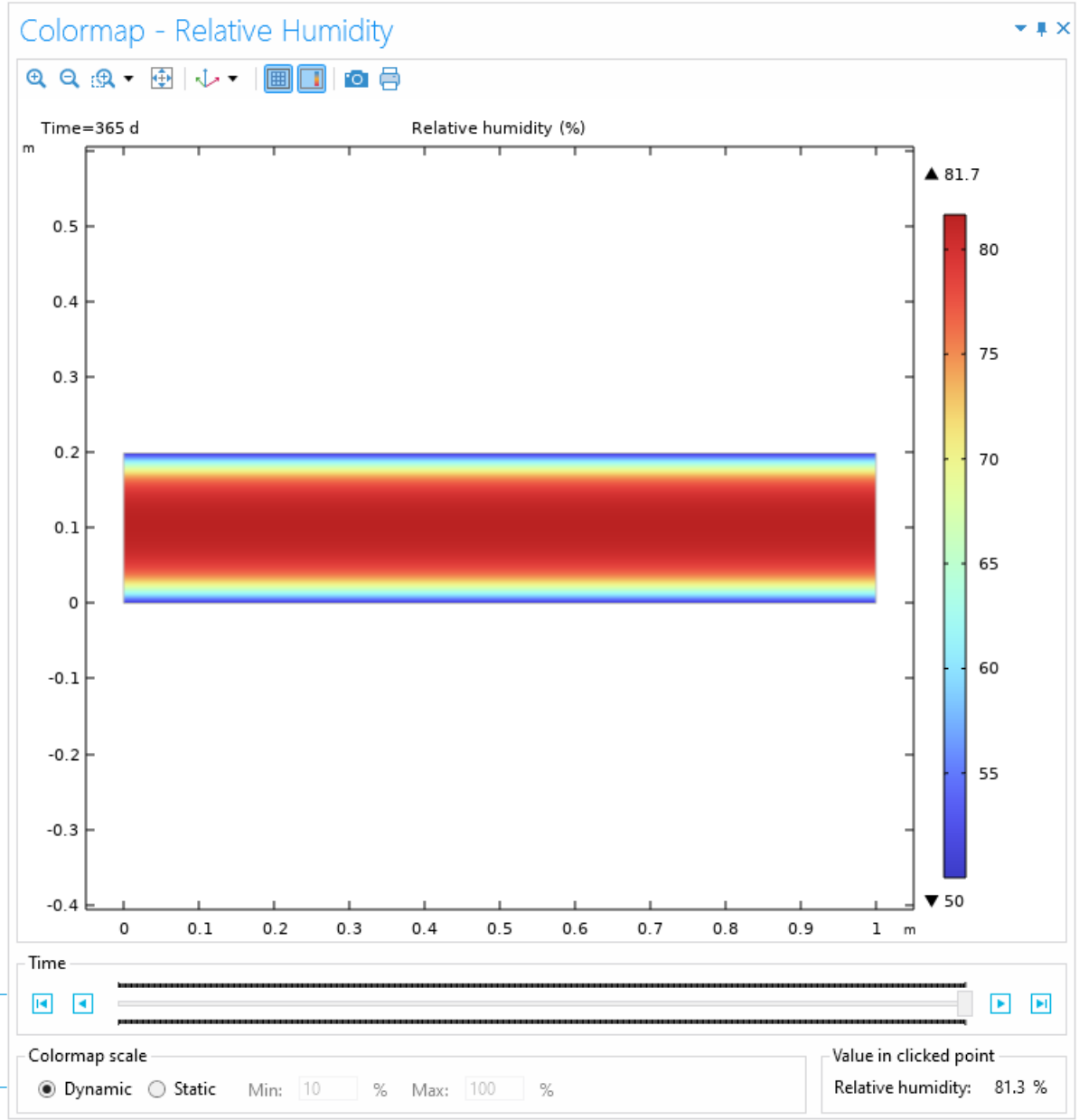
Graphics

Colormap – Relative Humidity



Drag slider to change time step

Set dynamic or static colormap scale

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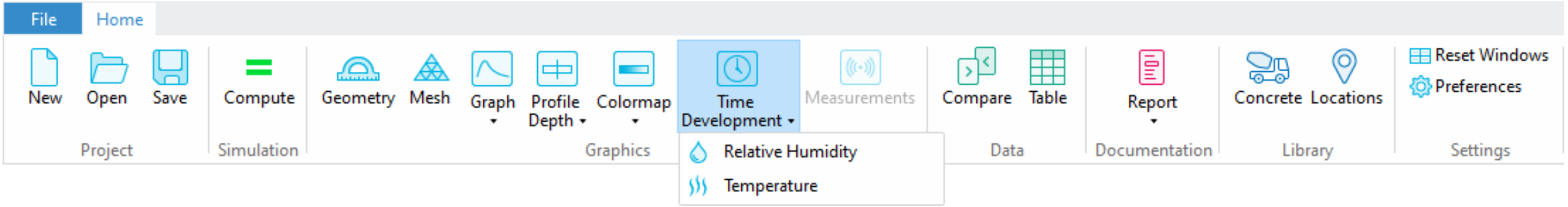
Graphics

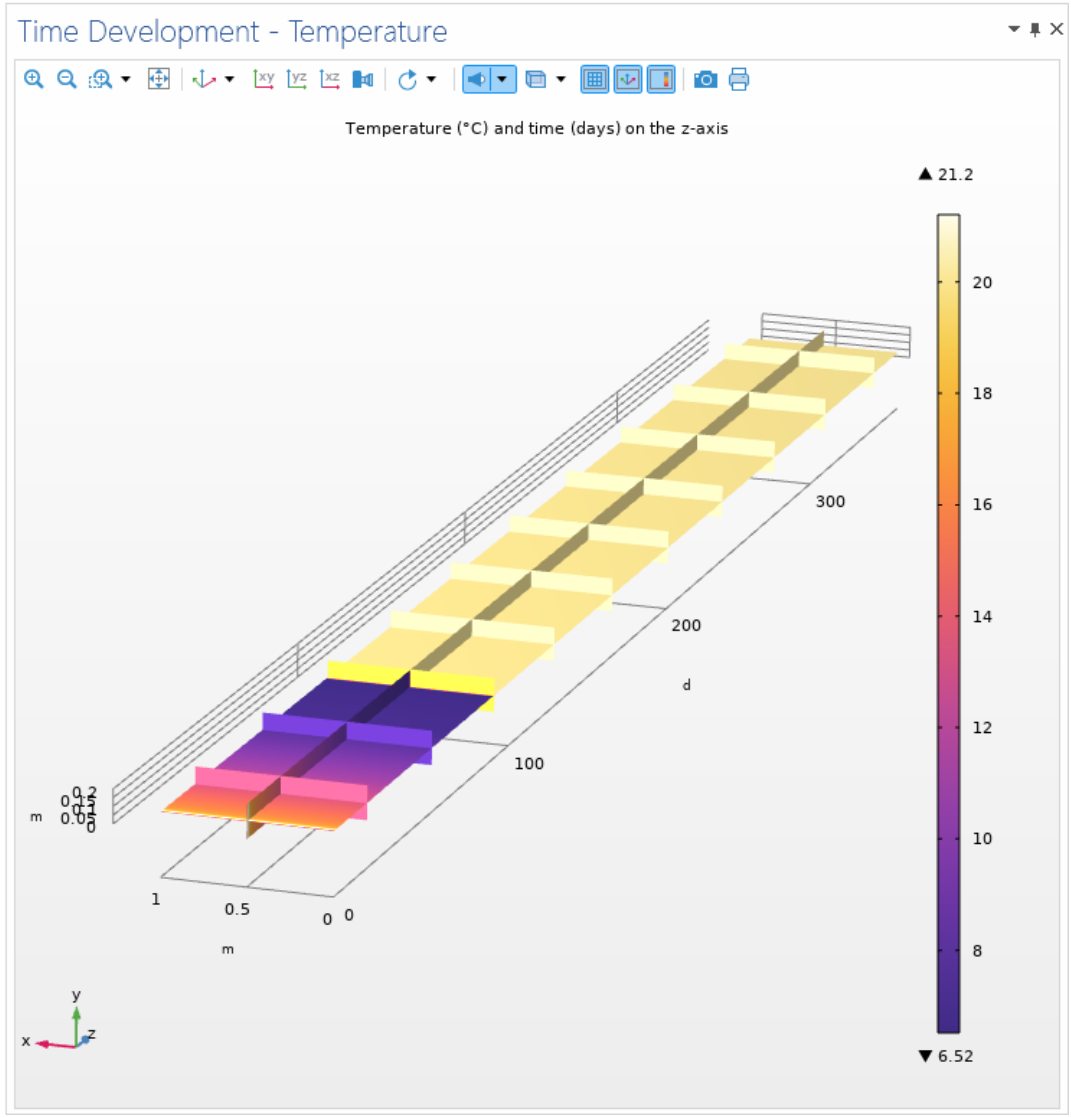
Time Development Menu



Graphics

Time Development - Temperature

- The z-coordinate represent time (days)



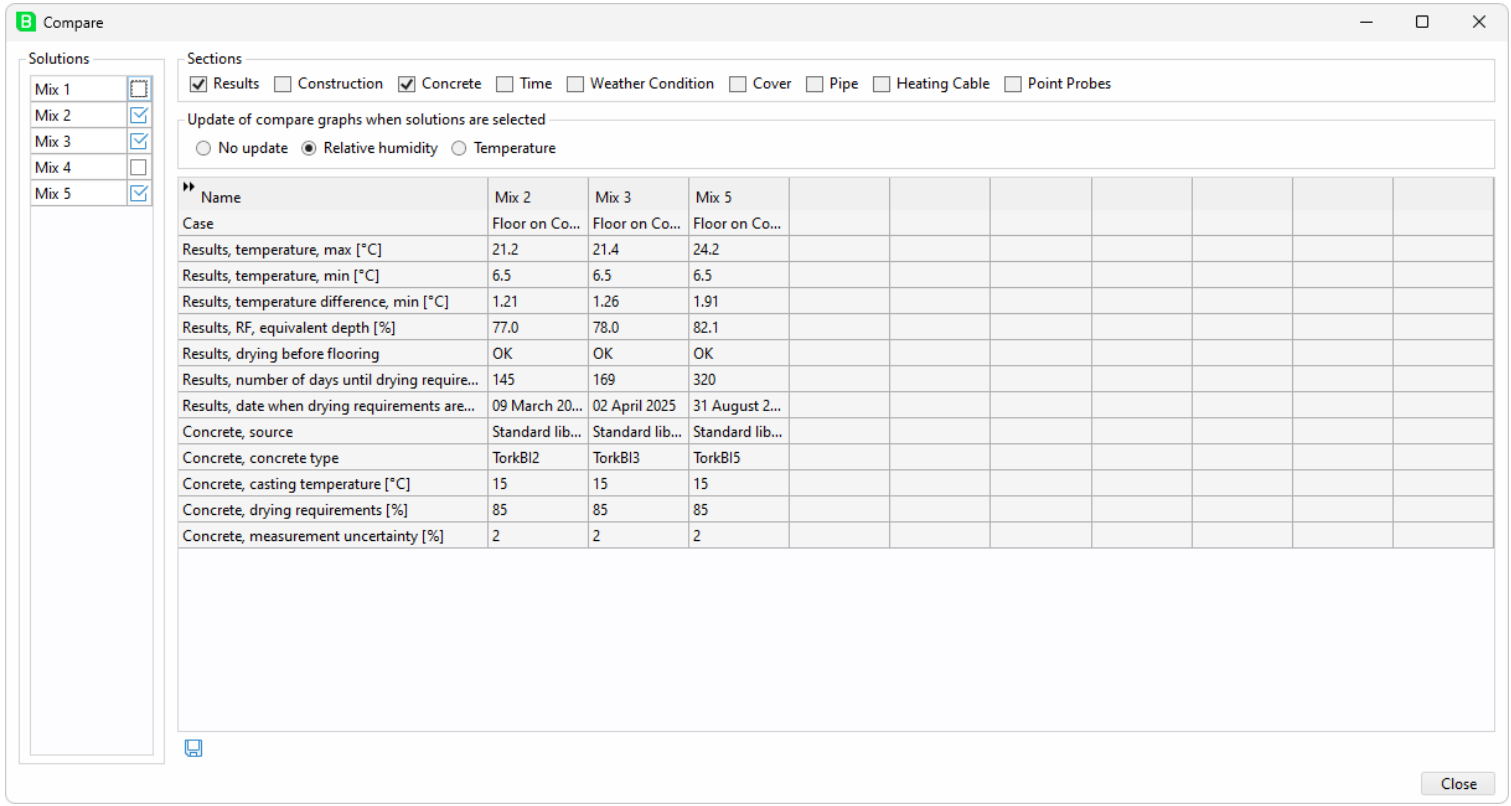
Results

Compare data and create reports

Compare

Compare and Visualize Different Solutions

- Each time a solution is computed, relevant data is saved, allowing for easy comparison of different inputs and outputs
- Solutions can be renamed and sections can be filtered
- Plots can be updated automatically

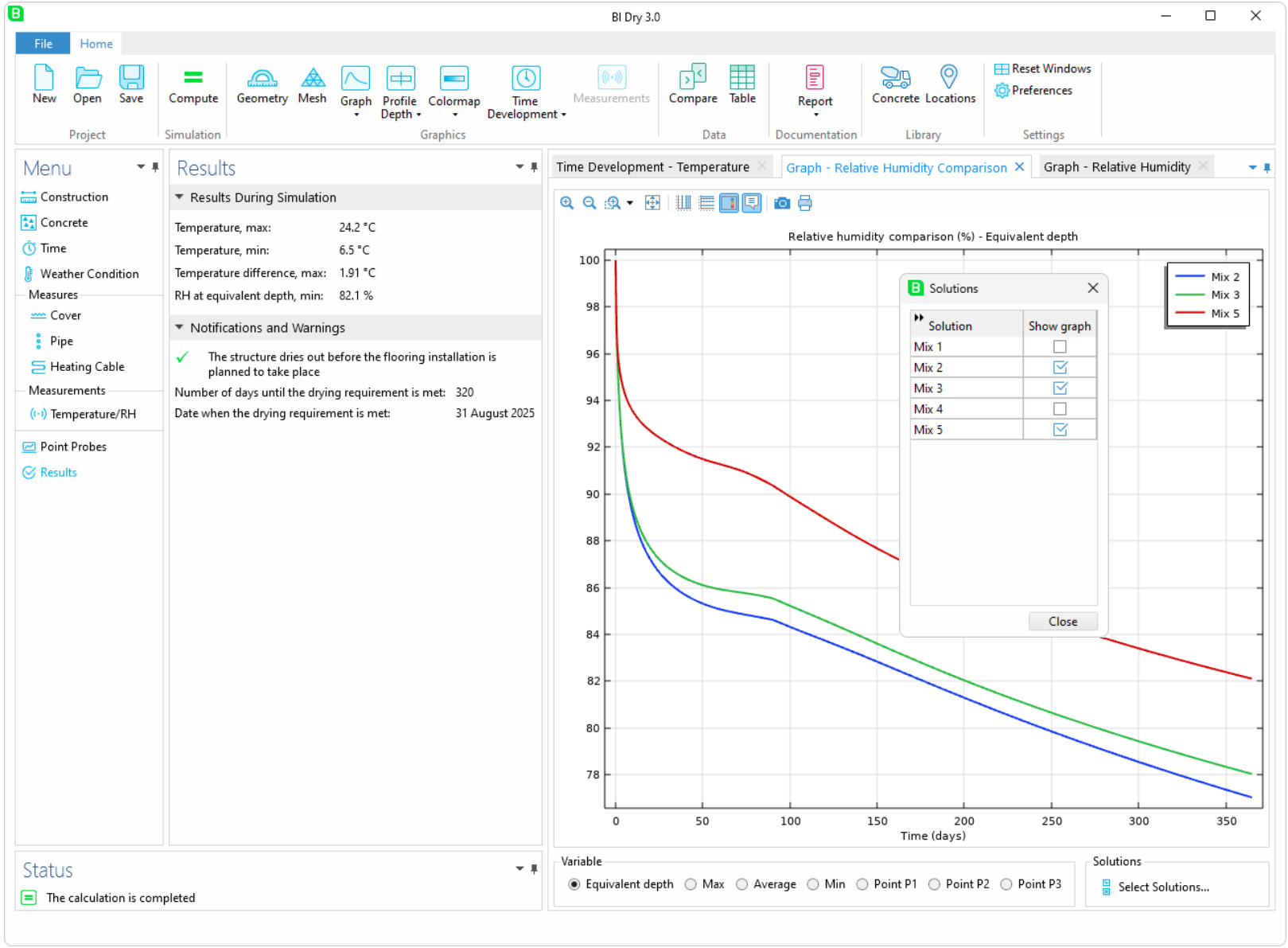


Name	Mix 2	Mix 3	Mix 5
Case	Floor on Co...	Floor on Co...	Floor on Co...
Results, temperature, max [°C]	21.2	21.4	24.2
Results, temperature, min [°C]	6.5	6.5	6.5
Results, temperature difference, min [°C]	1.21	1.26	1.91
Results, RF, equivalent depth [%]	77.0	78.0	82.1
Results, drying before flooring	OK	OK	OK
Results, number of days until drying require...	145	169	320
Results, date when drying requirements are...	09 March 20...	02 April 2025	31 August 2...
Concrete, source	Standard lib...	Standard lib...	Standard lib...
Concrete, concrete type	TorkBI2	TorkBI3	TorkBI5
Concrete, casting temperature [°C]	15	15	15
Concrete, drying requirements [%]	85	85	85
Concrete, measurement uncertainty [%]	2	2	2

Compare

Visualize

- Easy to rename and enable/disable the visualization of different solutions



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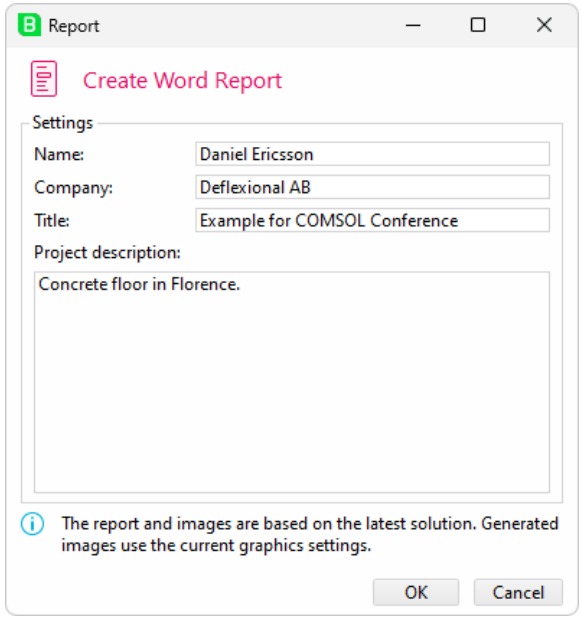
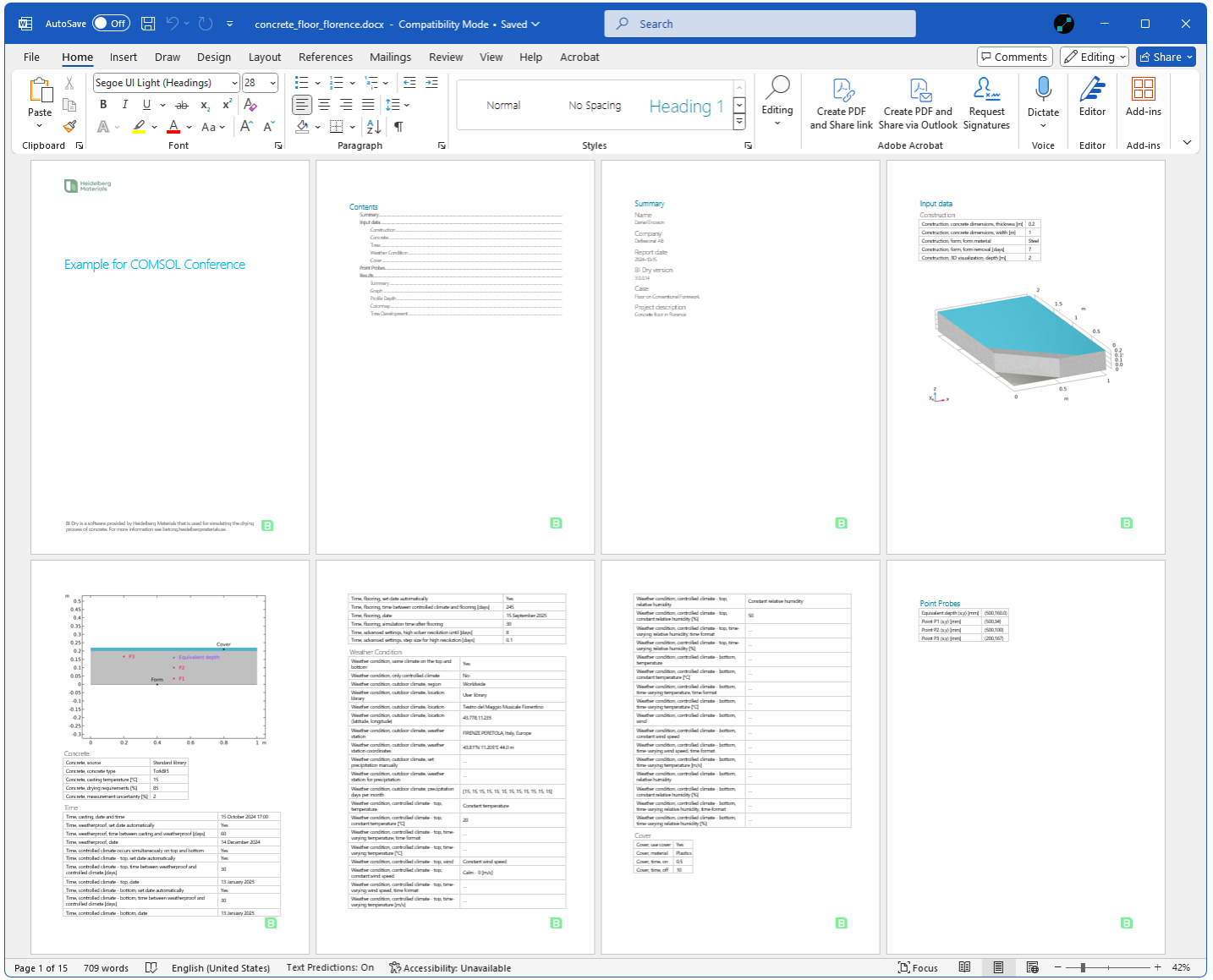
Report

Microsoft Word





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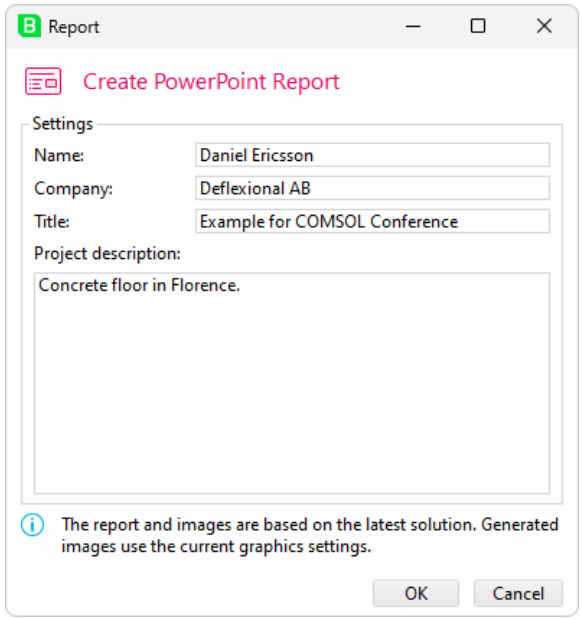
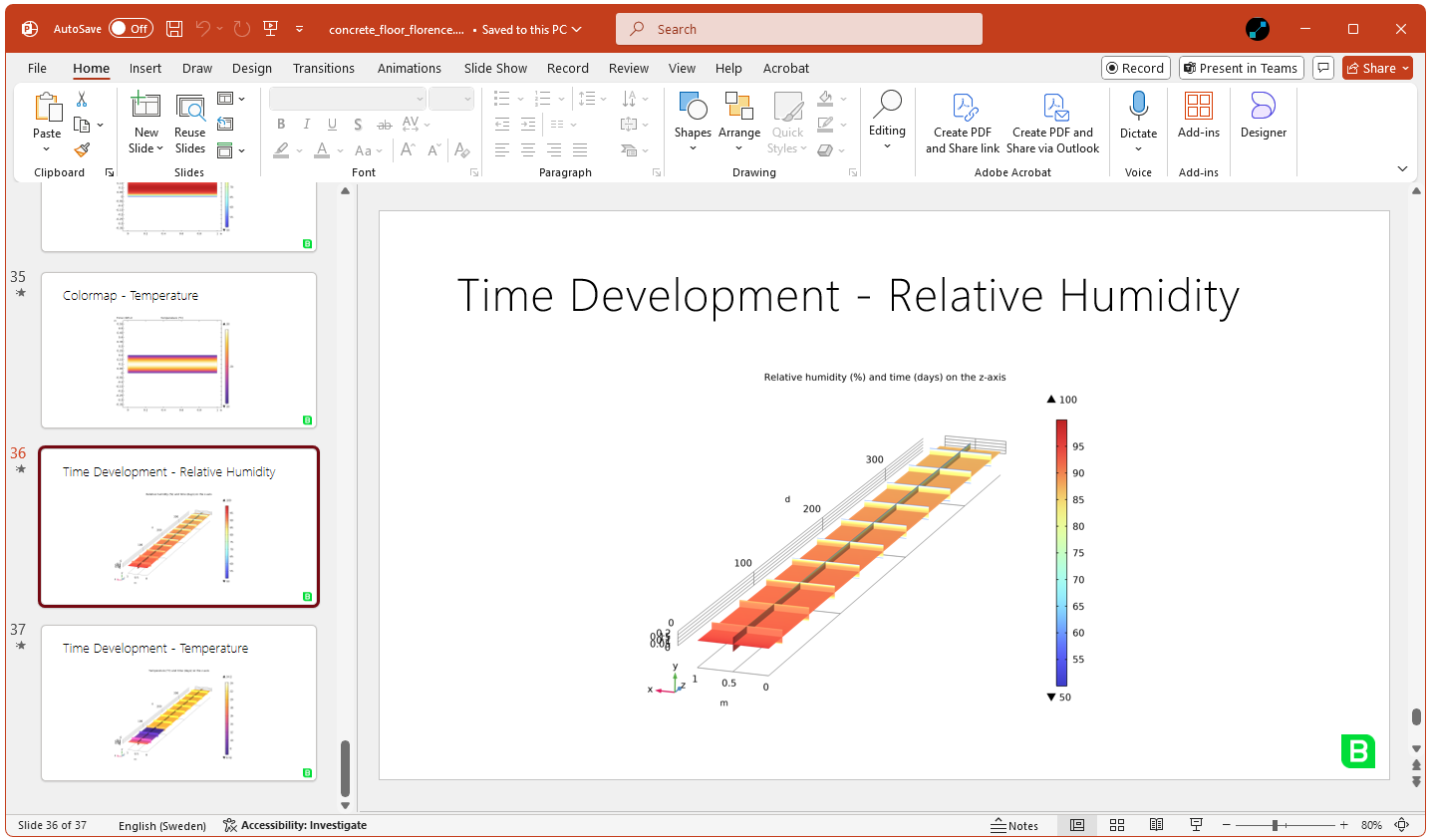
Report

Microsoft PowerPoint





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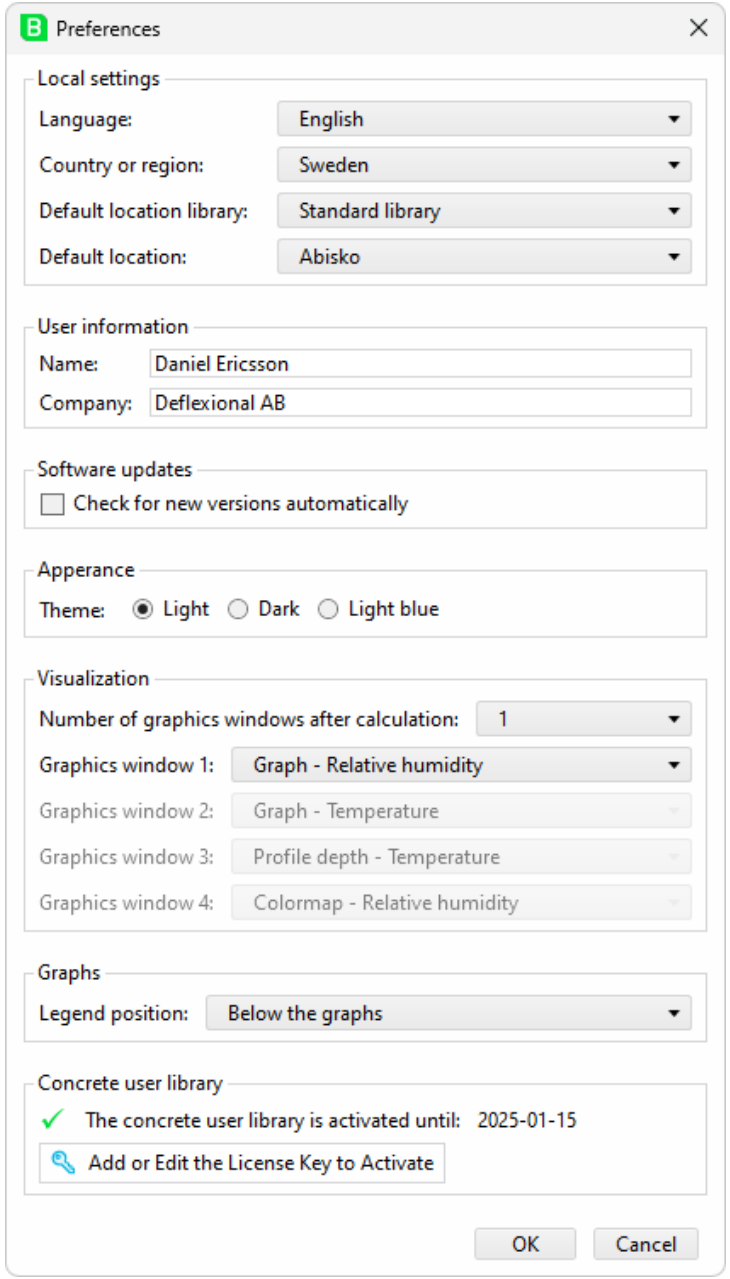
Preferences

Set language, region, appearance, and more

Preferences

Local Settings

- Language can be set to English or Swedish
- If the region is set to Sweden, precipitation data averaged from 1991 to 2020 is provided by the Swedish Meteorological and Hydrological Institute (SMHI).



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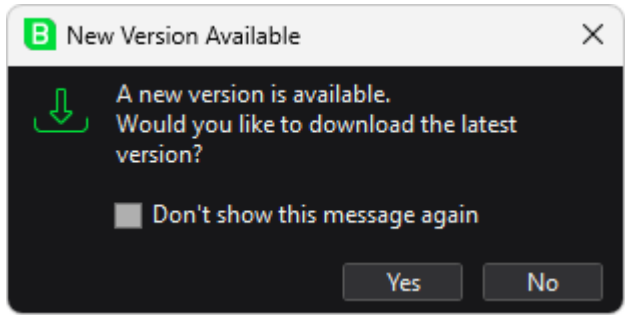
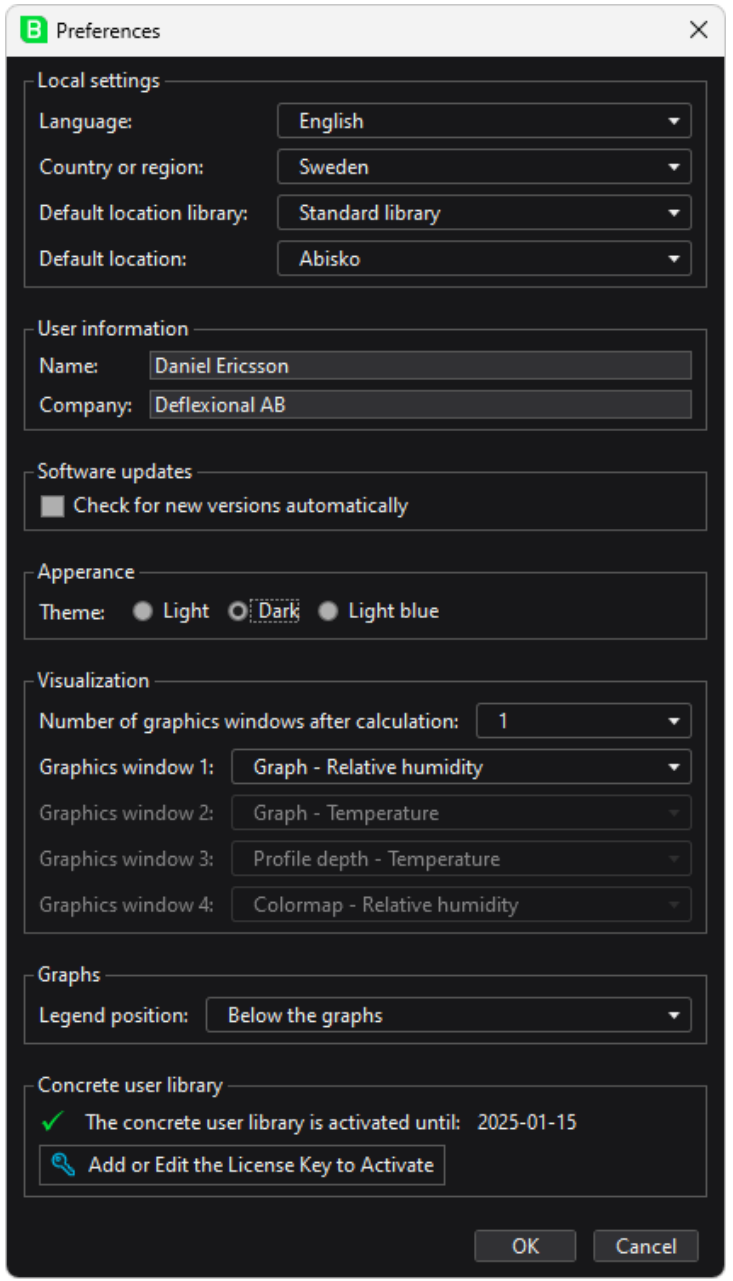
Preferences

Software Updates and Appearance

- The user can choose between three different themes
- Every time BI Dry starts it can check for new versions automatically





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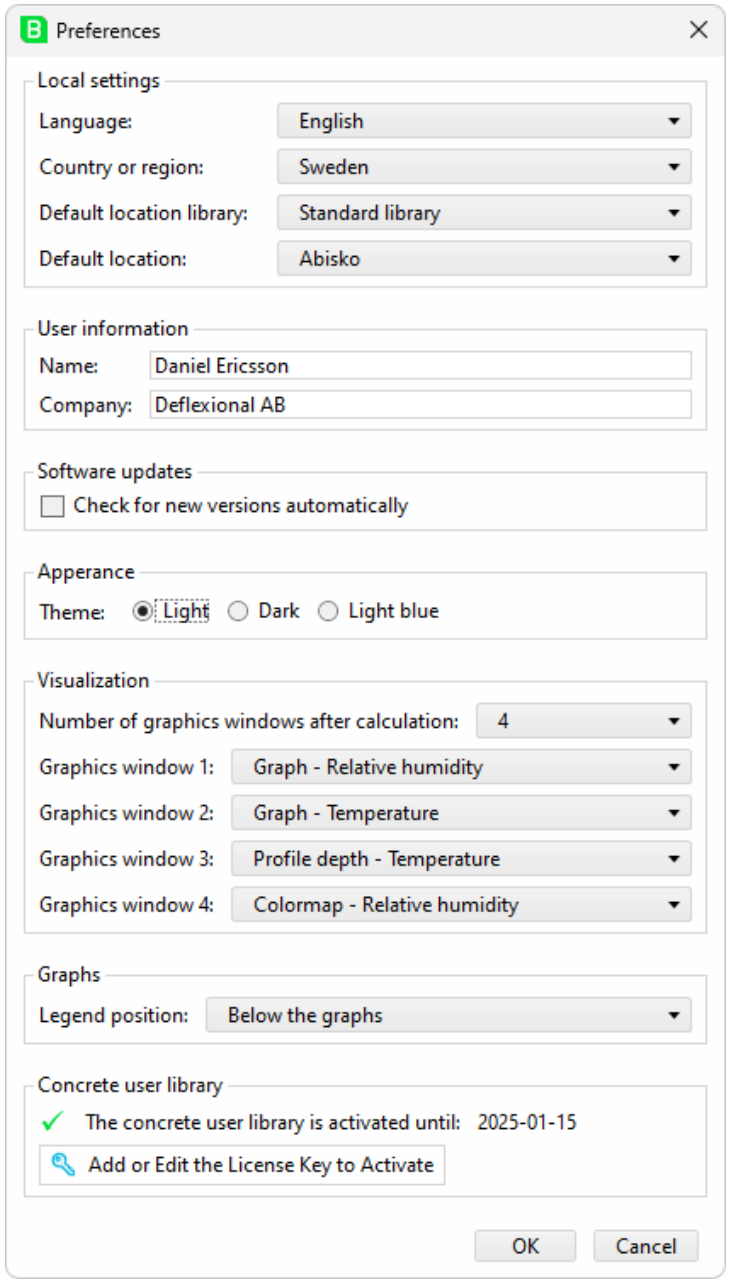
Preferences

Visualizations and Graphs

- The number of graphics windows after a calculation can be adjusted from 1 to 4
- Each graphics window can have a default plot
- For graphs, the default position for the legends can be set



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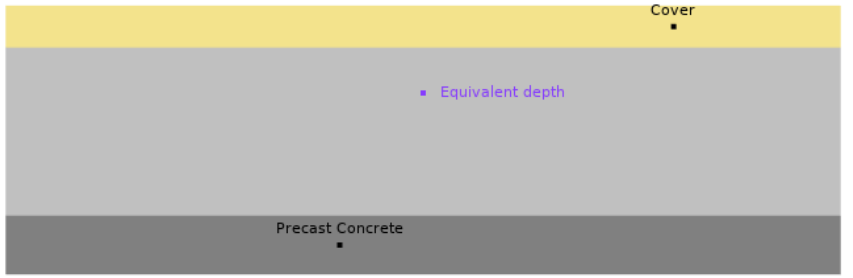
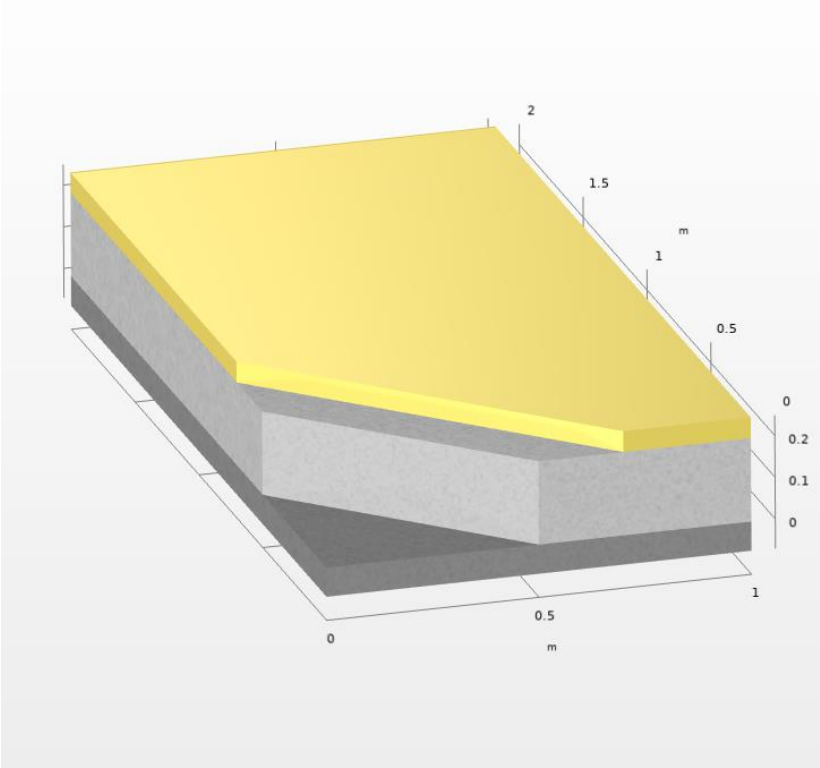
Underlying COMSOL Model

Combining the Model Builder with methods

Geometry

- The 2D geometry is dynamically generated in the Application Builder using methods tailored to the selected construction case
- A secondary 3D component is used to visualize the construction with material colors





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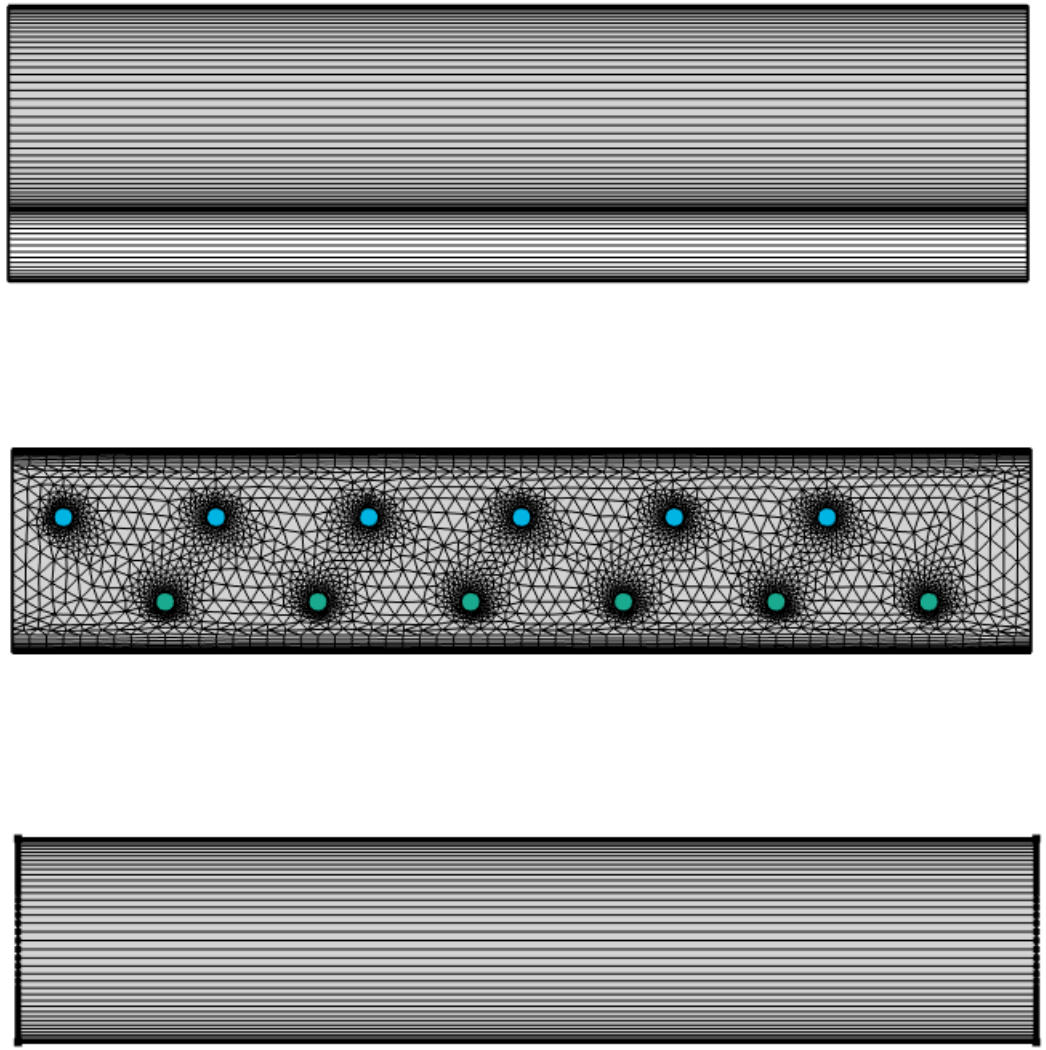
Mesh

- The mesh automatically adjusts to the selected construction scenario.
- If pipes or heating cables are included, boundary layer meshing is added automatically
- The problem is always solved in 2D, but the mesh has only one element in the x-direction, effectively reducing it to 1D when possible



Physics Interfaces

- Heat Transfer in Solids
  - Heat Source
  - Heat Flux
  - Thin Layer
- Stabilized Convection-Diffusion Equation
- Domain ODEs and DAEs
  - Calculate the equivalent time (maturity)
- Events
  - Efficiently manages dynamic changes in the model such as formwork removal, cover additions, or the activation/deactivation of heating cables or pipes

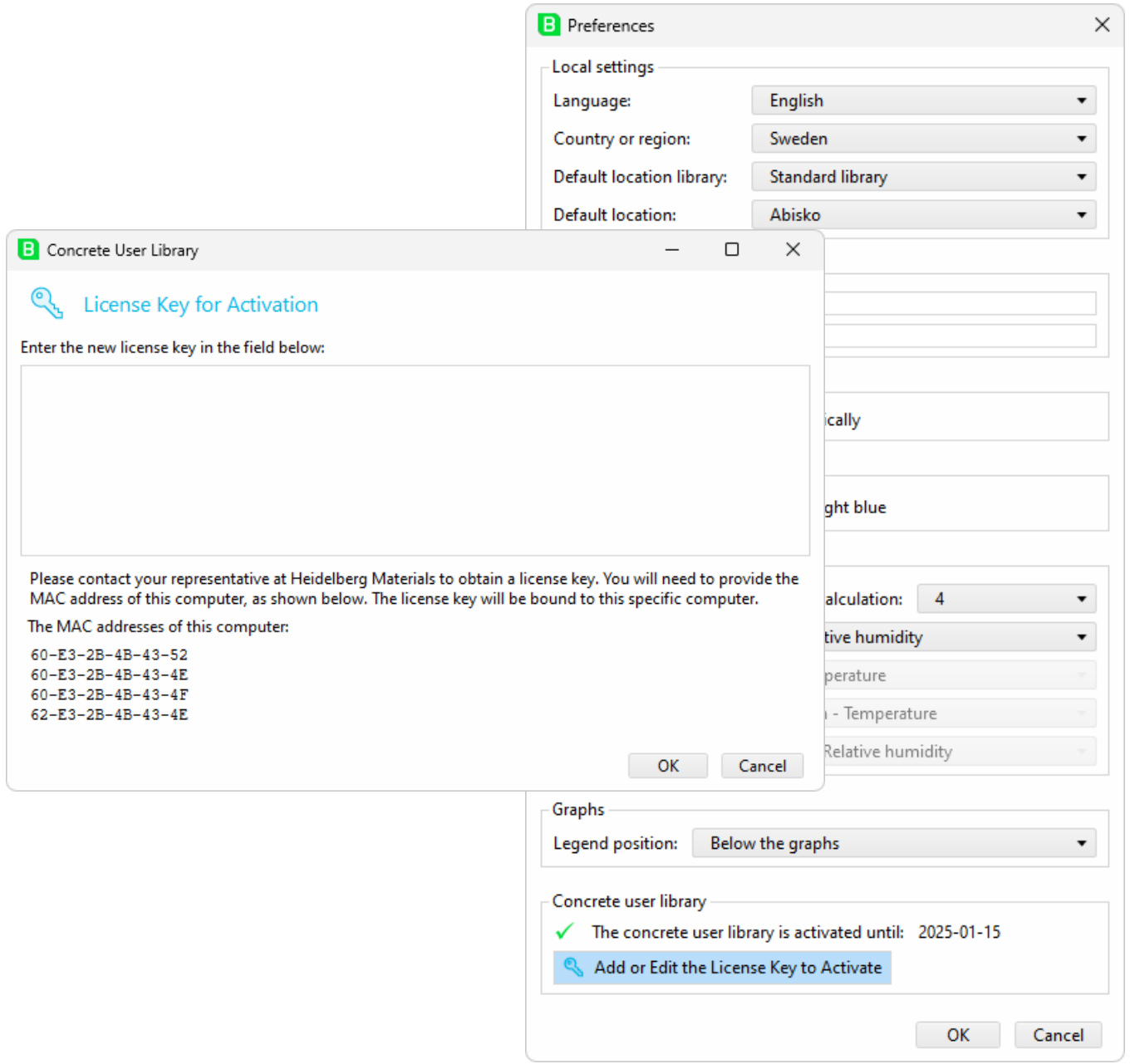
Access to Specific Functionality

A portion allocated for advanced users and researchers

Preferences

Concrete User Library

- The Concrete User Library enables researchers to add their own concrete mixes
- Requires a license key which is bound to the MAC address



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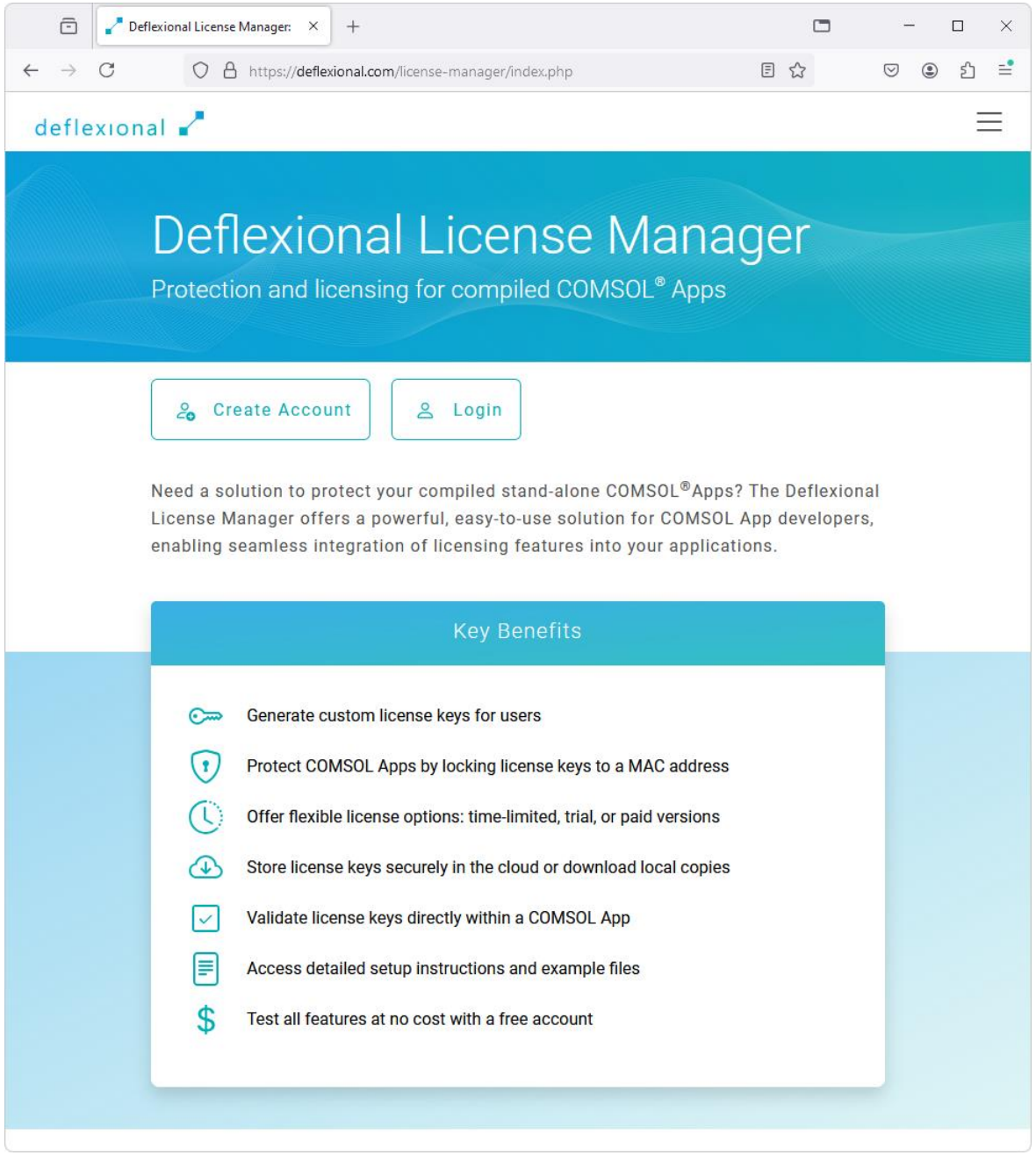
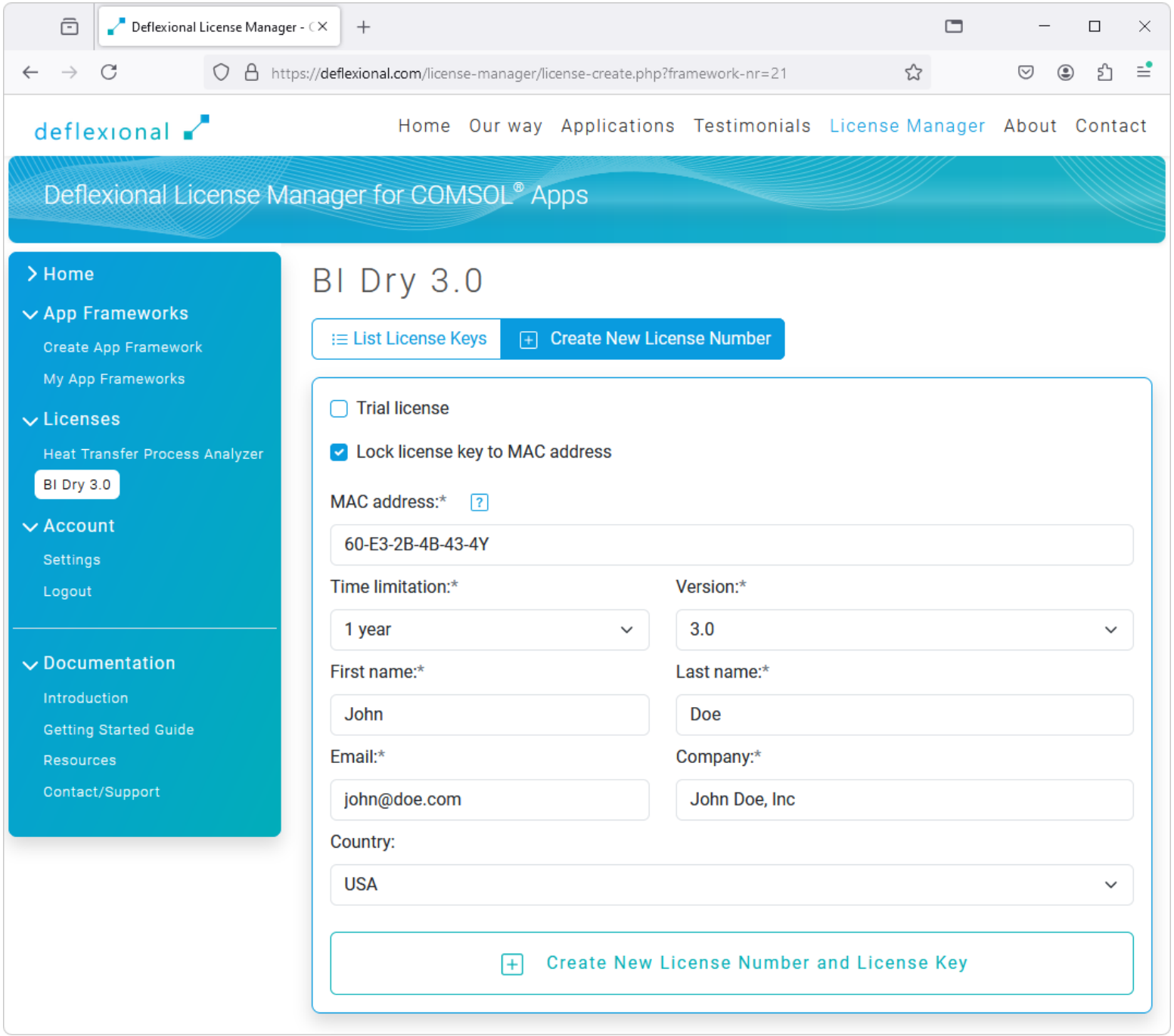
License Keys

- The Deflexional License Manager manages license key generation and integration with the COMSOL App
- Can be tested for free at: deflexional.com/license-manager

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Time limitation:*
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Version:*
3.0
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John
Last name:*
Doe
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John Doe, Inc
Country:
USA
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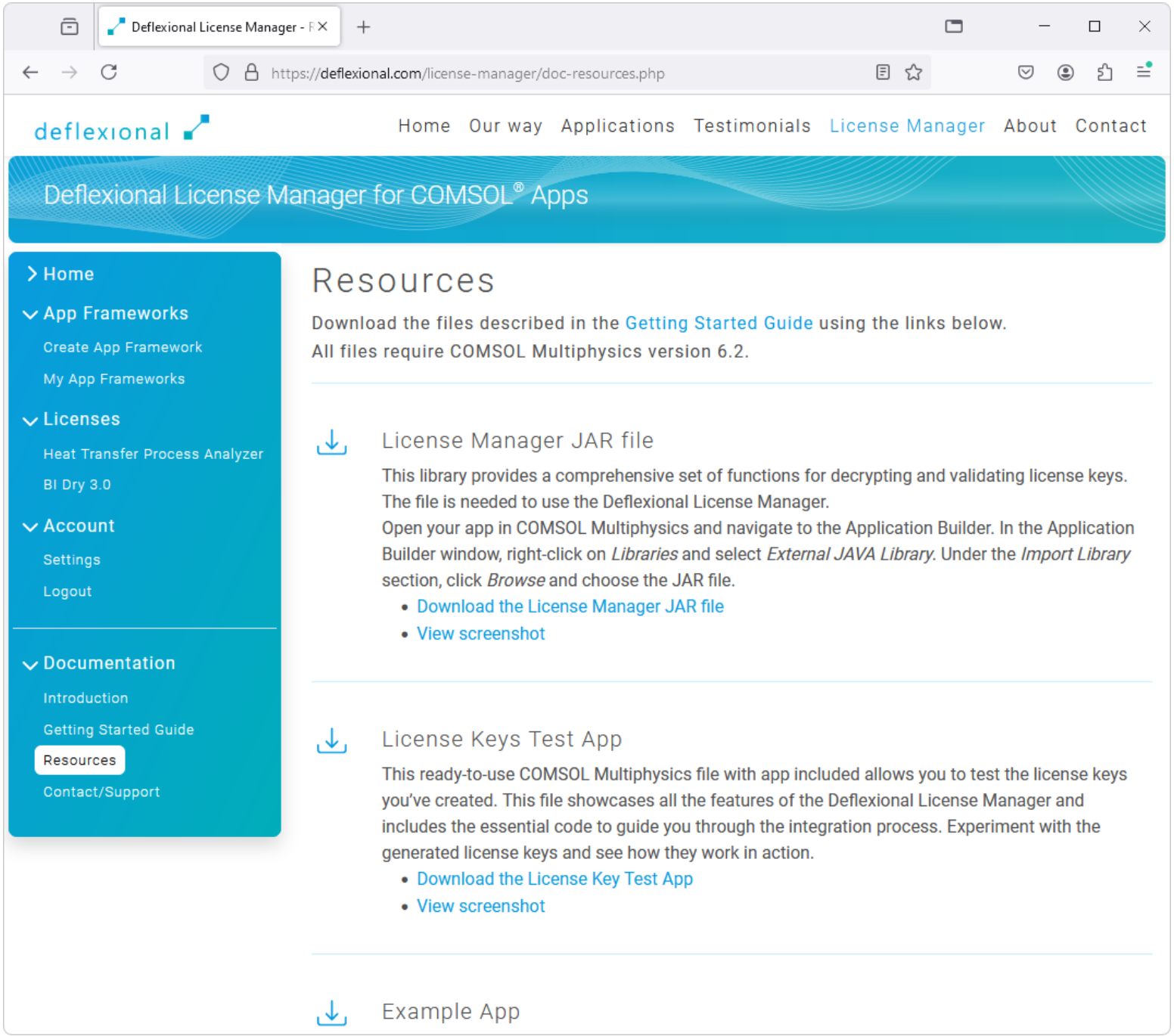
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Resources
Download the files described in the Getting Started Guide using the links below.
All files require COMSOL Multiphysics version 6.2.
License Manager JAR file
This library provides a comprehensive set of functions for decrypting and validating license keys. The file is needed to use the Deflexional License Manager.
Open your app in COMSOL Multiphysics and navigate to the Application Builder. In the Application Builder window, right-click on Libraries and select External JAVA Library. Under the Import Library section, click Browse and choose the JAR file.
Download the License Manager JAR file
View screenshot
License Keys Test App
This ready-to-use COMSOL Multiphysics file with app included allows you to test the license keys you've created. This file showcases all the features of the Deflexional License Manager and includes the essential code to guide you through the integration process. Experiment with the generated license keys and see how they work in action.
Download the License Key Test App
View screenshot
Example App

Conclusions

Contractors can now use the latest technology to simulate drying of concrete

Conclusions

- Given the success of HETT[22], BI Dry 3.0 has been completely rebuilt on the same platform utilizing COMSOL Multiphysics® and COMSOL Compiler™.
- BI Dry 3.0 uses the Maturity Method and the heat transfer equation plus a convection-diffusion equation for moisture content, coupled with heat transfer.
- By using simulations, significant cost savings and environmental benefits can be realized by choosing the right concrete and construction under certain conditions.
- BI Dry 3.0 is scheduled for release before the end of 2024.
- Any contractor can now leverage the power of COMSOL Multiphysics® to simulate the drying of concrete.

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We maximize the benefits of engineering simulations

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