HETT^{22} – A COMSOL® App to Accurately Simulate, Plan and Monitor Concrete Castings

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[4] Heidelberg Materials Betong Sverige AB, Stockholm, Sweden

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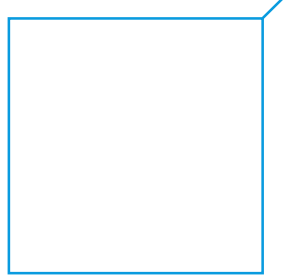
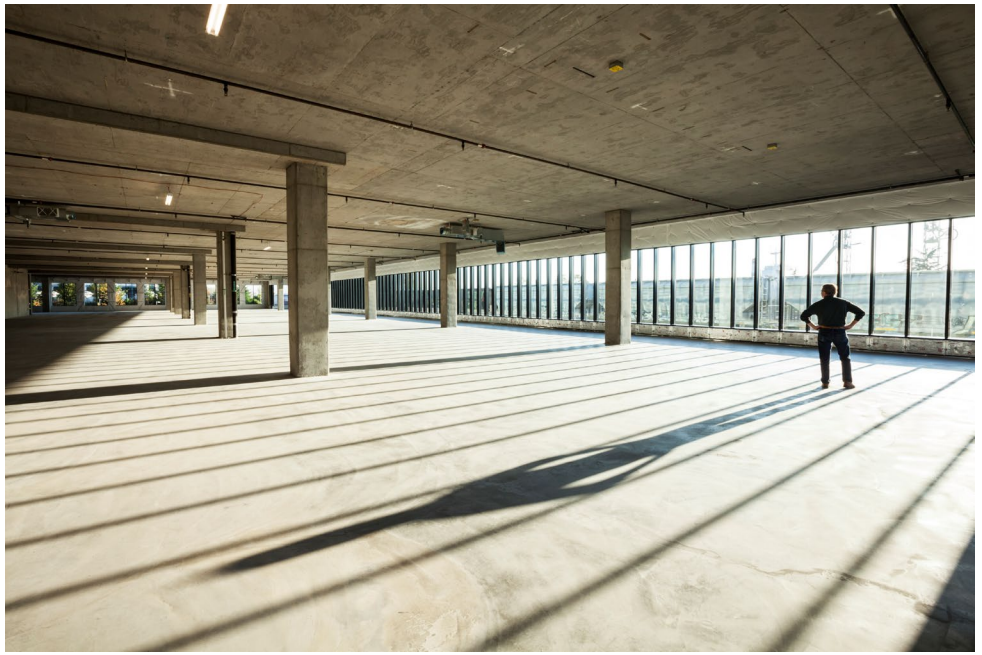
Contents

Introduction

Background and benefits of the software



Background



- Concrete is the world's most utilized building material
- The early-age performance of concrete depends on temperature, wind conditions, construction type, and dimensions
- Significant cost savings and environmental benefits can be realized by choosing the right concrete and design for specific conditions

Reductions & Savings

- Reduce CO_2 emission by
  - decreasing the amount of binder
  - not using too high concrete quality
  - adding a binder combination with slag or fly ash
  - choosing the right design
- Cost savings by
  - building the construction faster
  - preventing failures

History & Present

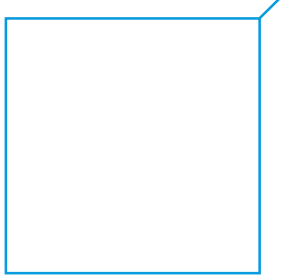
- Heidelberg Materials, a global leader in building materials, has long provided customers with finite element-based software solutions to predict heat generation and strength development in concrete
- Existing software was becoming outdated and in need of an update, incorporating new functionalities and features
- Deflexional, a Certified COMSOL Consultant, was commissioned to undertake the development of HETT^{22}, leveraging the versatile capabilities COMSOL®

Heidelberg Materials

COMSOL Certified Consultant

The Maturity Method

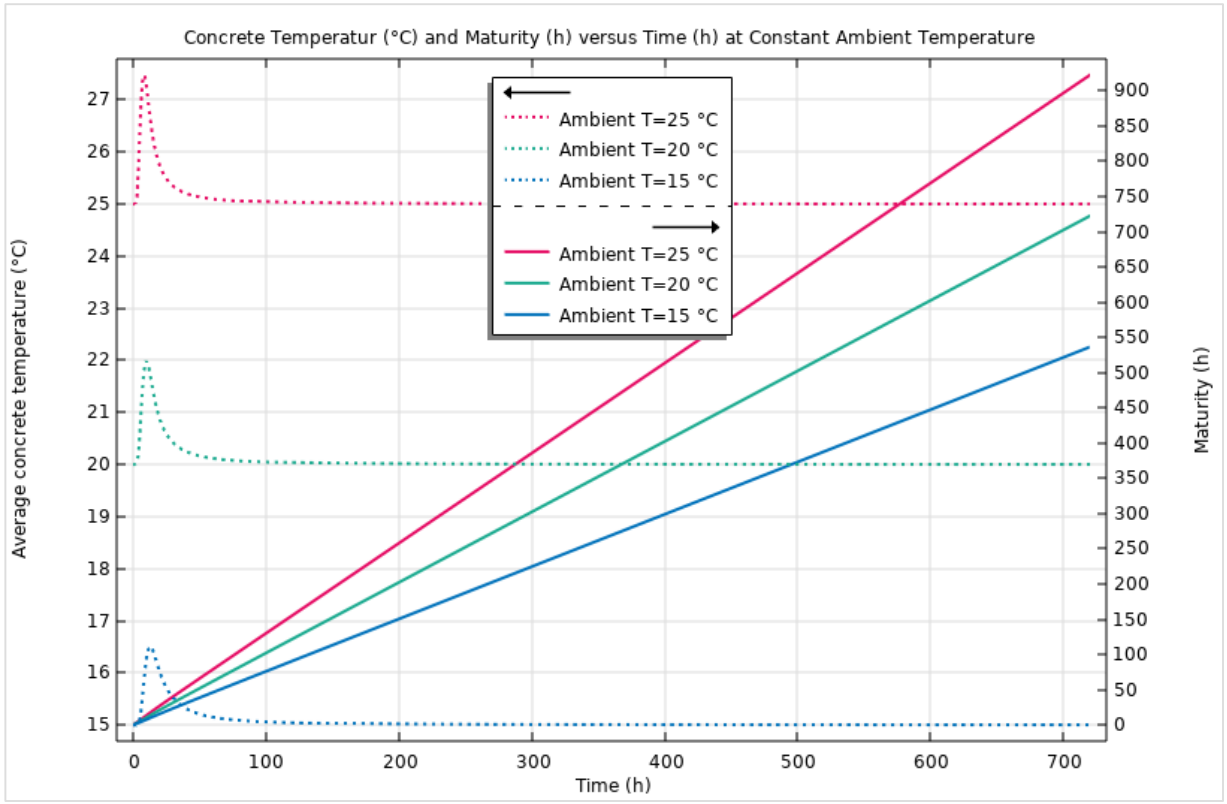
Prediction of concrete strength over time



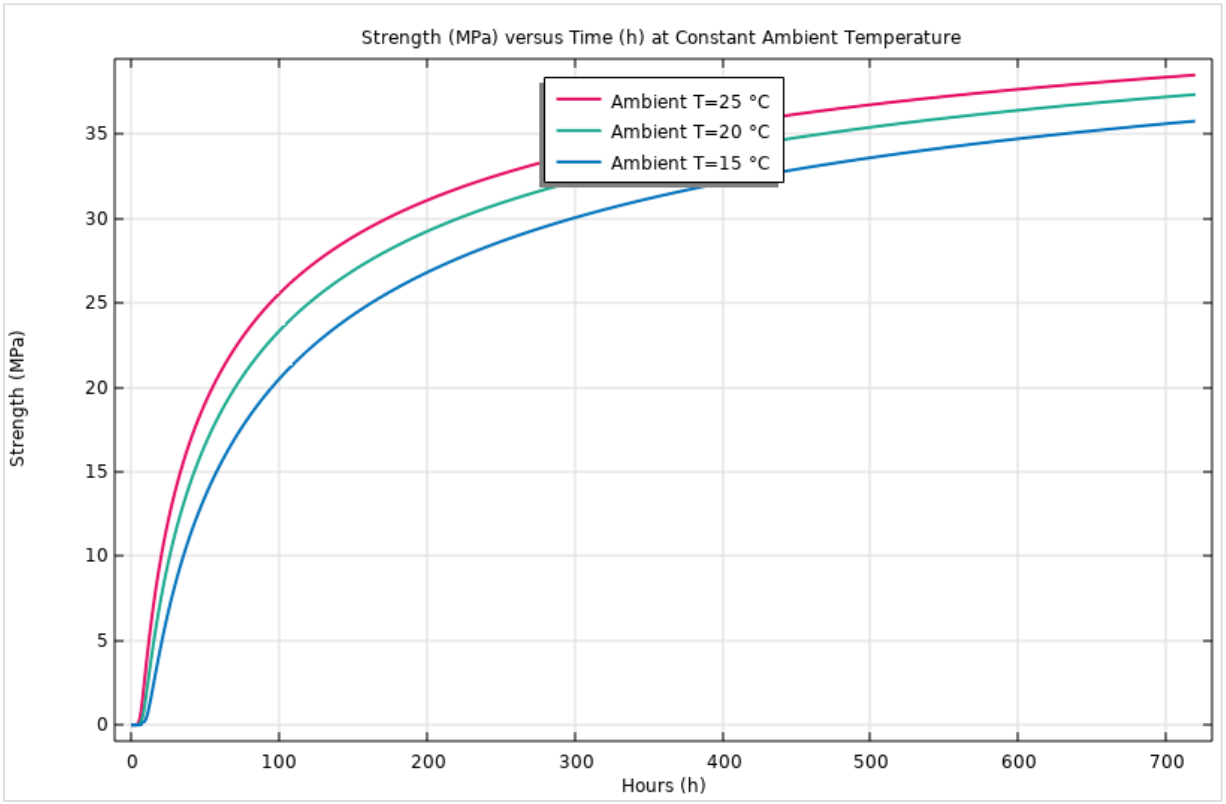
Based on Discoveries of Svante Arrhenius

- Concrete gains strength as it cures, and this process is highly temperature dependent
- The maturity method is founded on the principle that the rate of concrete strength gain is directly influenced by the temperature history
- Utilizing the Arrhenius Equation, the so-called equivalent time, and thus, the concrete maturity can be determined during the concrete hardening process
- The equivalent time represents the total amount of time at a standard reference temperature that is equivalent to the actual time-temperature history experienced by the concrete
- The concrete strength is based on the concrete maturity

Temperature, Maturity & Strength



The maturity increases with increased ambient temperature



The strength increases with increased ambient temperature

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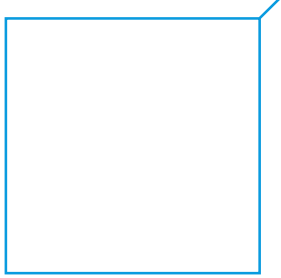
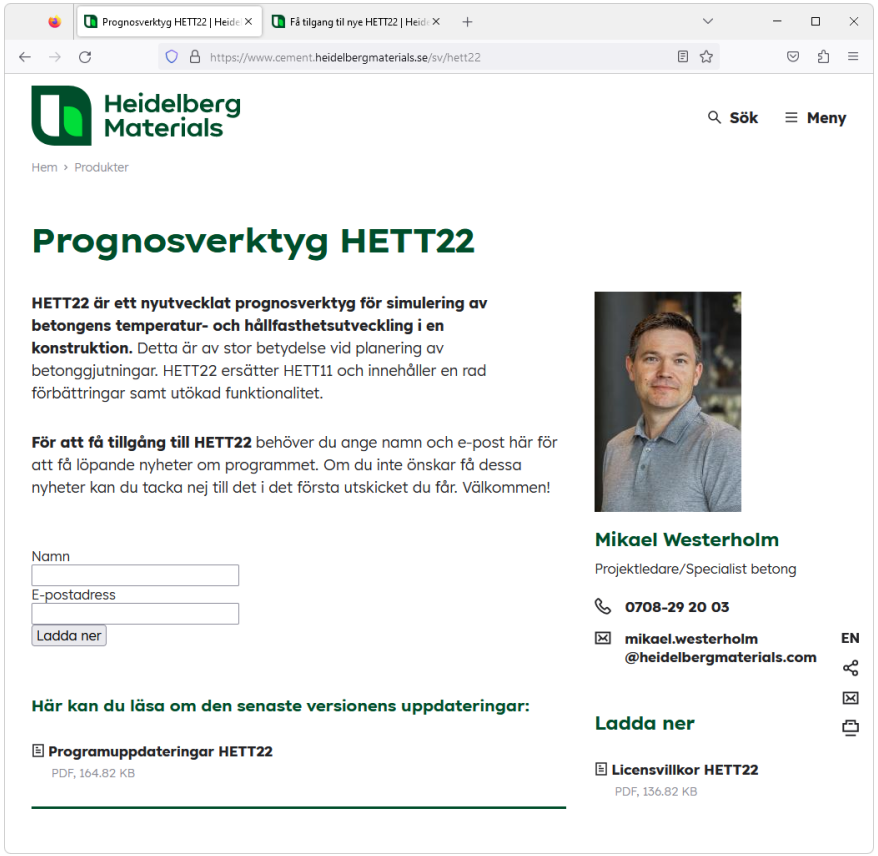
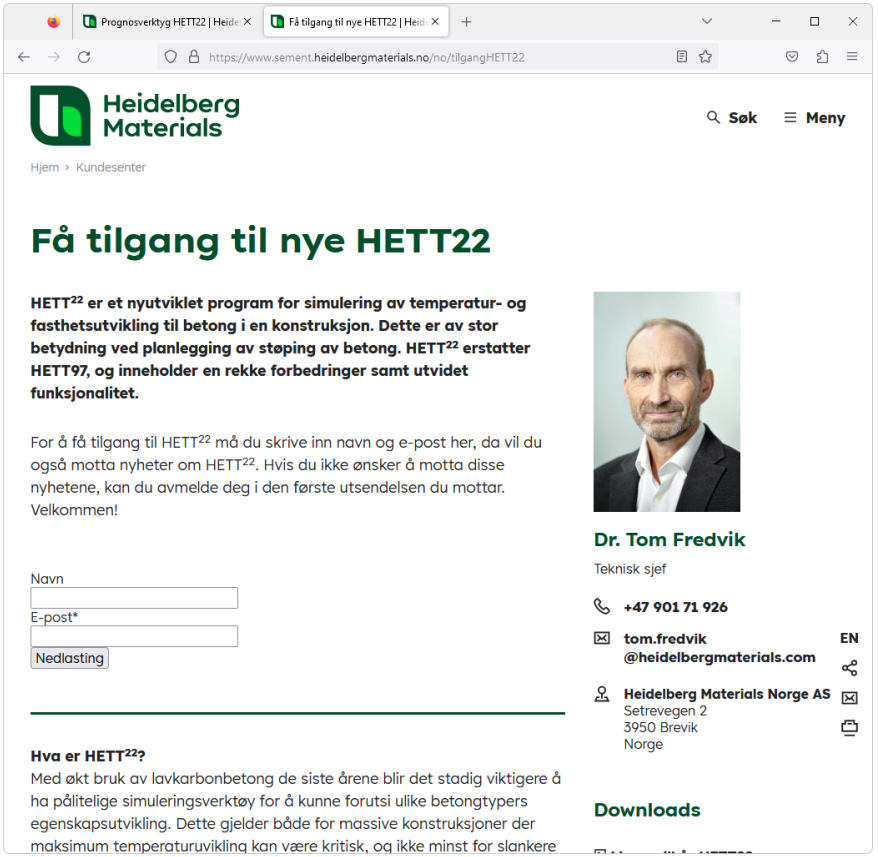
Installation

A powerful tool accessible to contractors



Download the Installer





www.cement.heidelbergmaterials.se/sv/hett22

www.sement.heidelbergmaterials.no/no/tilgangHETT22

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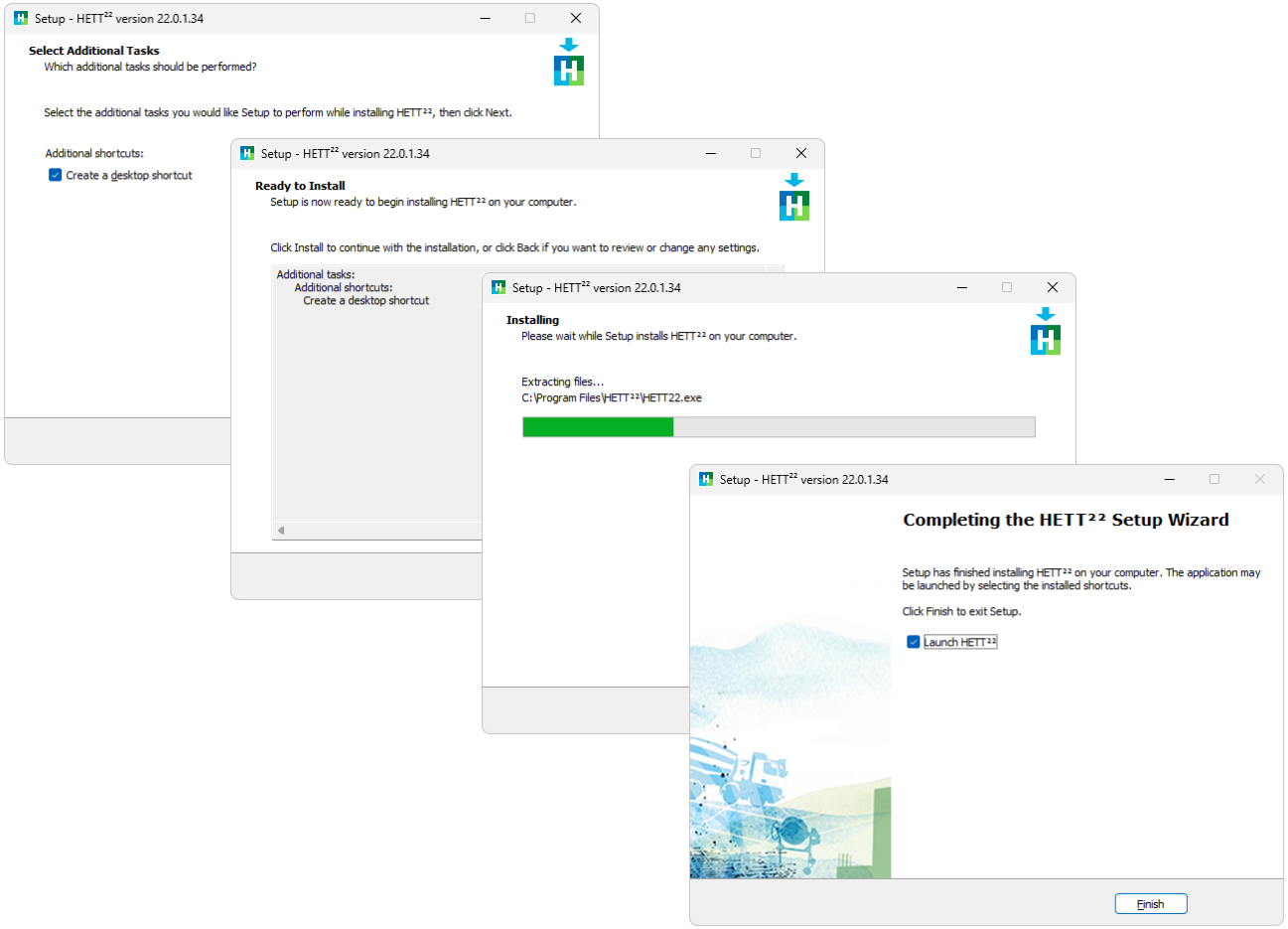
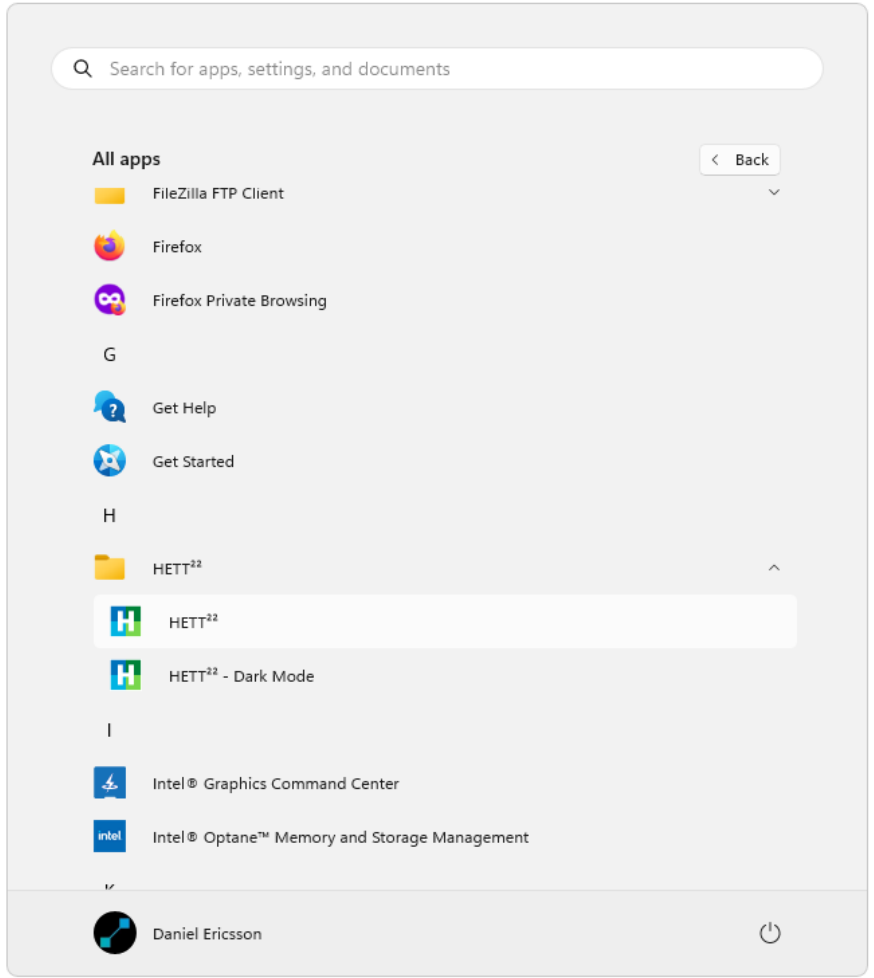
Run the Installer





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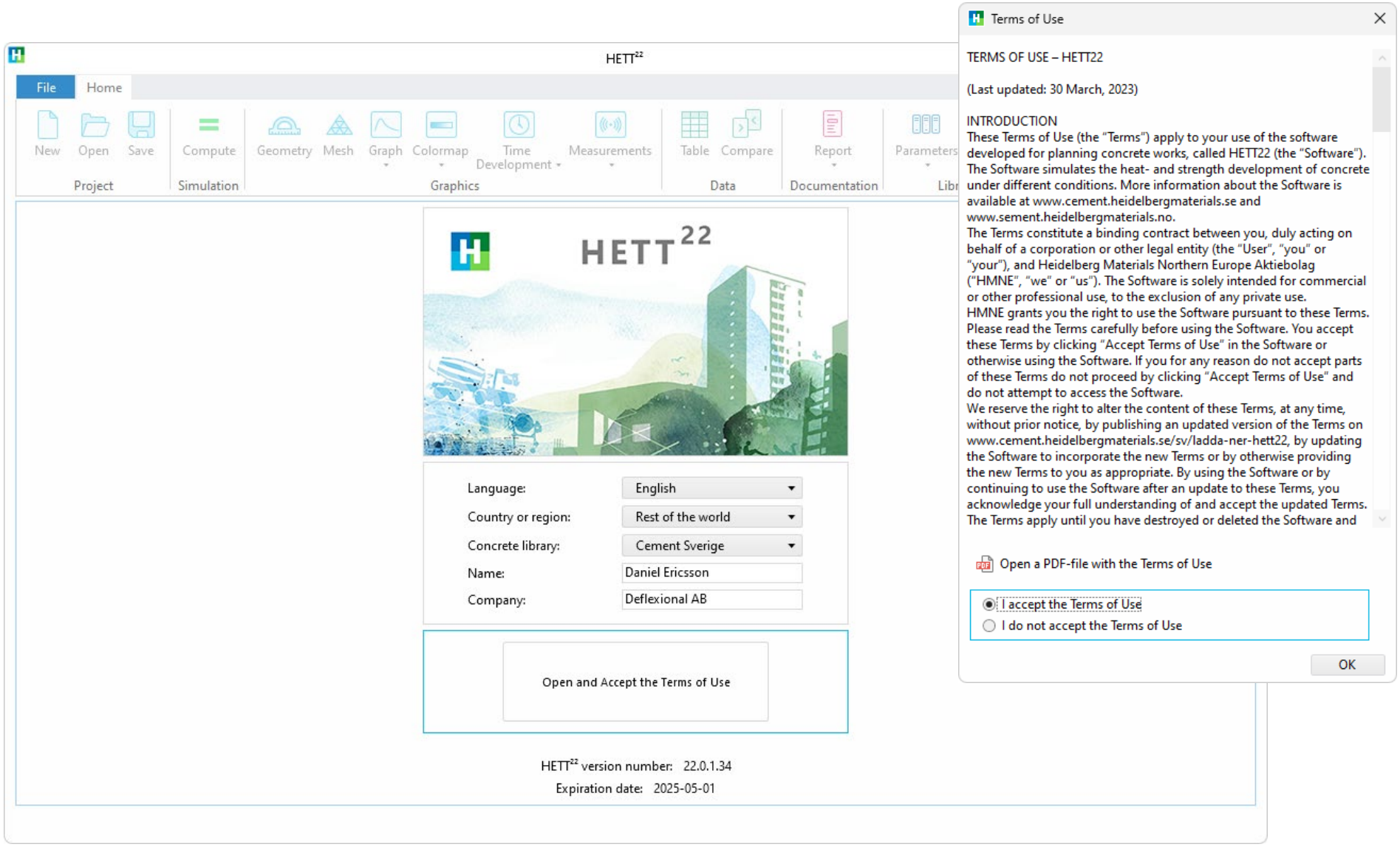
Splash Screen

If COMSOL Runtime™ is not already installed, it will be automatically downloaded

Terms of Use



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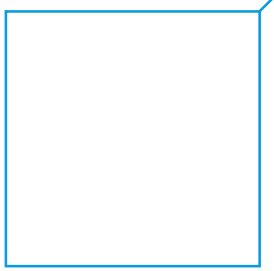
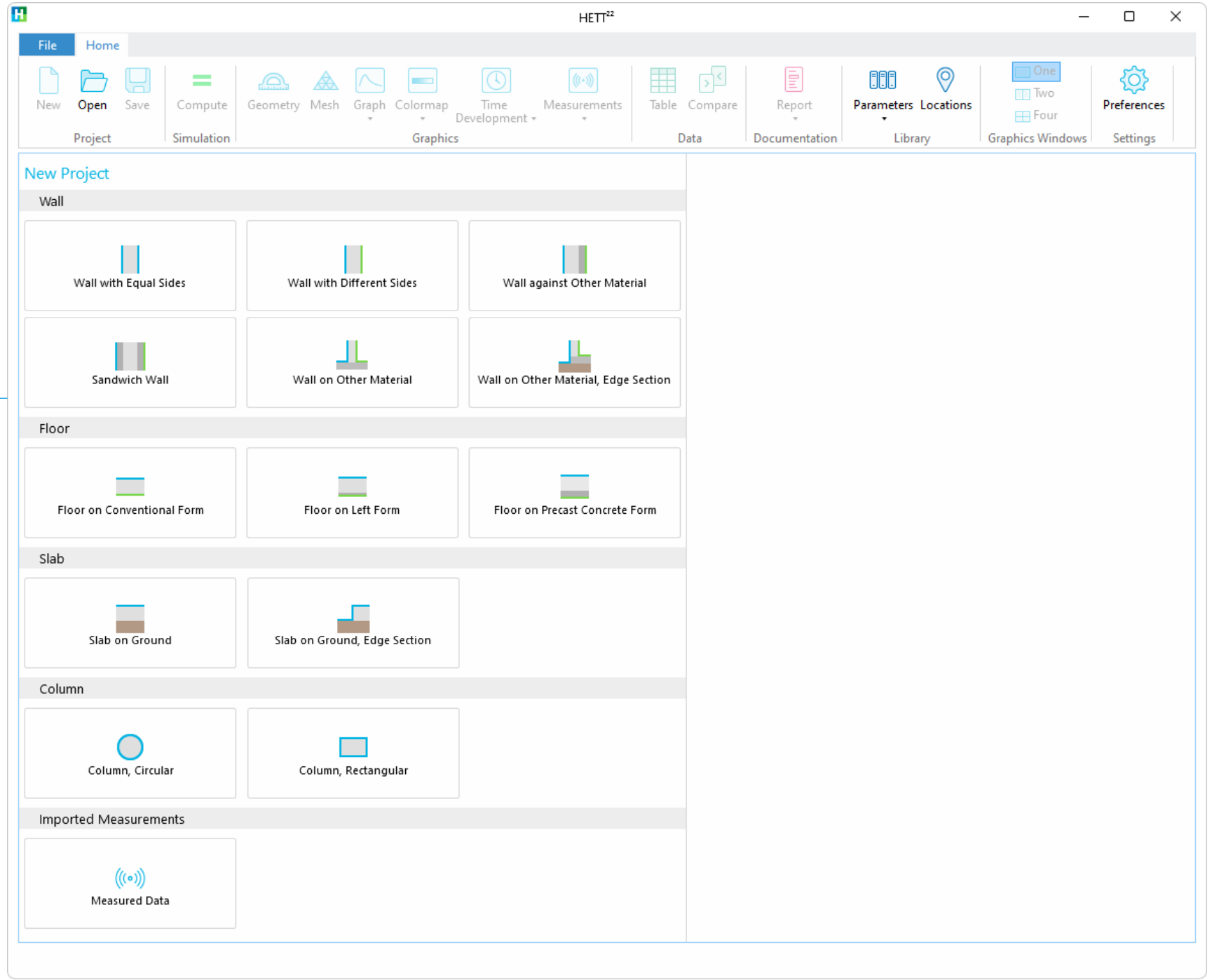
The Graphical User Interface

Equipped with pre-defined construction scenarios



Select case



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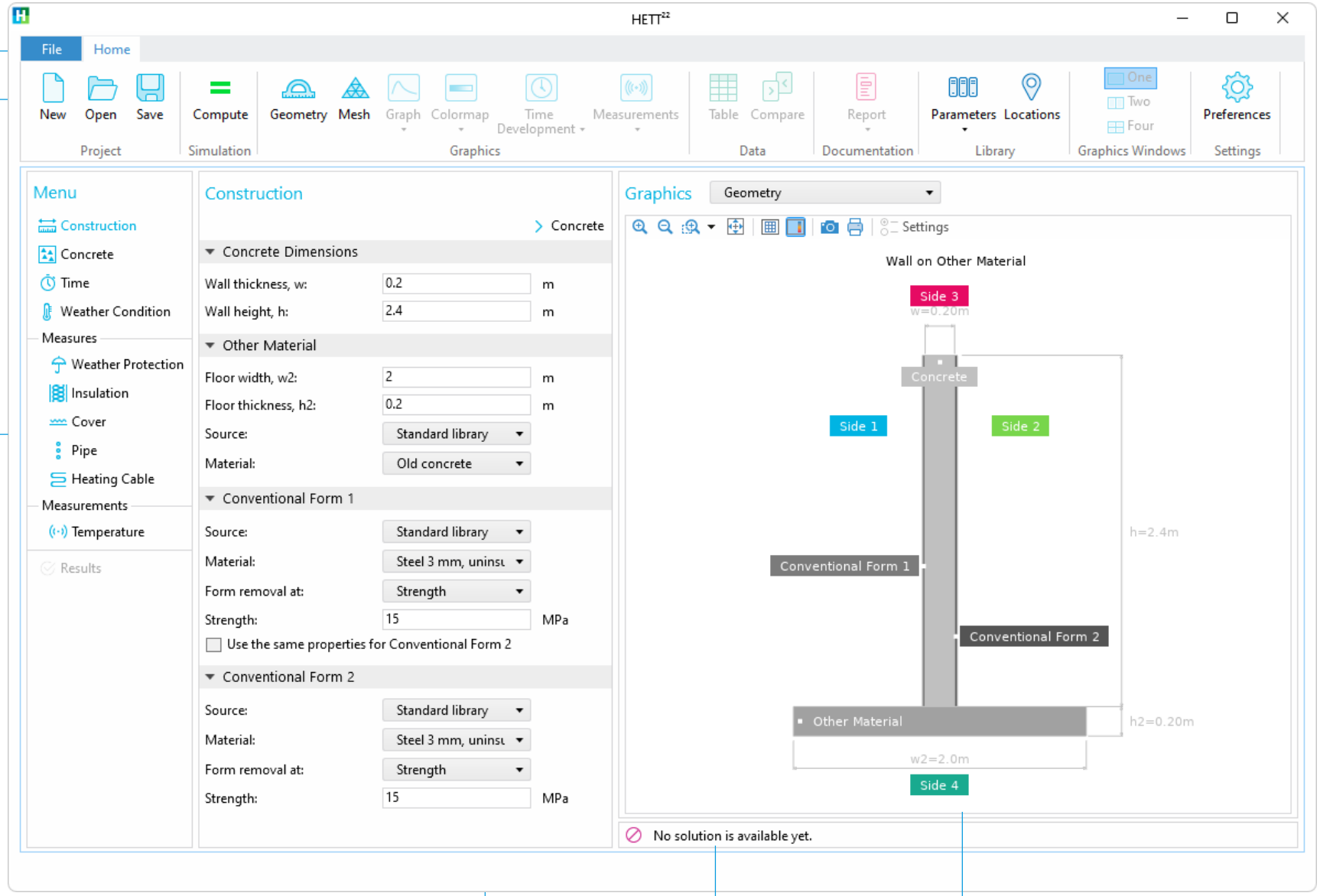
File Menu

Ribbon

Navigation



Settings

Status

Graphics

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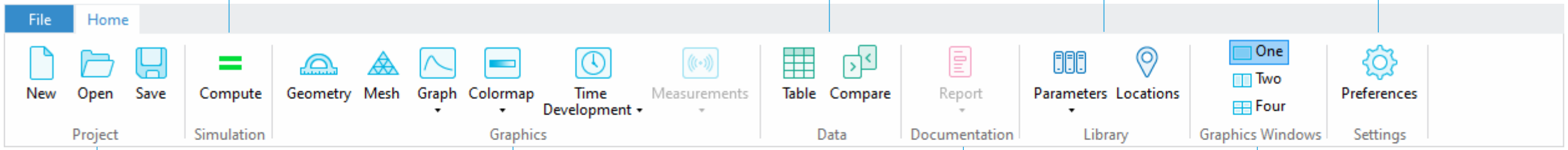
Ribbon

Compute

Results as numerical data

Standard libraries and user libraries

User preferences



Create a new project, save, and open

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

Microsoft® Word® and Microsoft® PowerPoint® reports

Number of concurrent graphics windows

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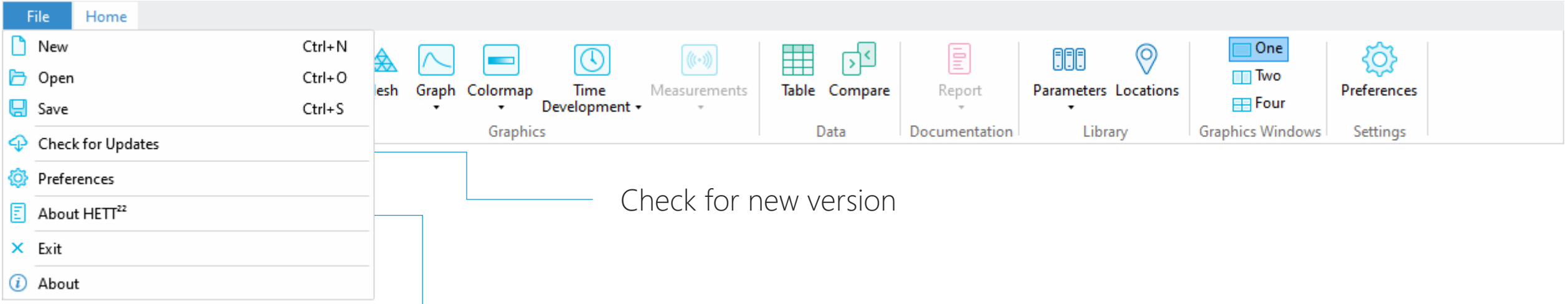
File Menu



Check for new version

License information

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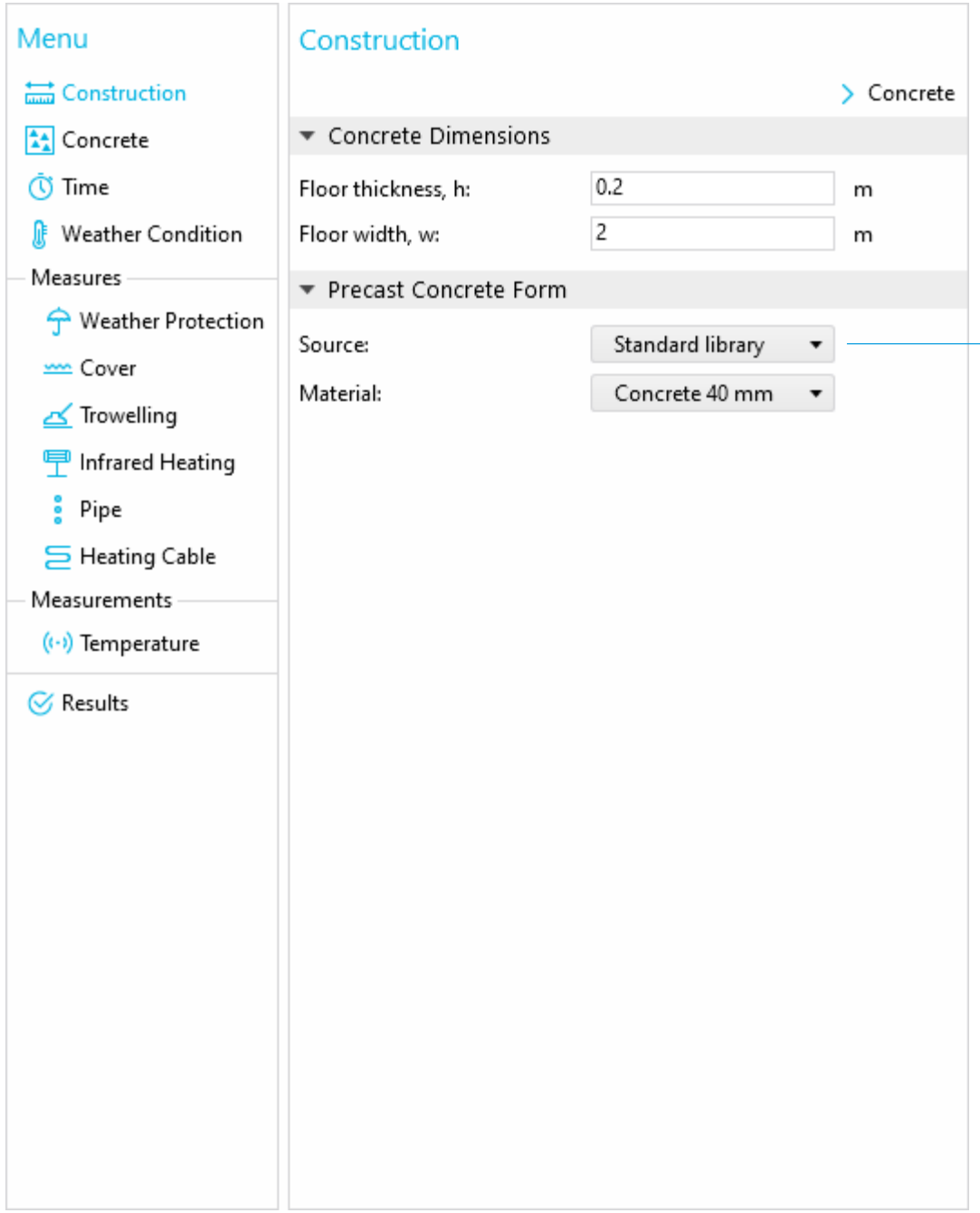
Navigation

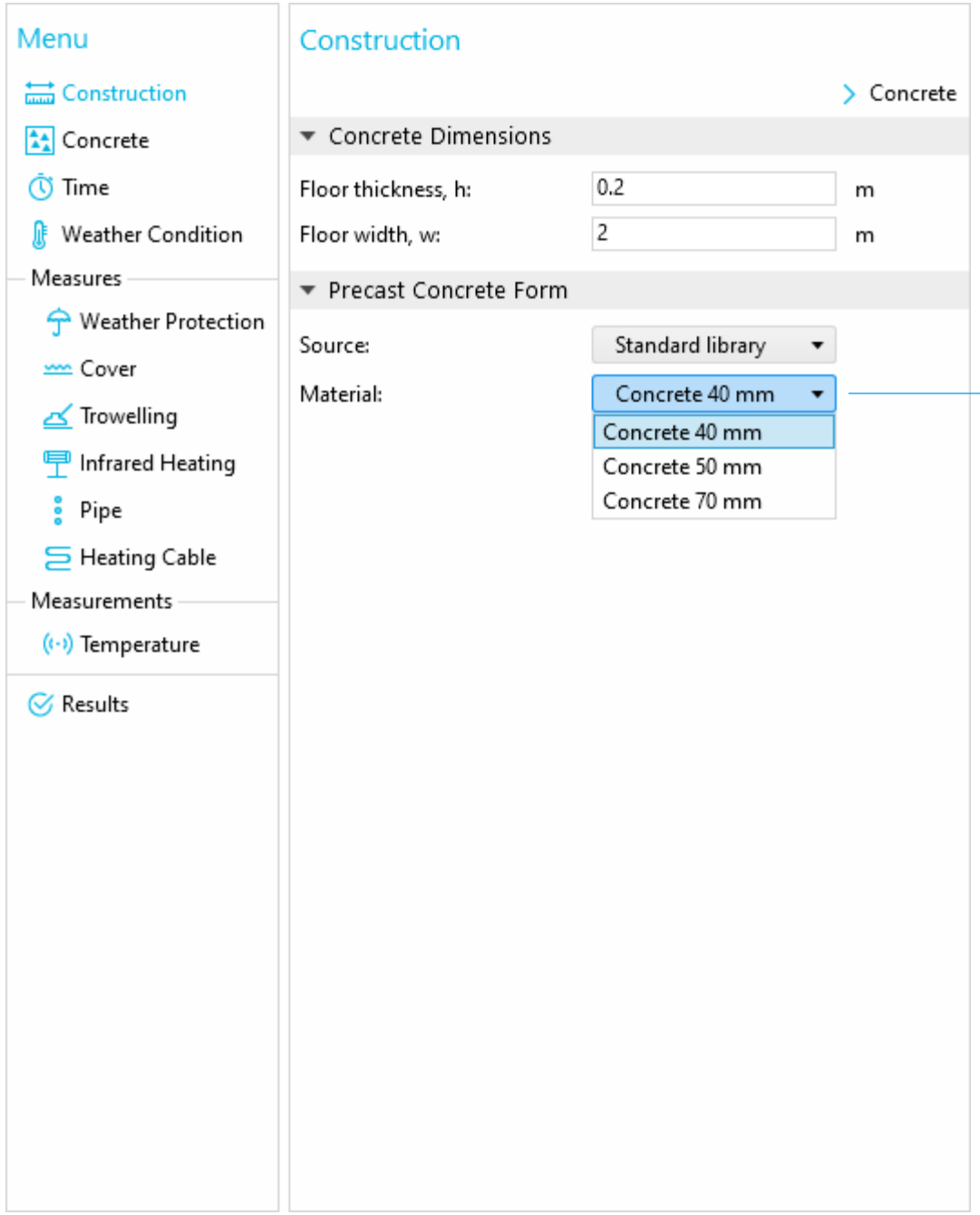
Construction



Standard library

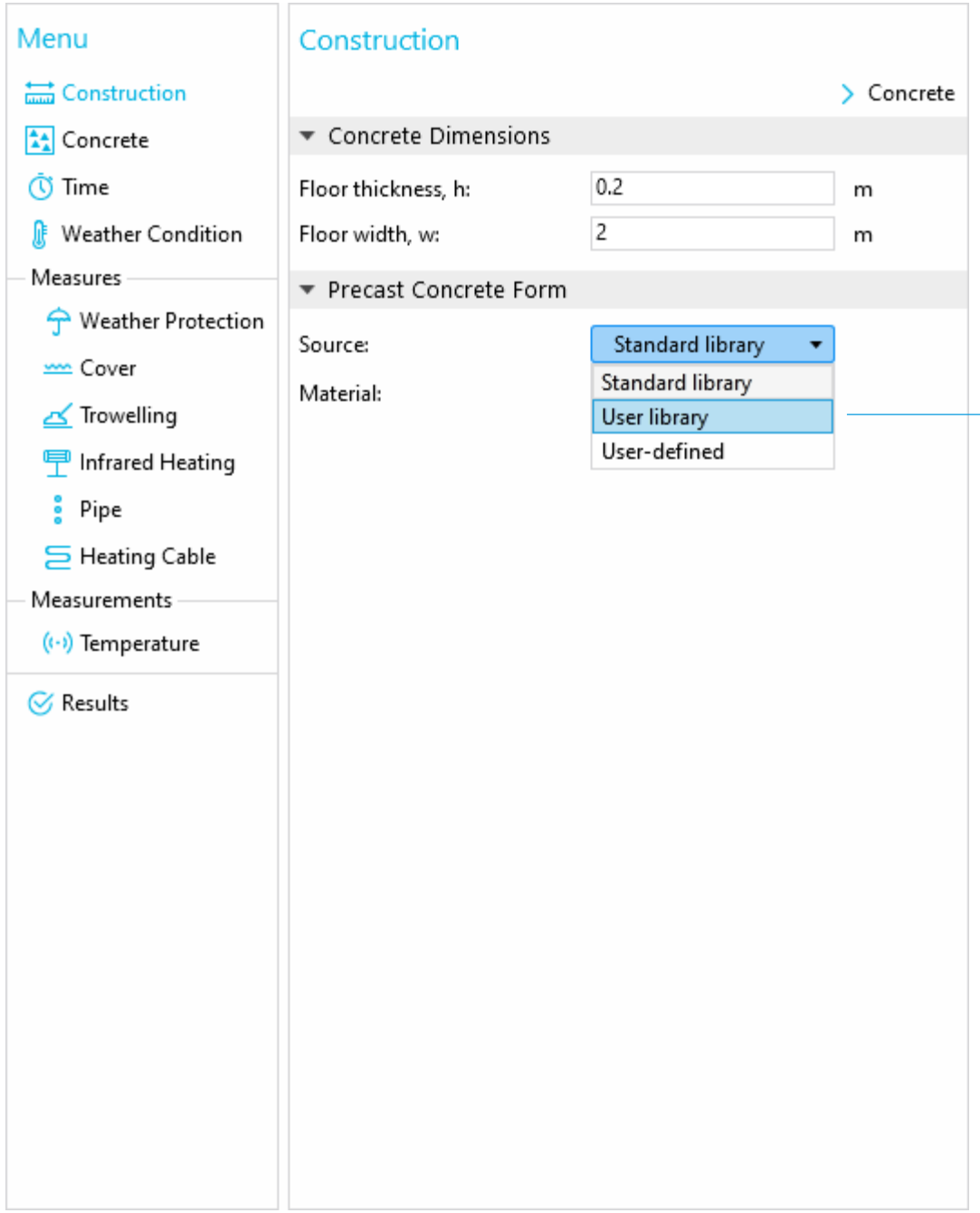
Navigation

Construction



Navigation

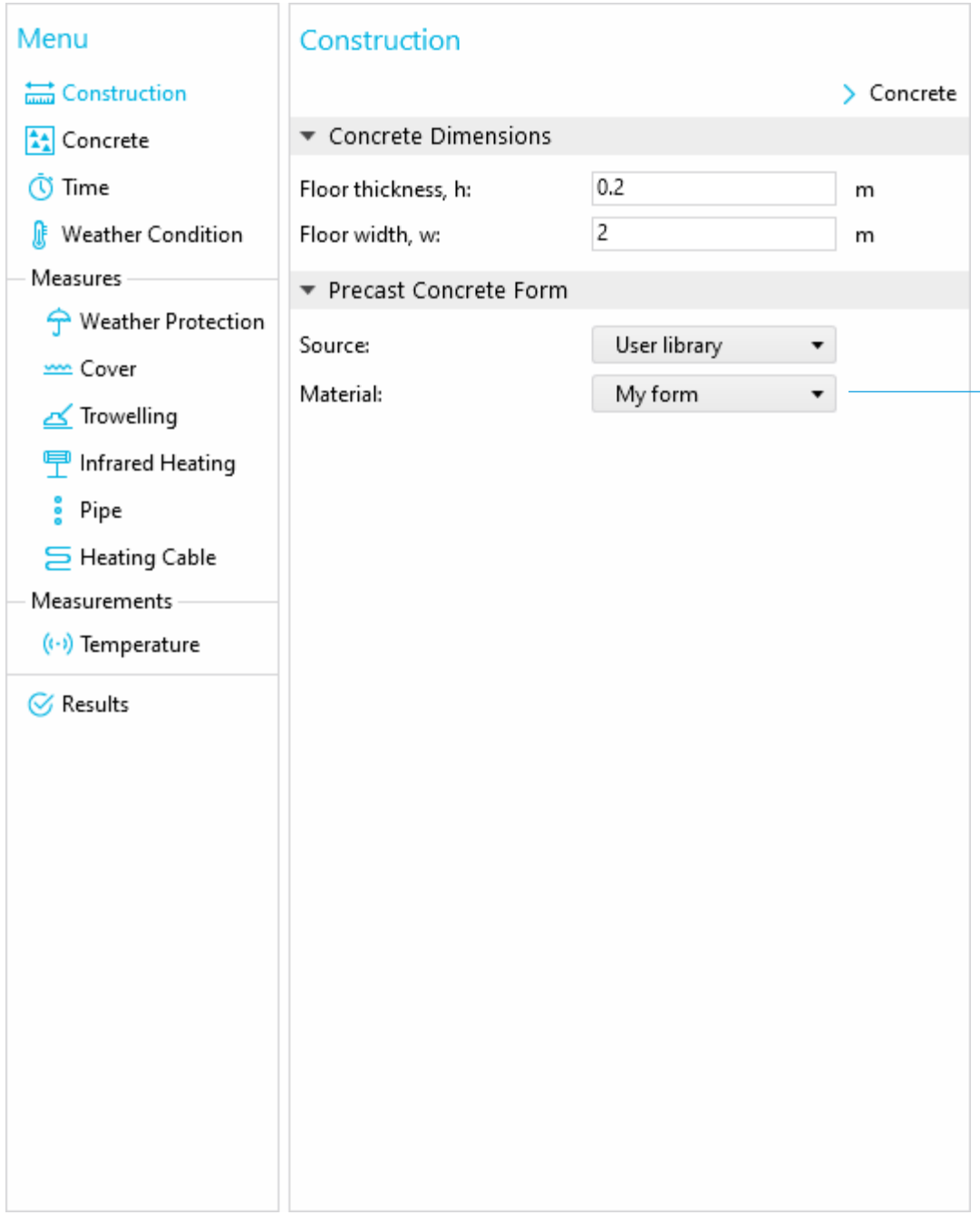
Construction



User library

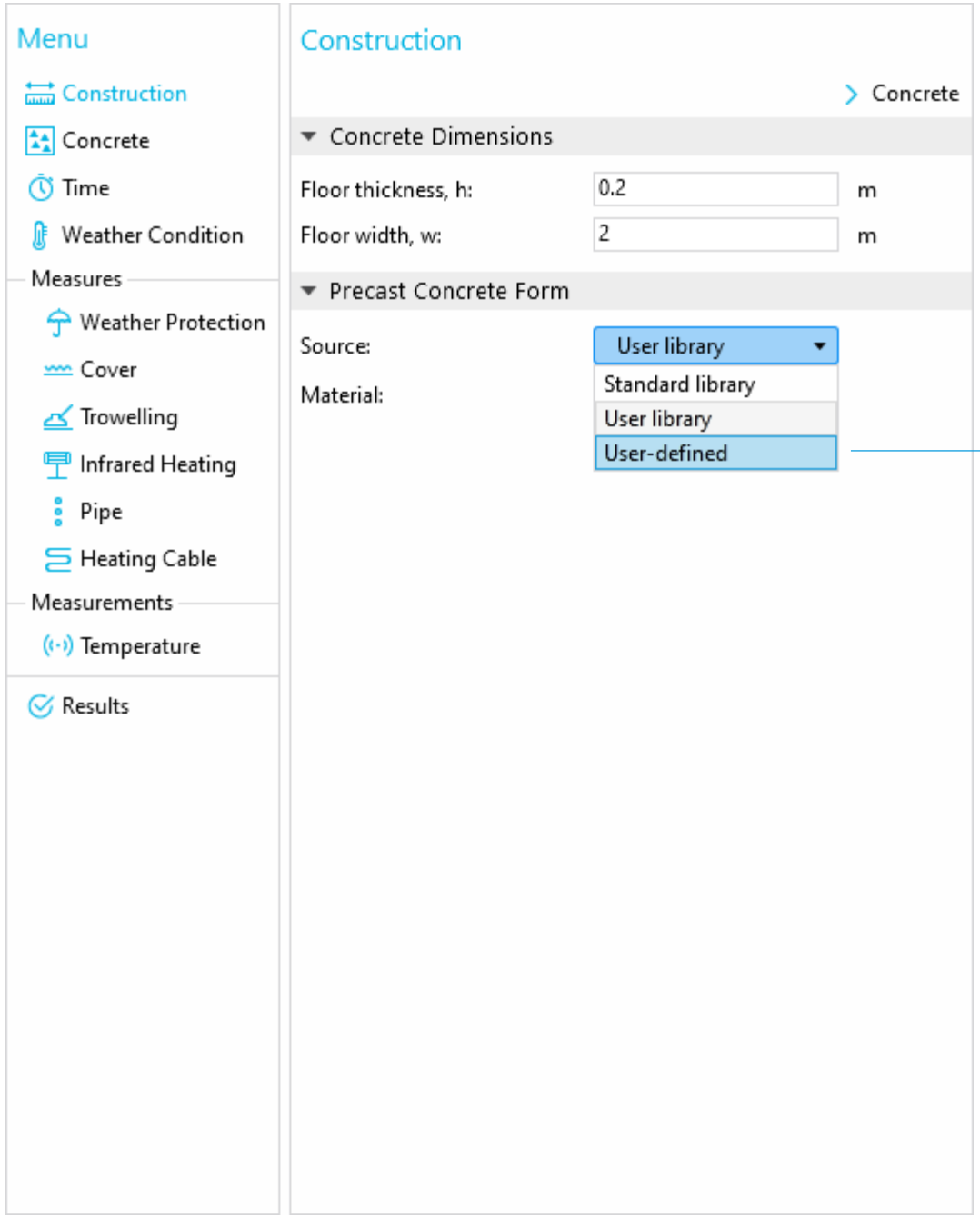
Navigation

Construction



Navigation

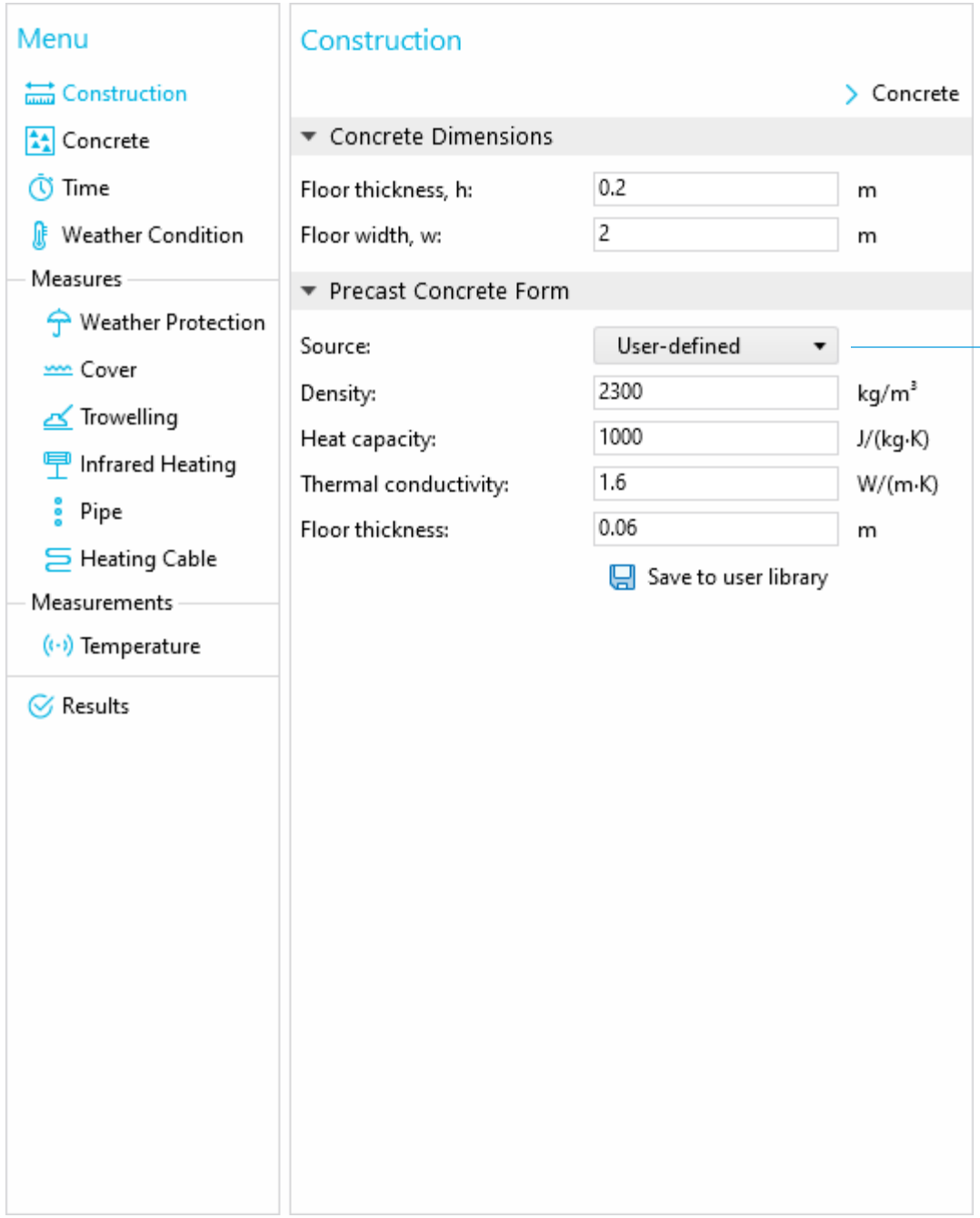
Construction



User-defined

Navigation

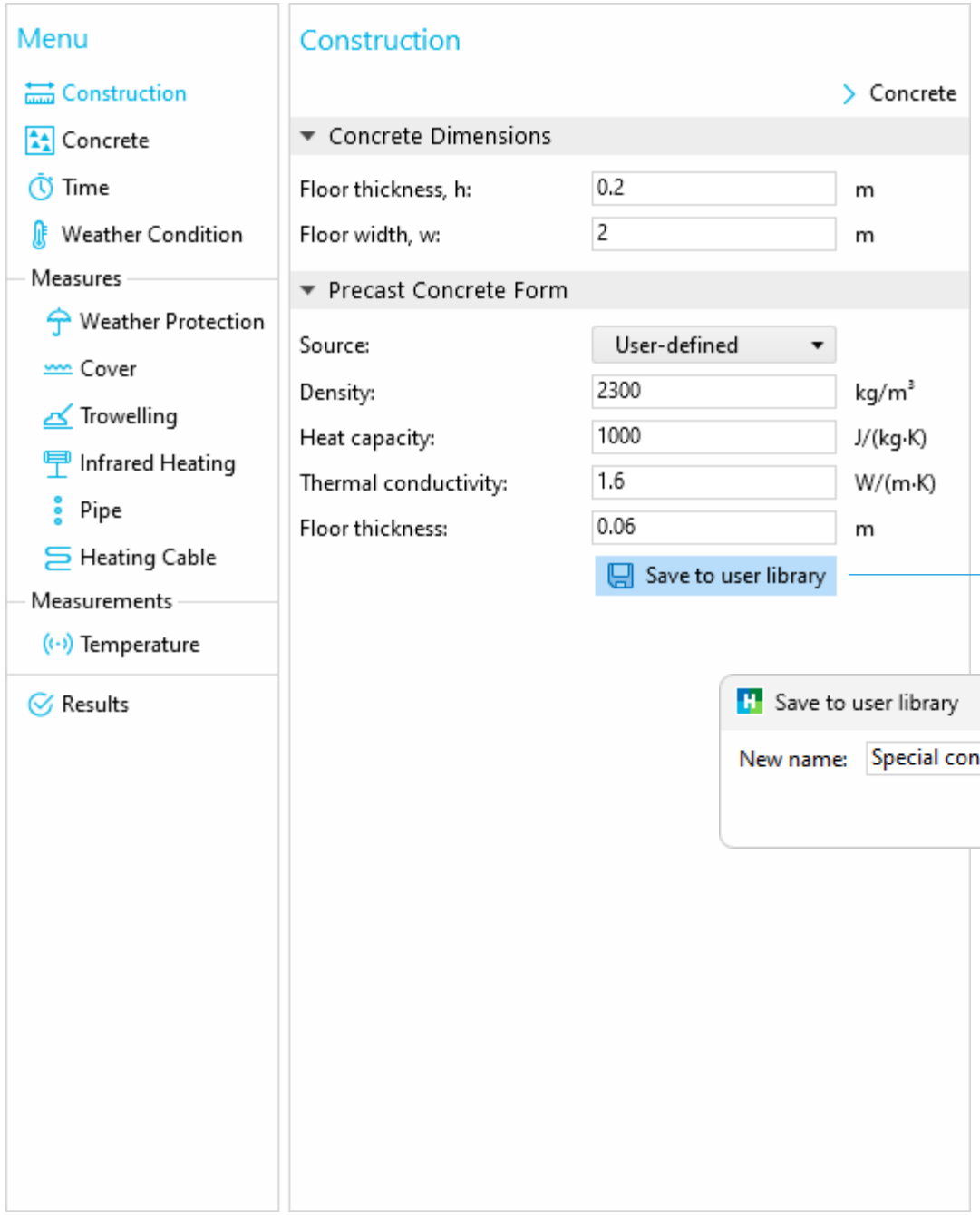
Construction



User-defined

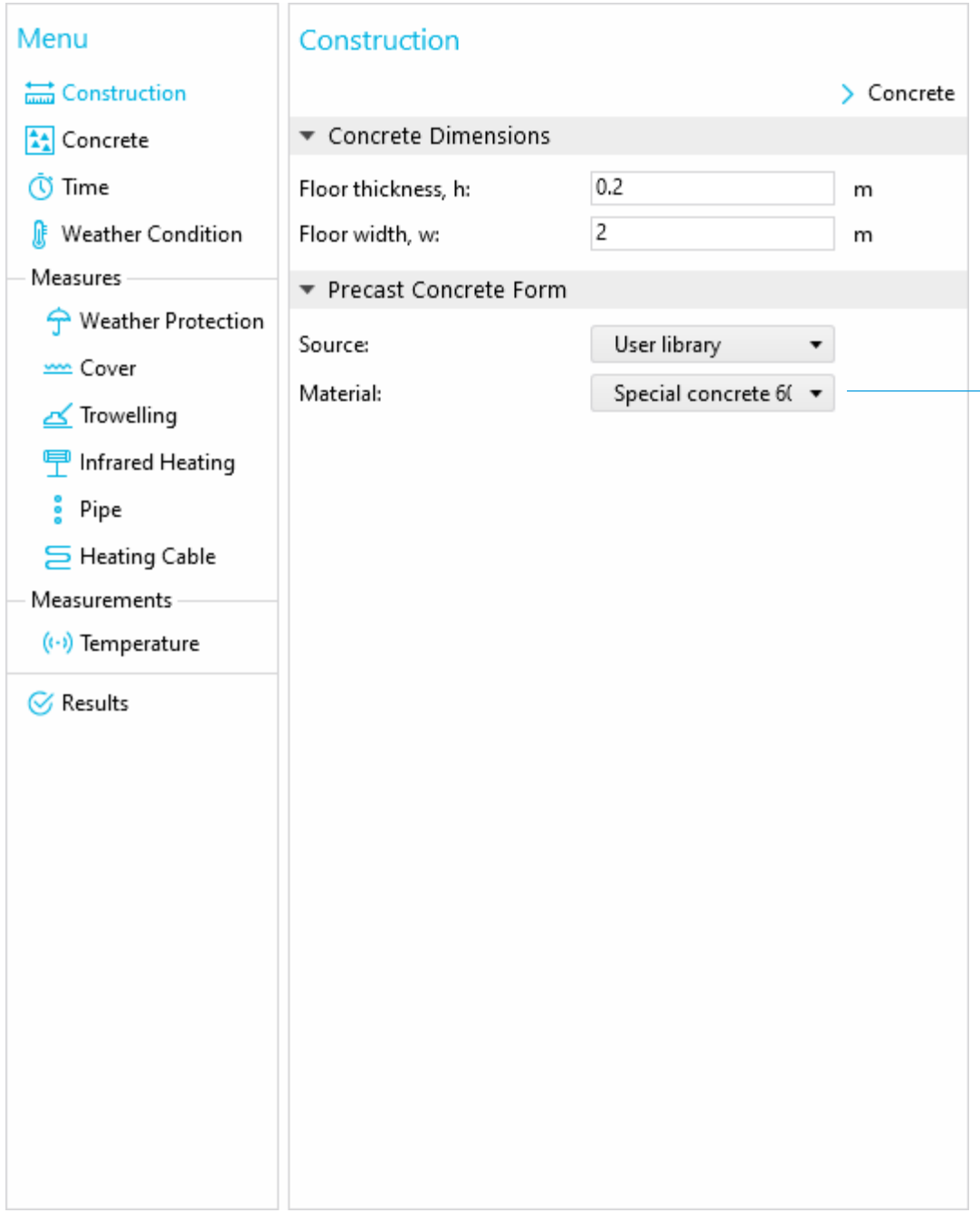
Navigation

Construction



Navigation

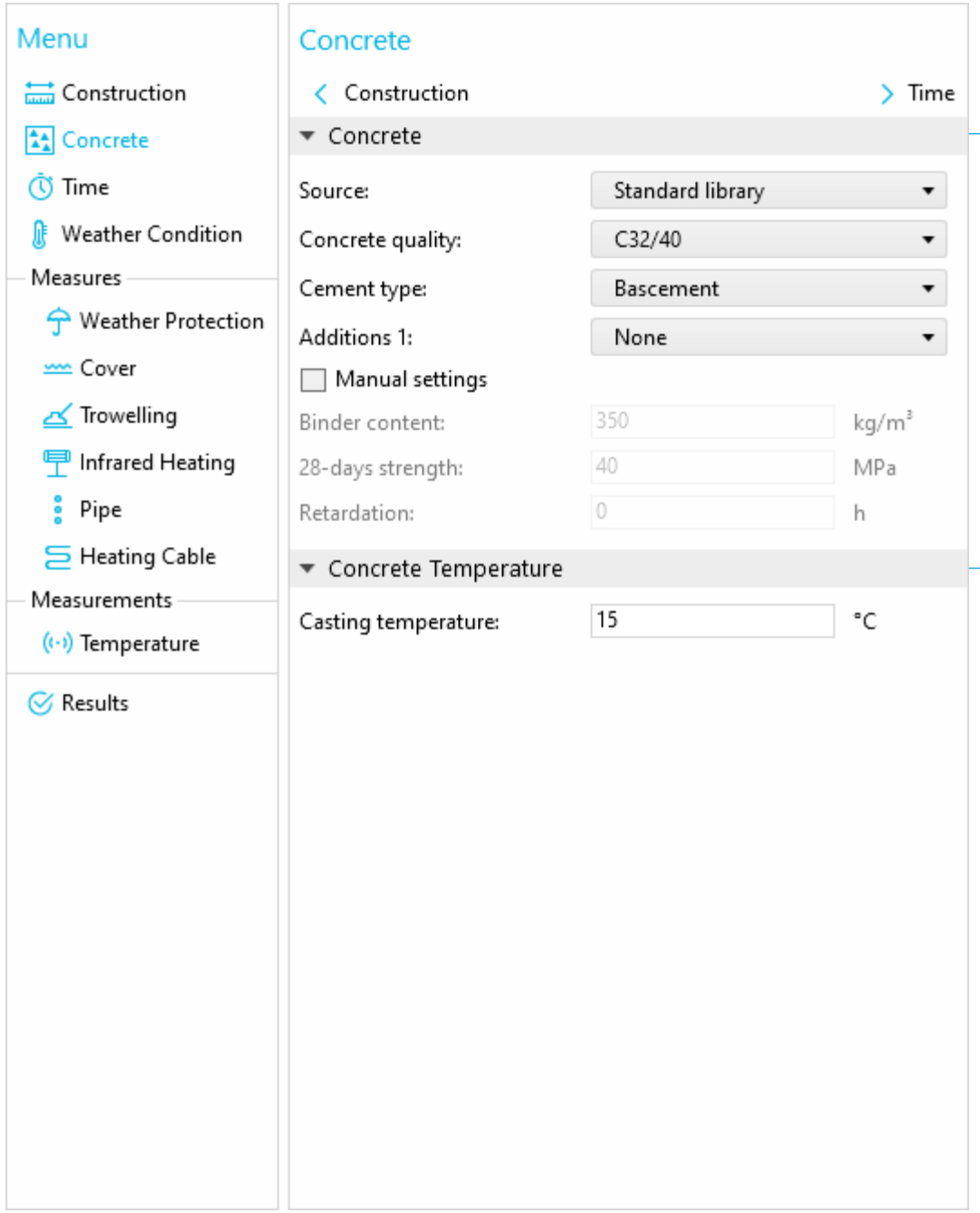
Construction



Saved material

Navigation

Concrete



Select concrete

Temperature

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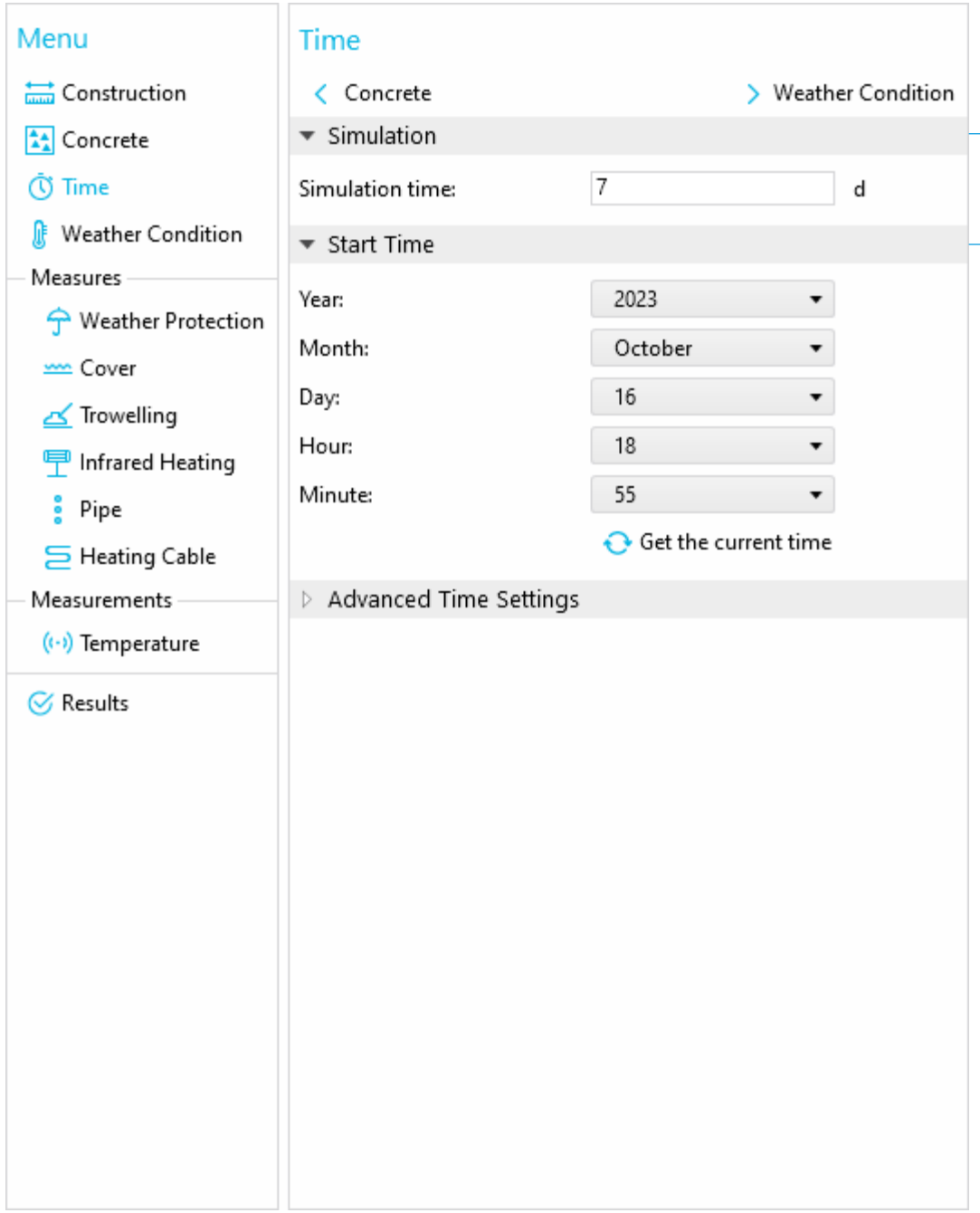
Navigation

Time



Simulation time

Start time

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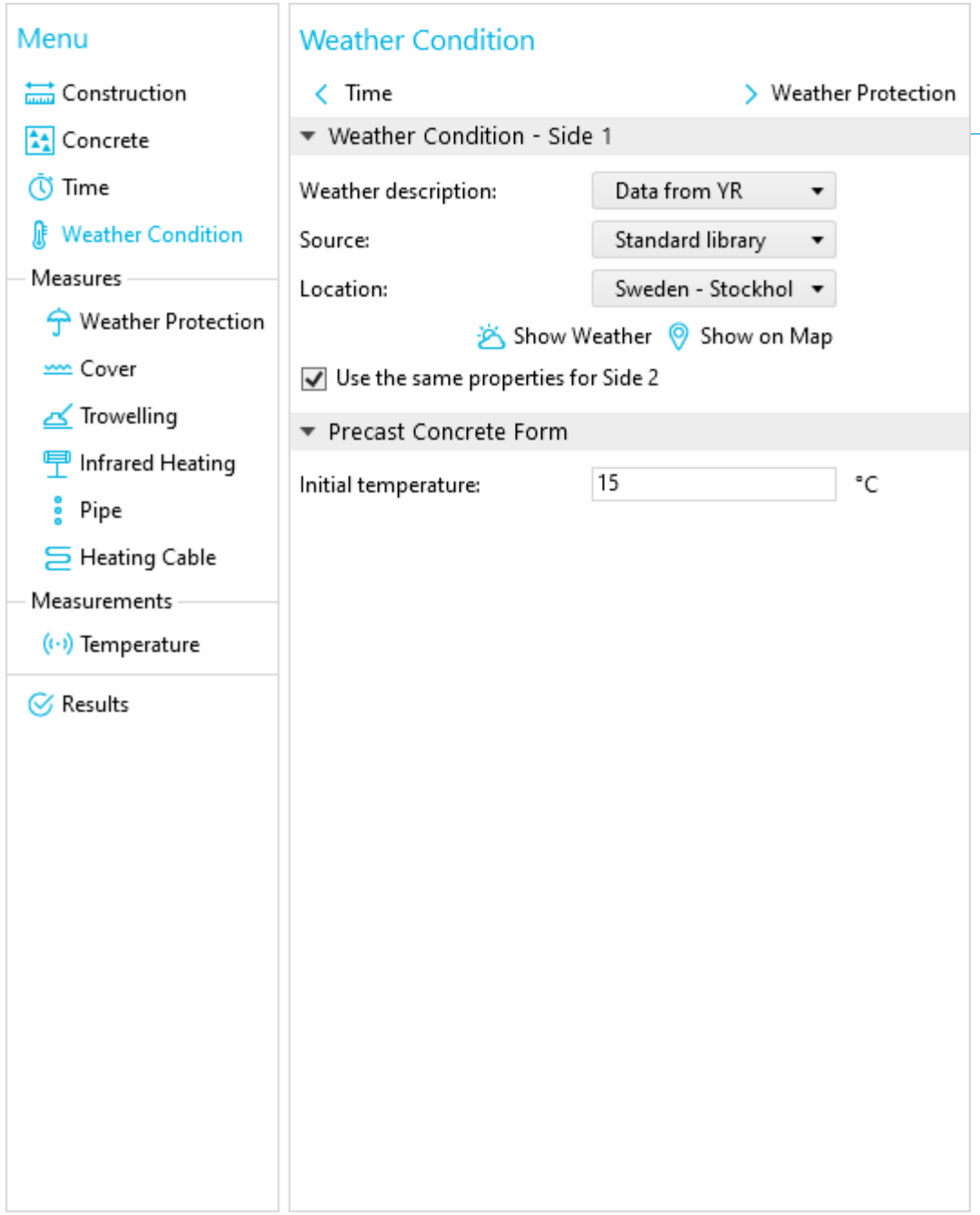
Navigation

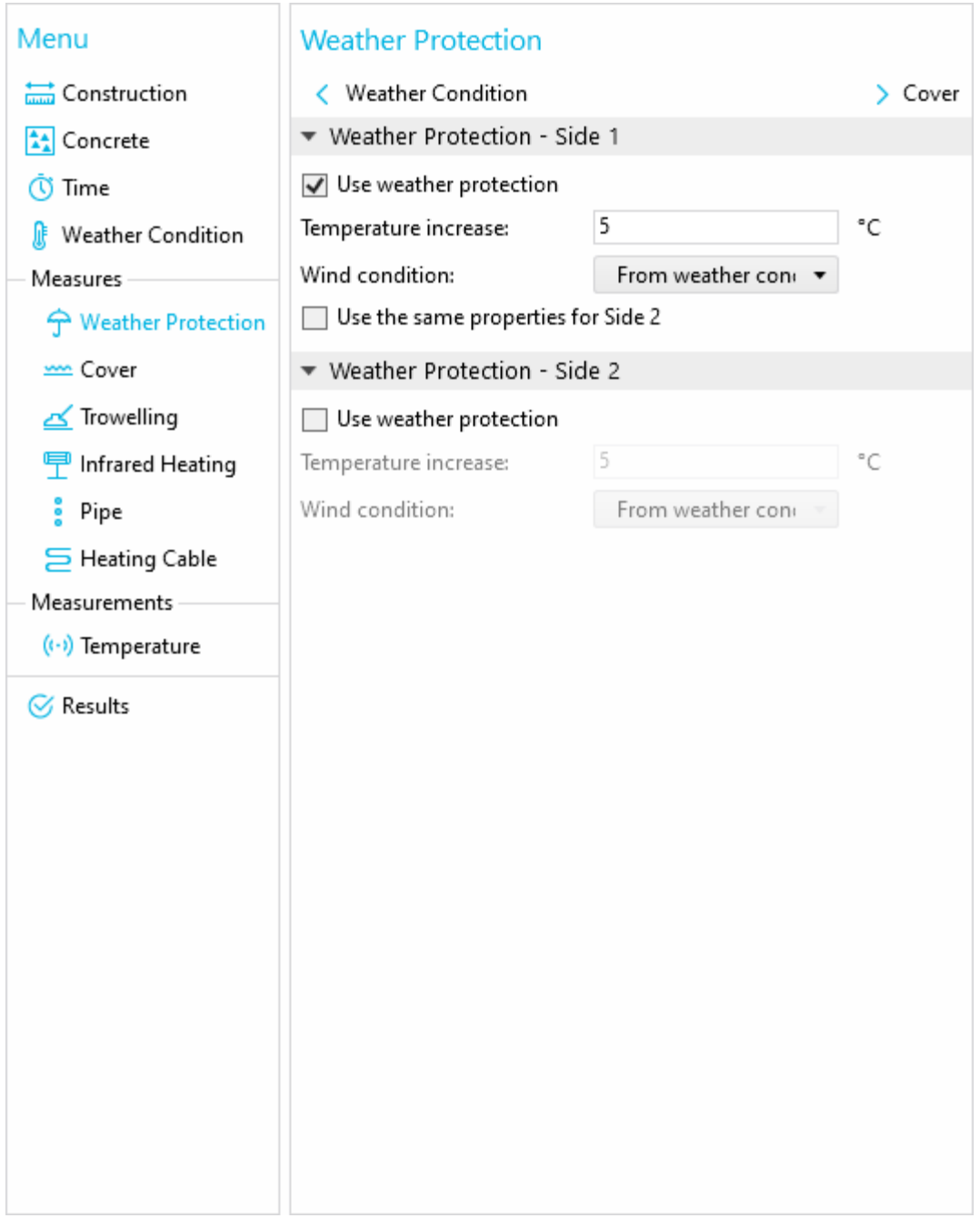
Weather Condition



Weather

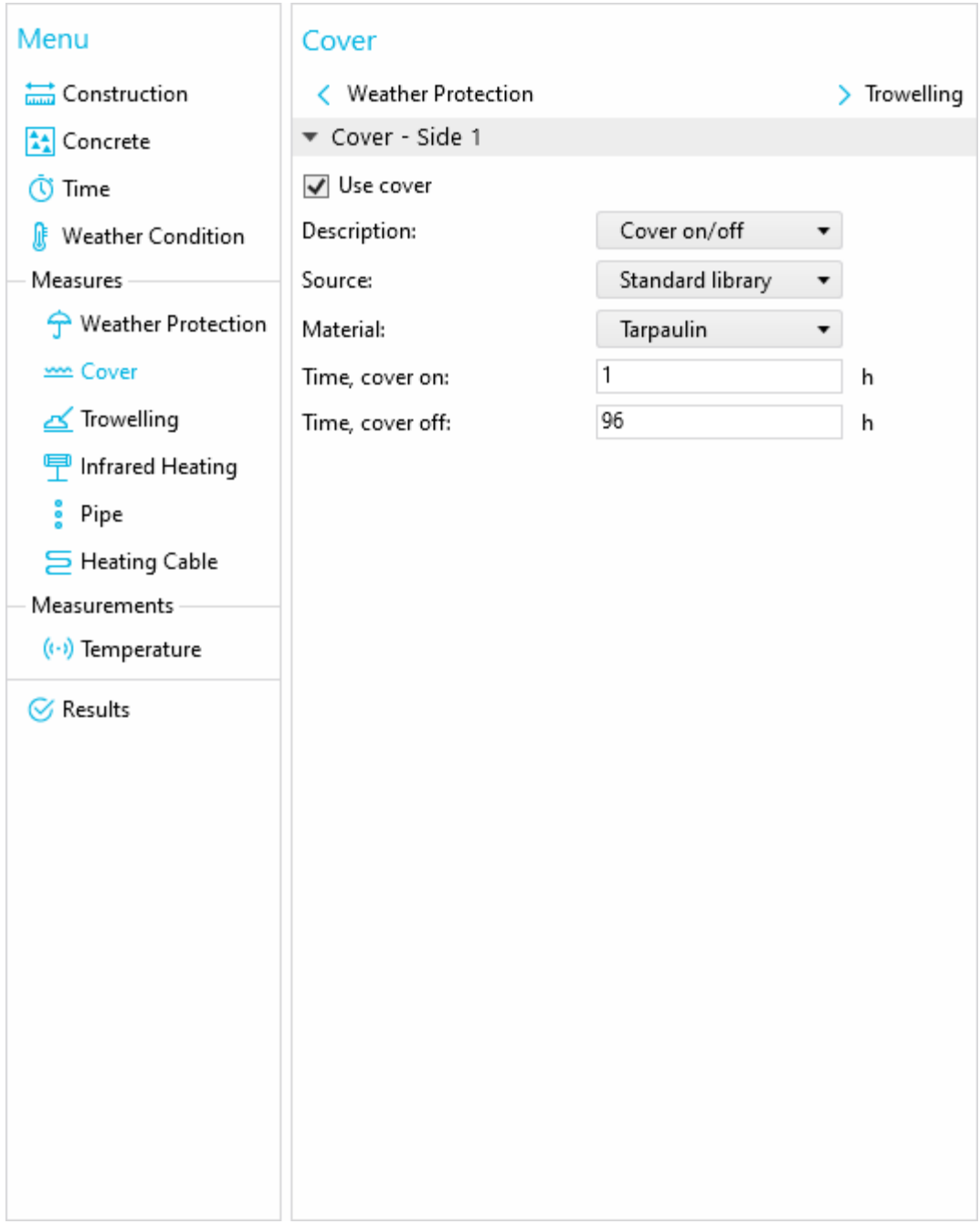
Navigation

Weather Protection



Navigation

Cover



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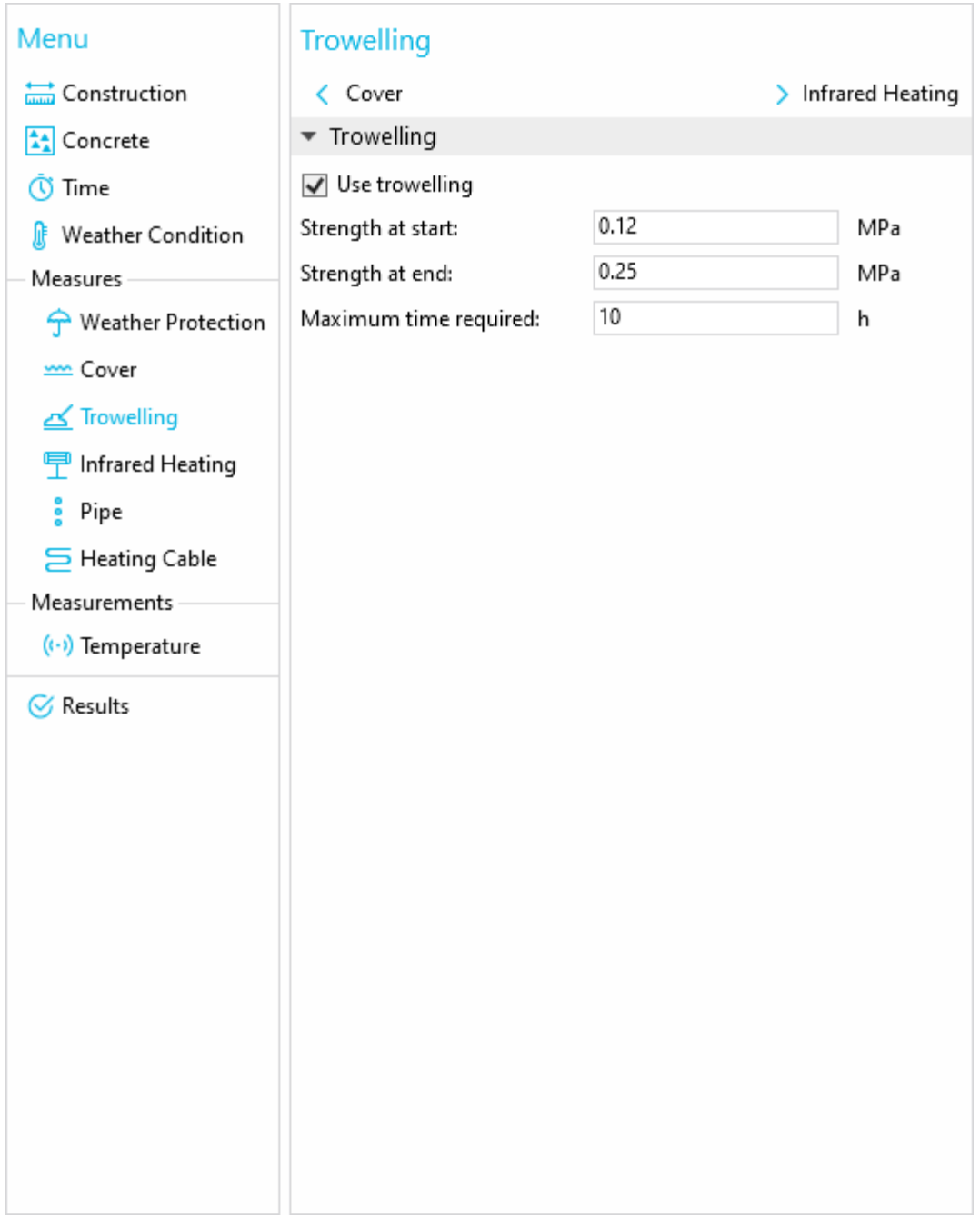
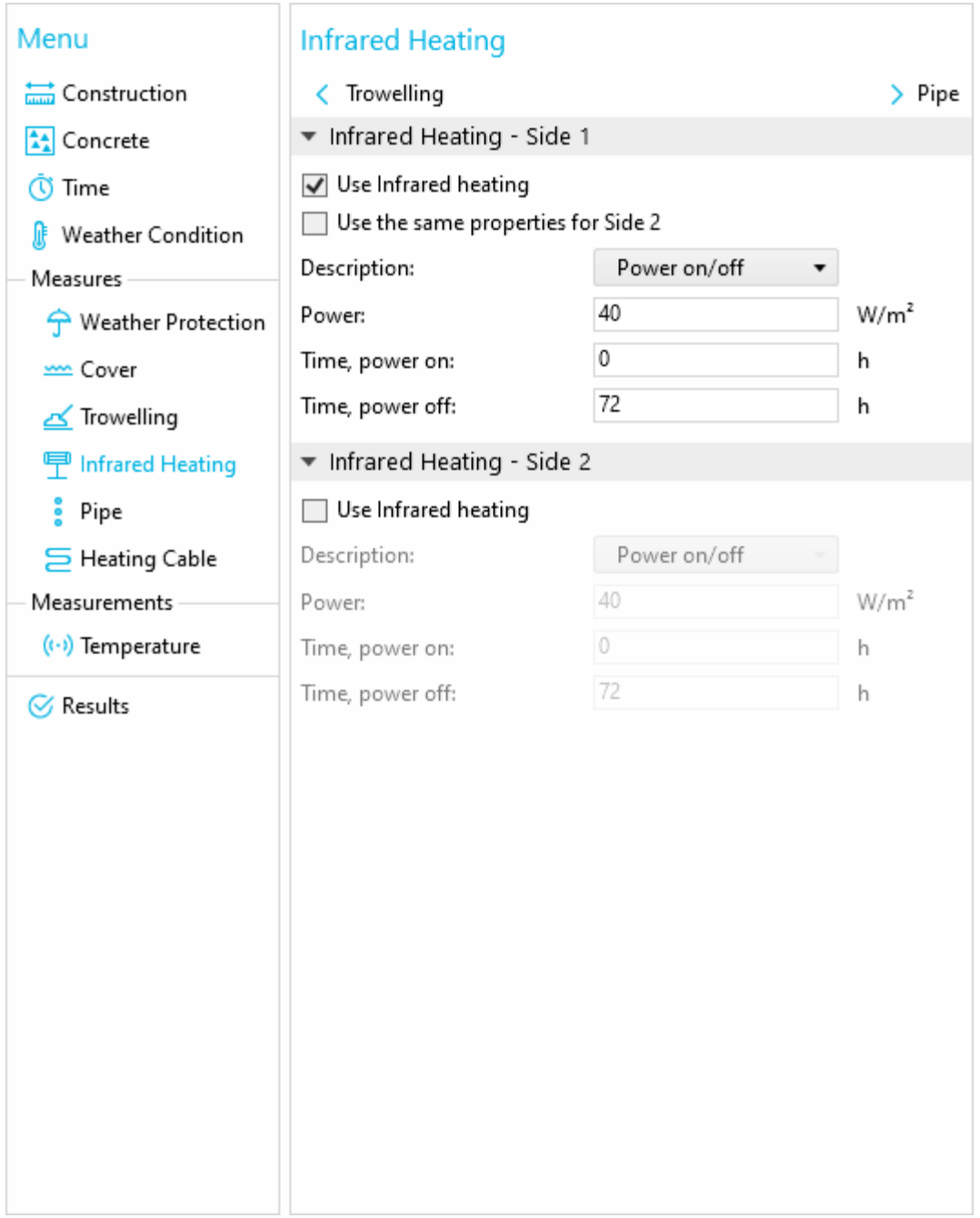
Navigation

Trowelling



Navigation

Infrared Heating



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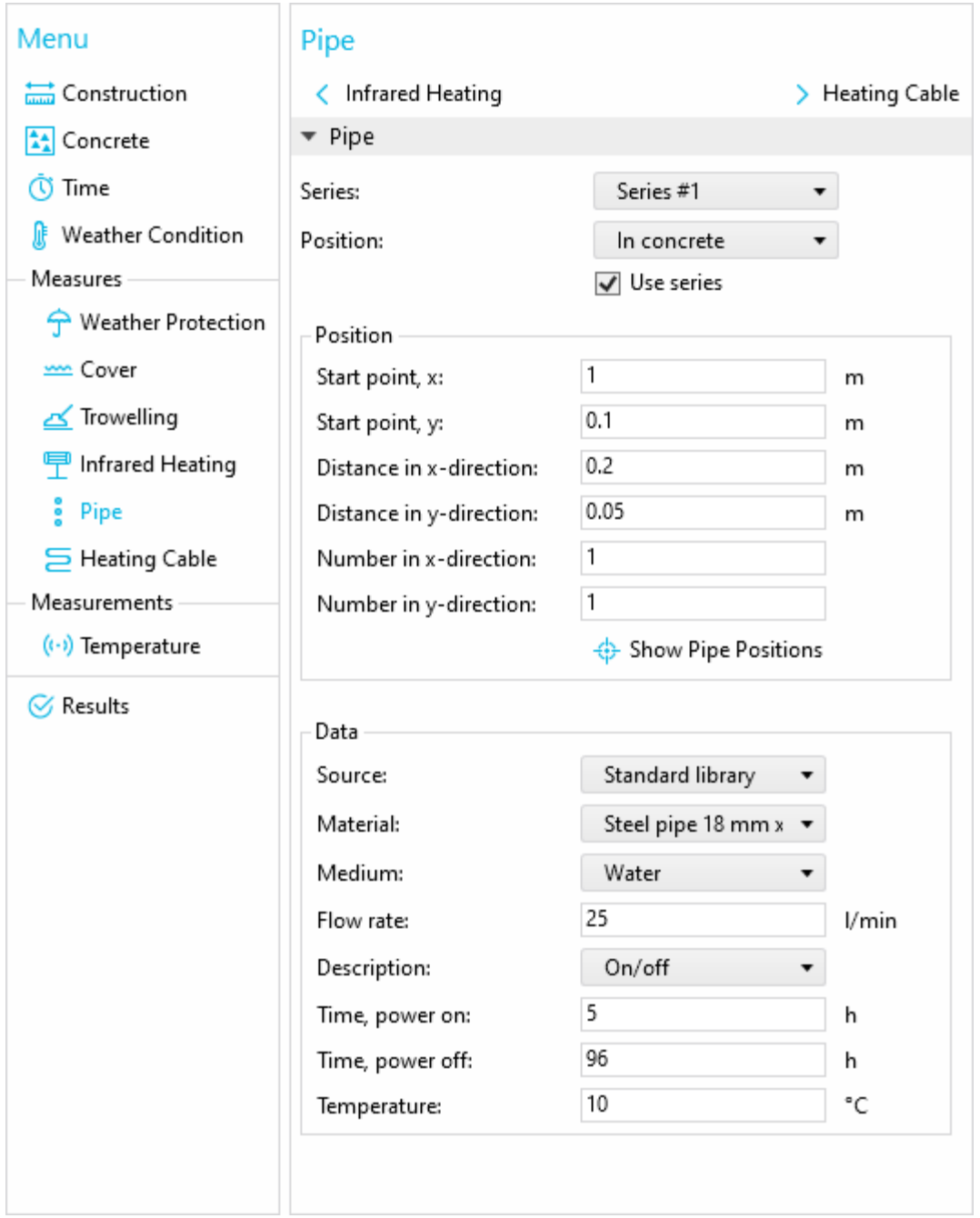
Navigation

Pipe



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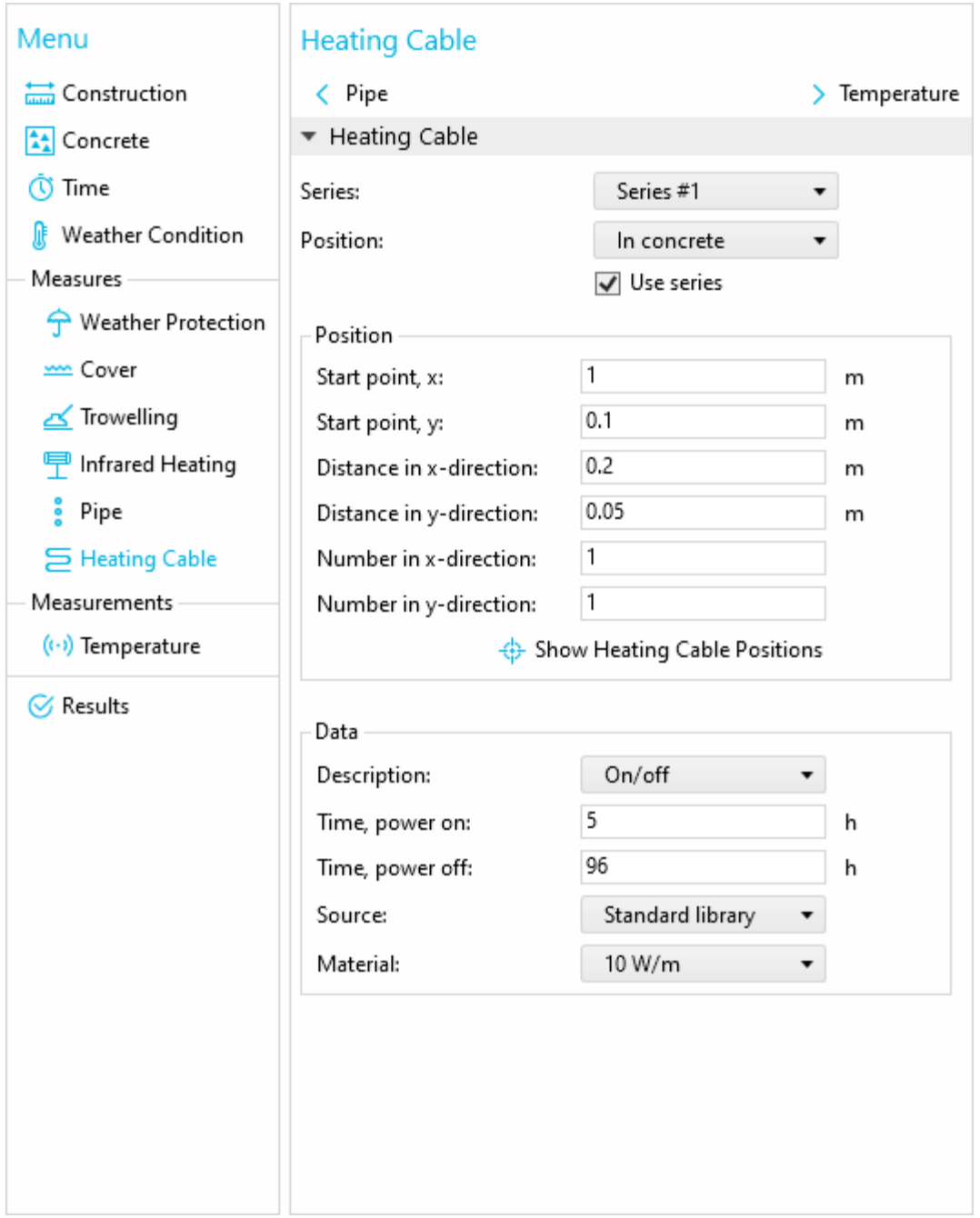
Navigation

Heating Cable



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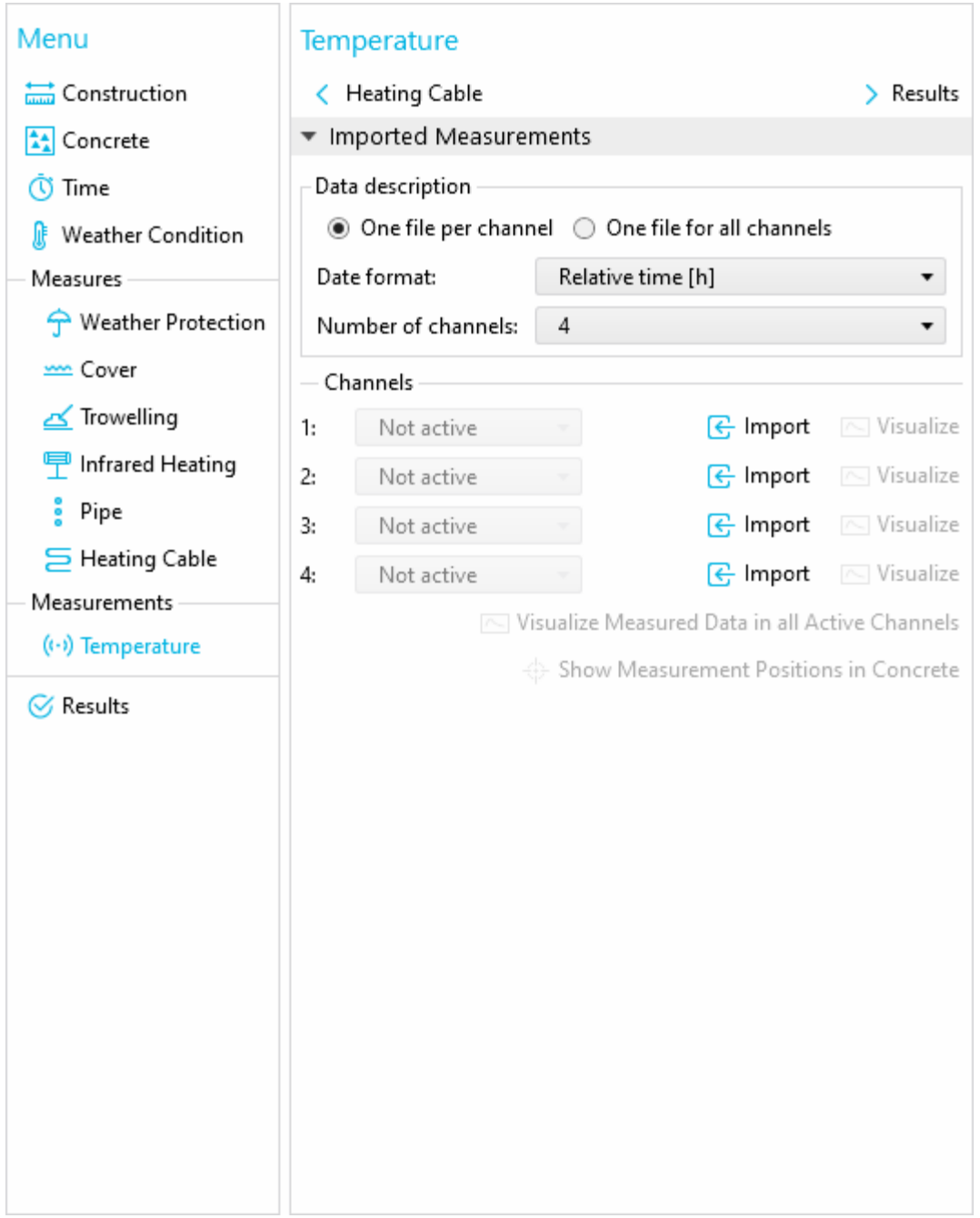
Navigation

Temperature



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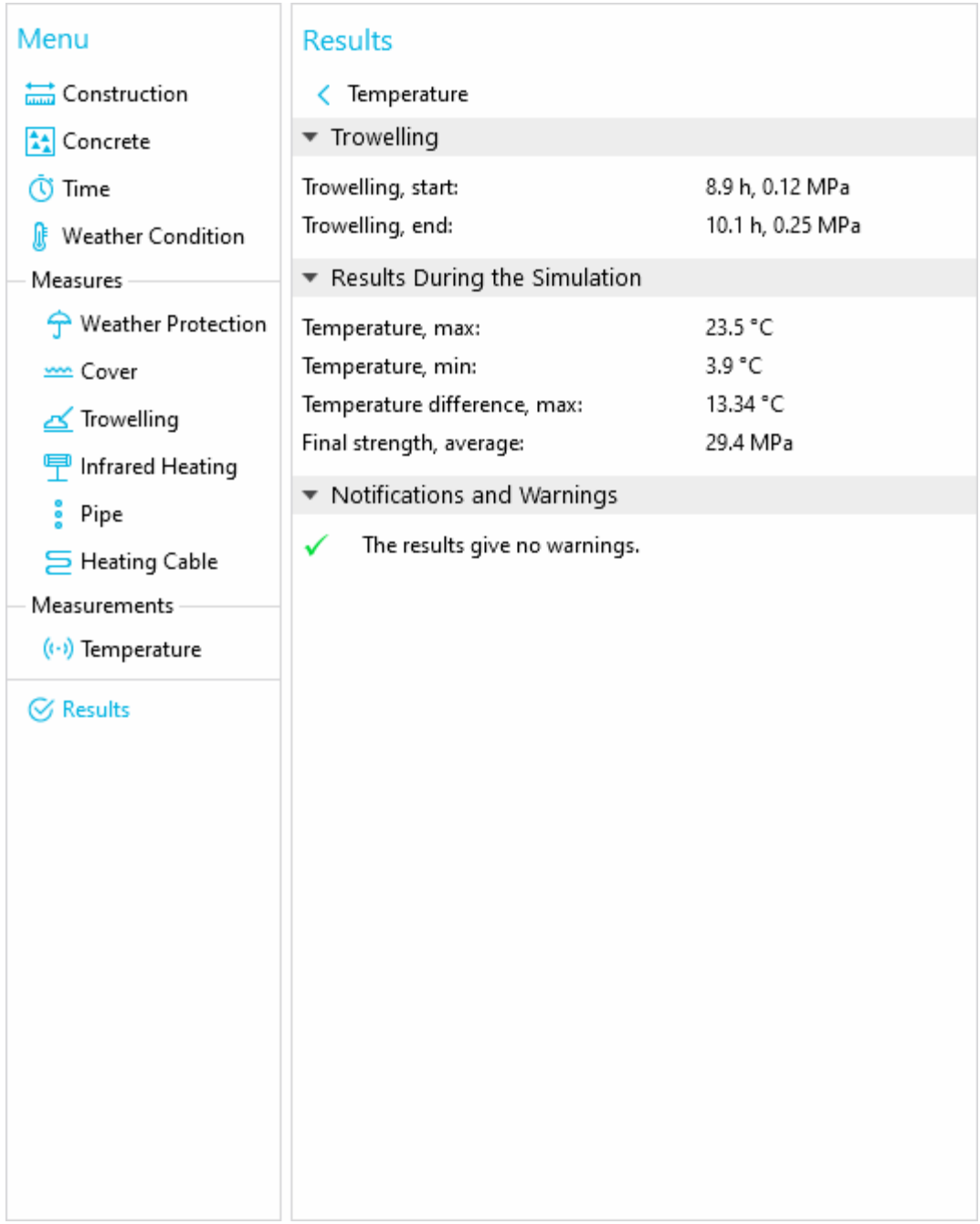
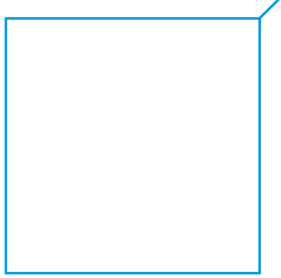
Navigation

Results



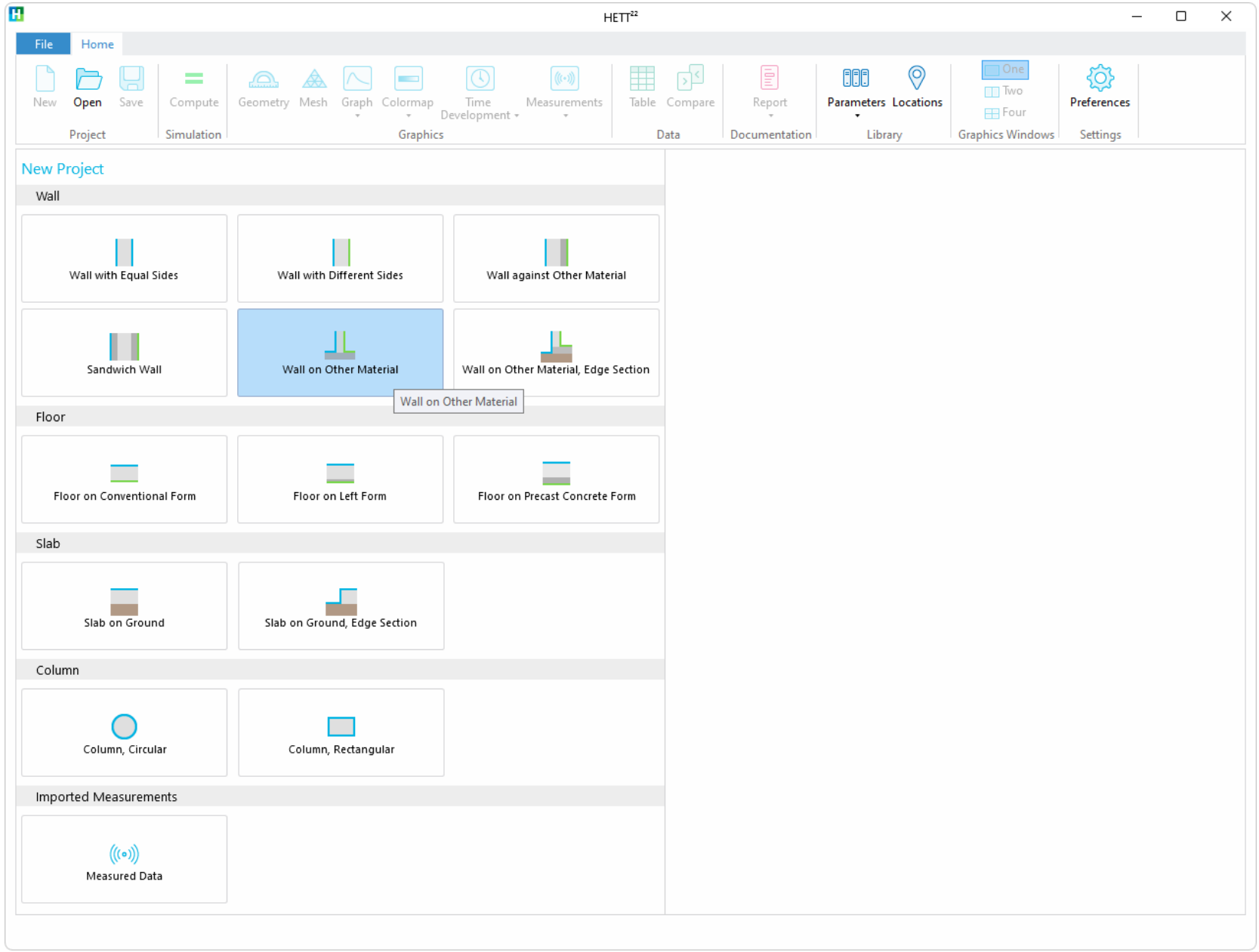
Exploring & Understanding

Example of casting a wall onto a concrete floor



Scenario

- Casting of a wall onto a concrete floor
- Construction site in Luleå in Northern Sweden
  - A significant portion of these mathematical models were developed in Luleå
- Start of casting on October 12th, 2023, at 15:00
- Select a construction and a concrete that will
  - Keep the time plan to remove the form after 18 hours
  - Minimize the carbon footprint



Select *Wall on Other Material*

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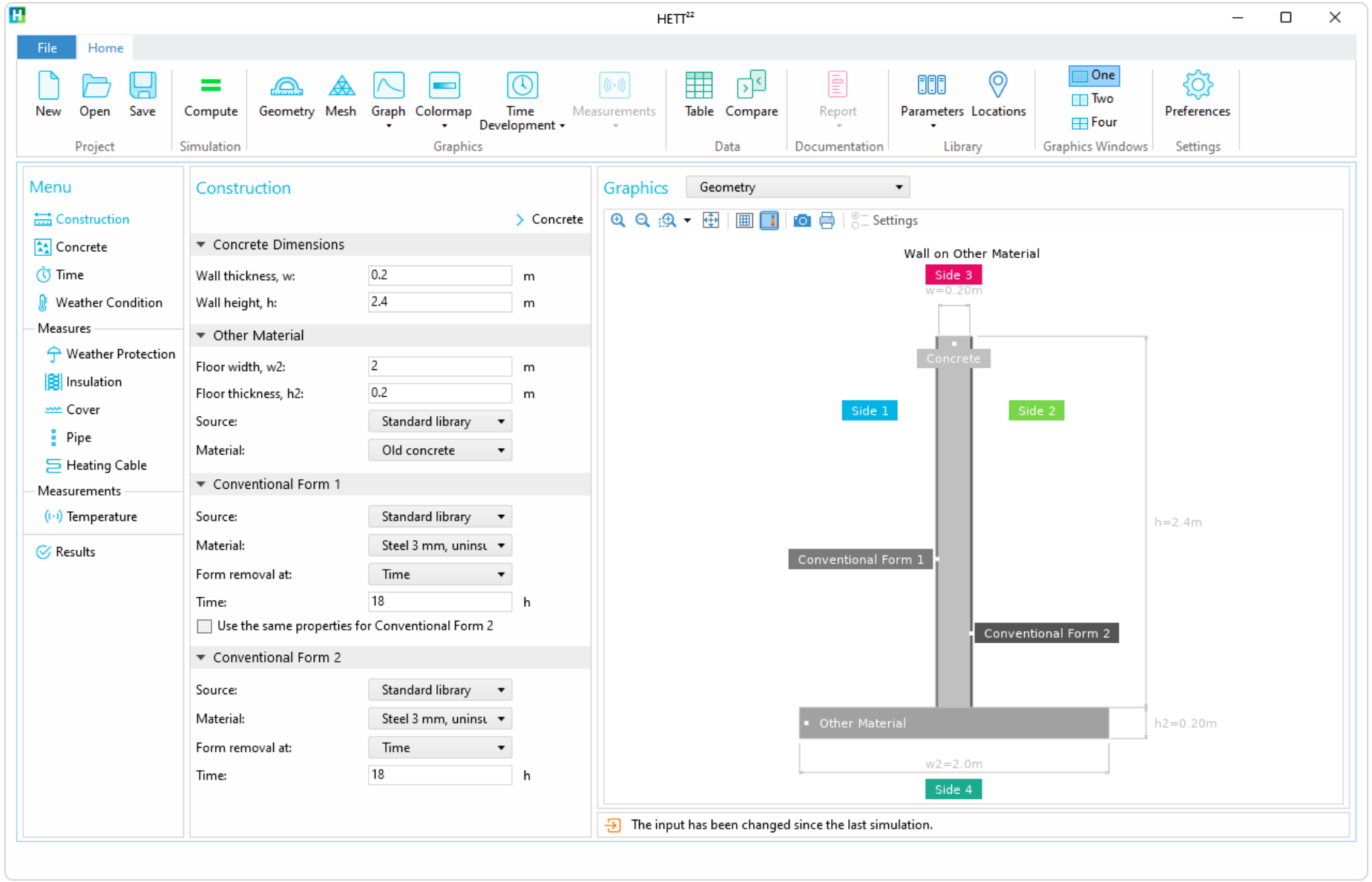

Set dimension and set the time of form removal to 18 hours

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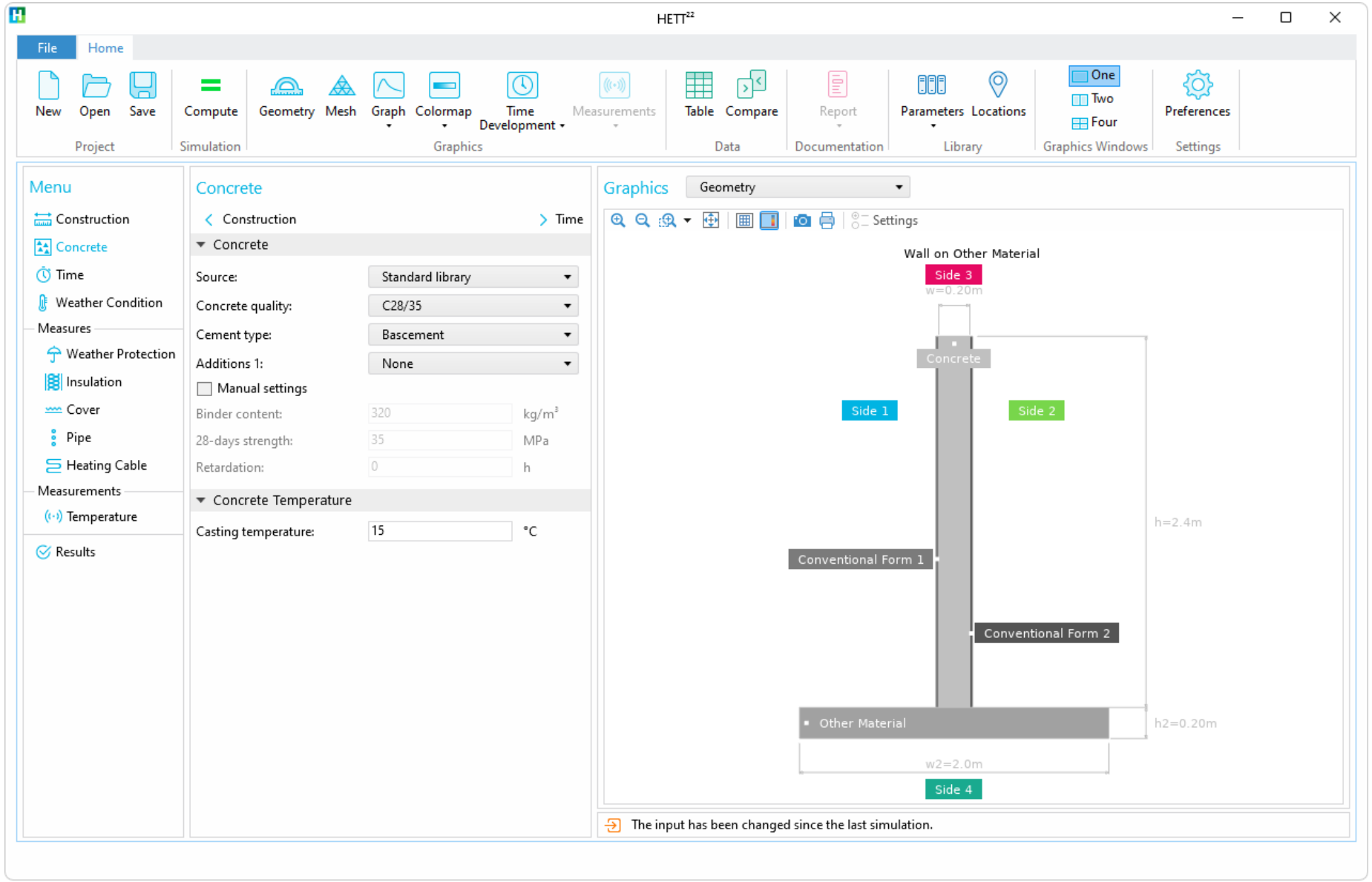

Select the concrete quality C28/35

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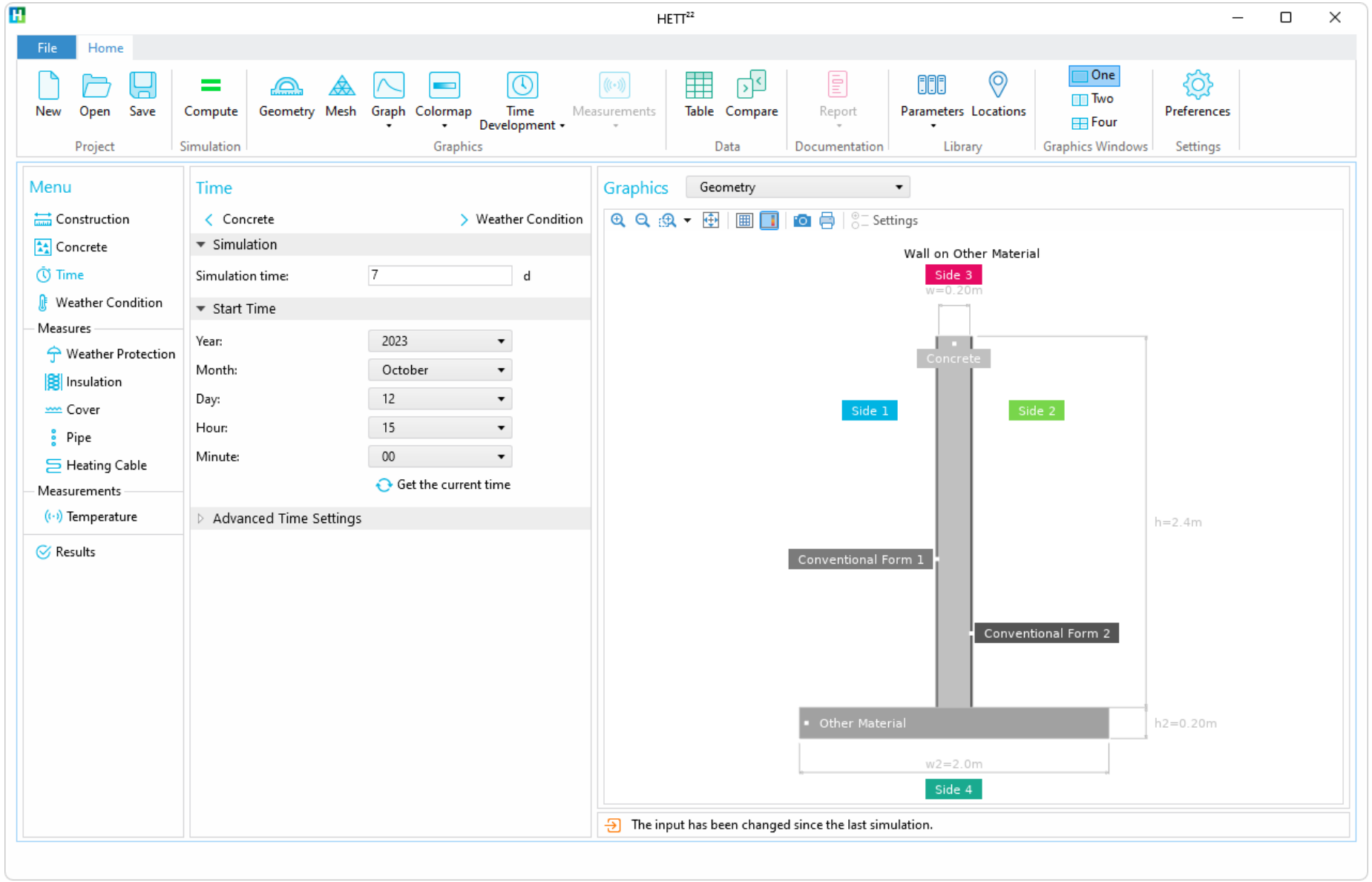

Set the simulation time and the start time for the casting

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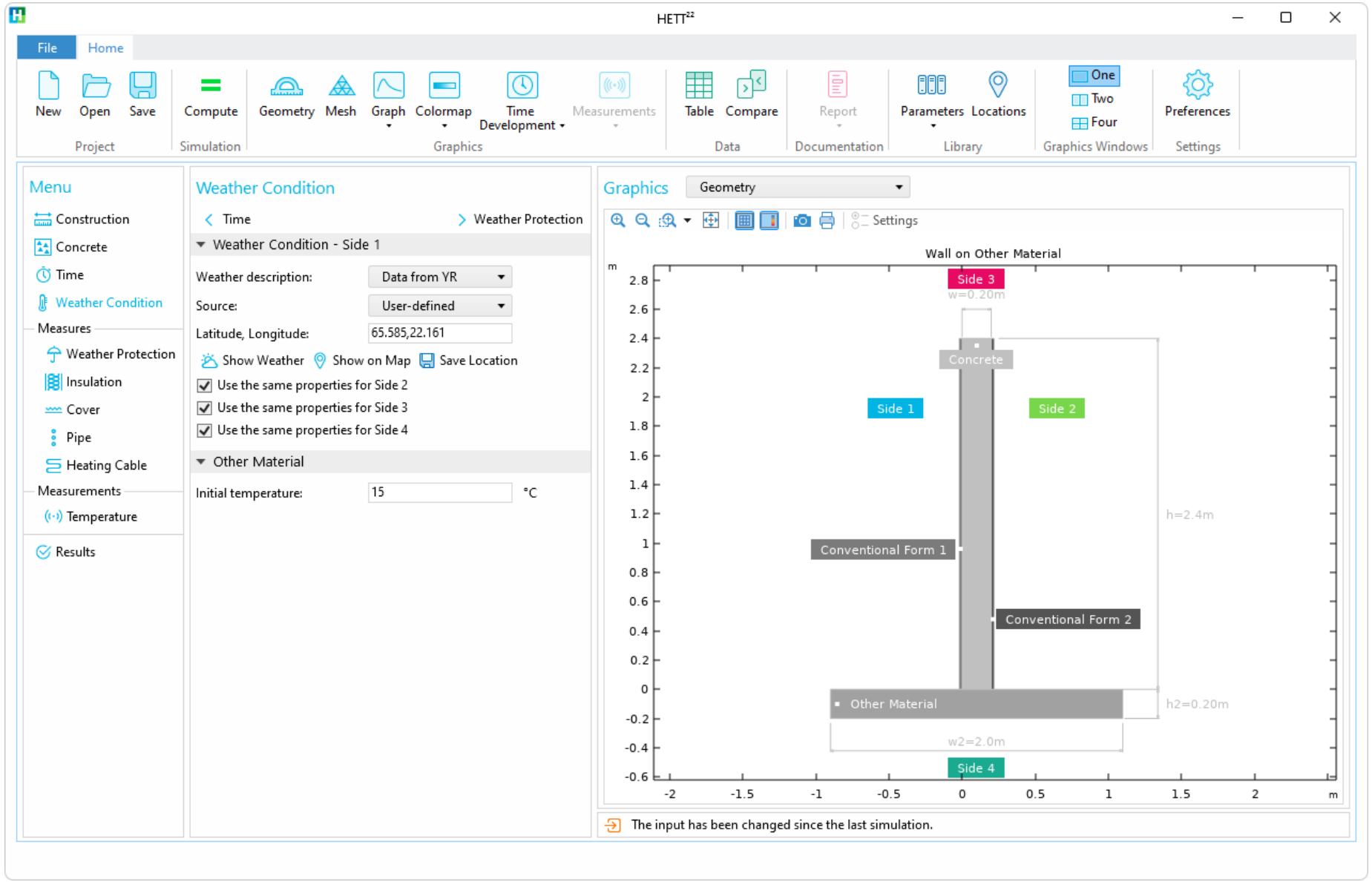

Set the weather condition and use a forecast from YR using latitude and longitude

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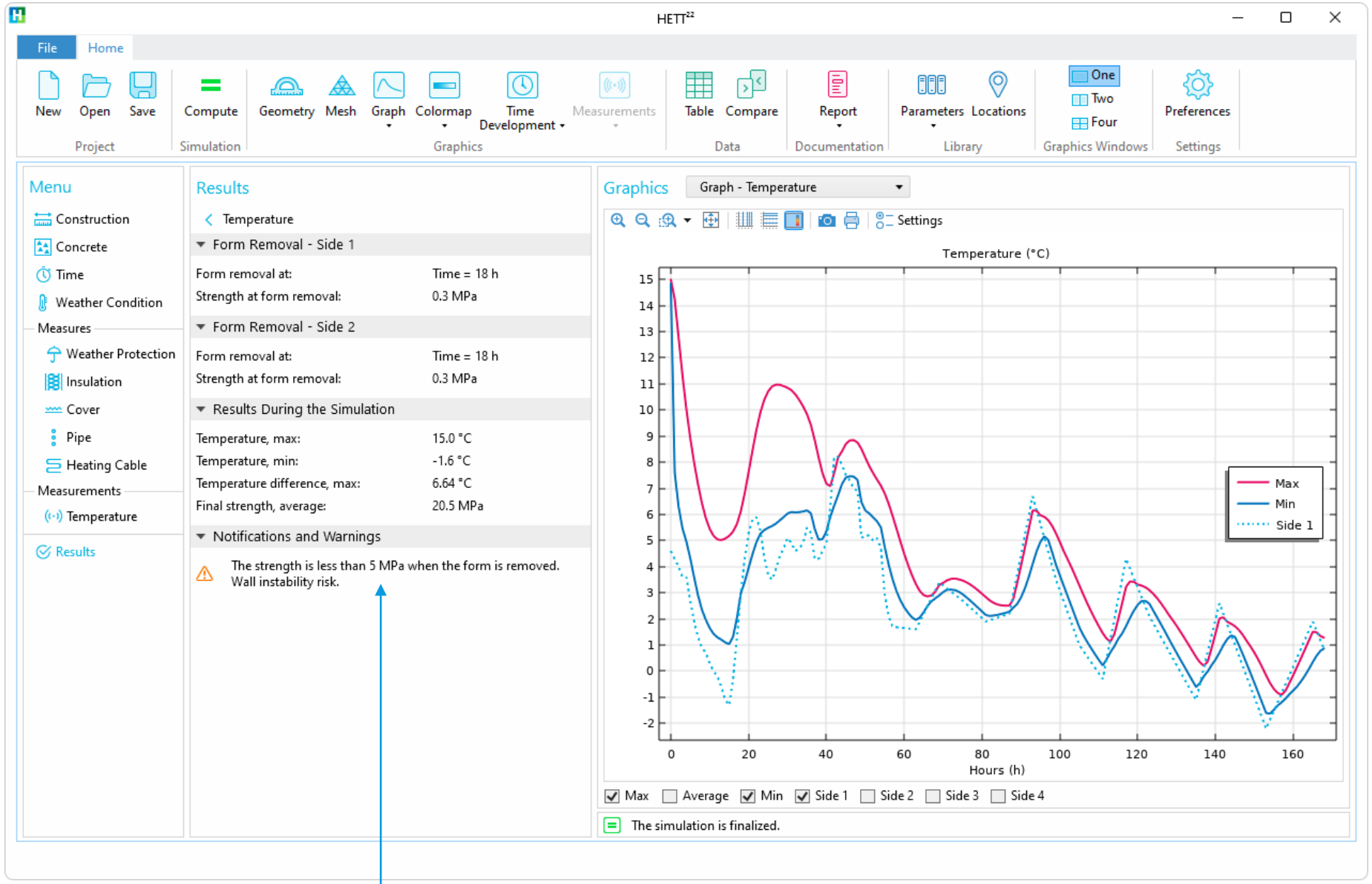

With the chosen construction and concrete quality, the form cannot be removed after 18 hours

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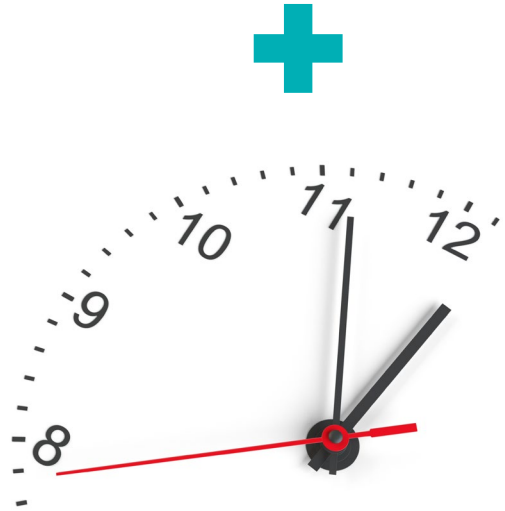
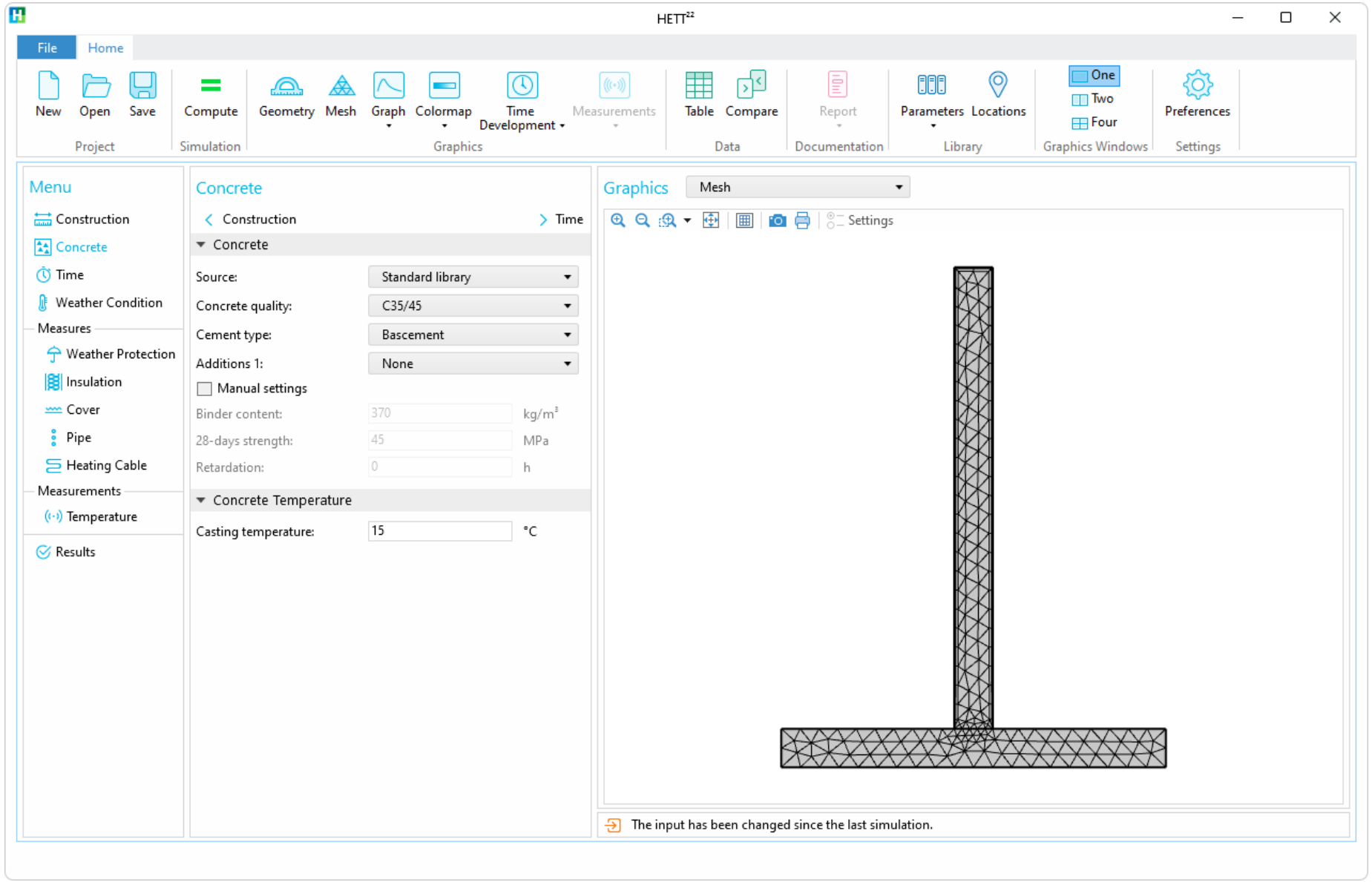
Try a Higher Concrete Quality

- Cures faster
- Higher cost
- Increased environmental impact





Increase the concrete quality and simulate again

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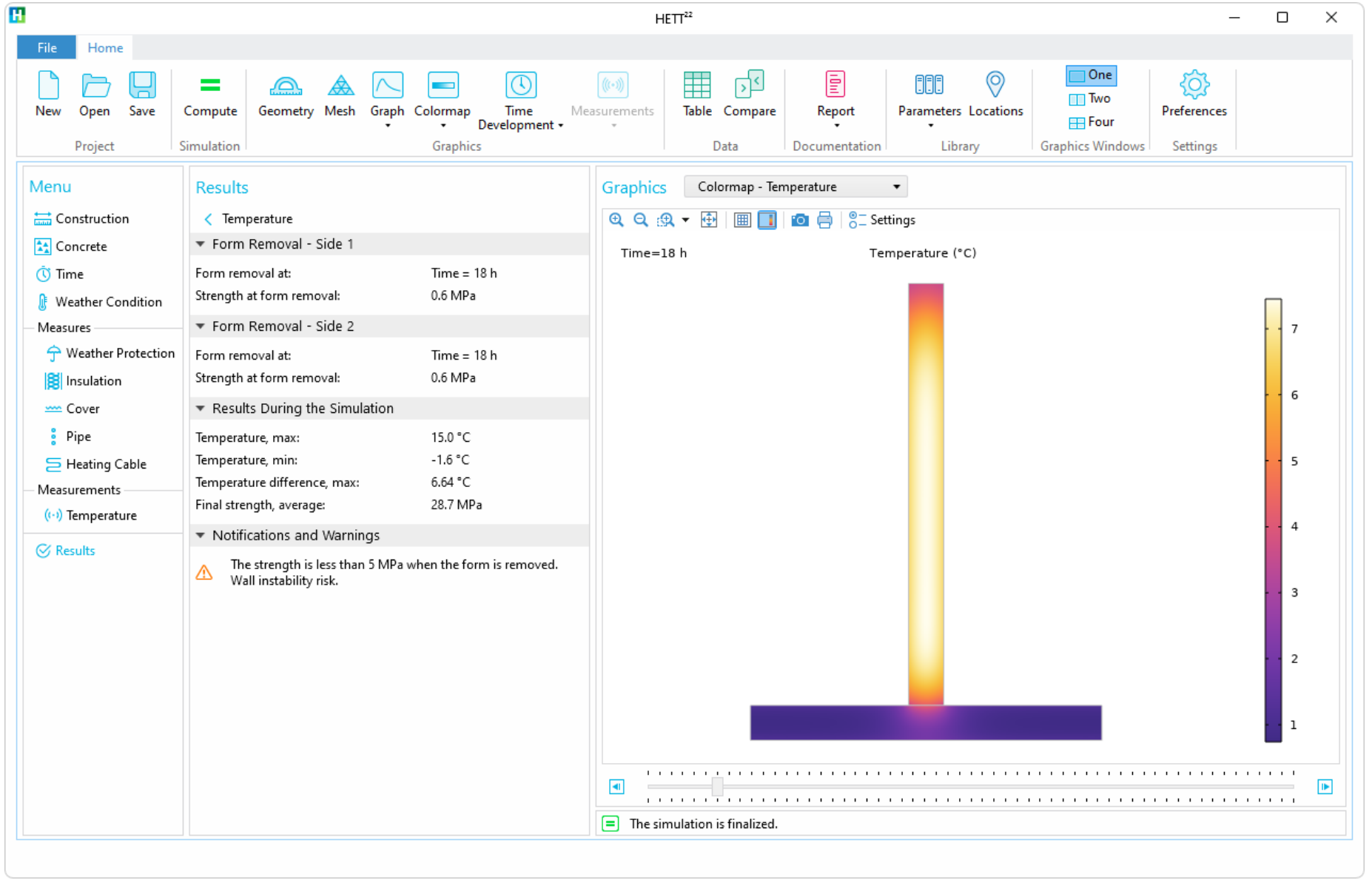

Even with the higher concrete quality, the form cannot be removed after 18 hours

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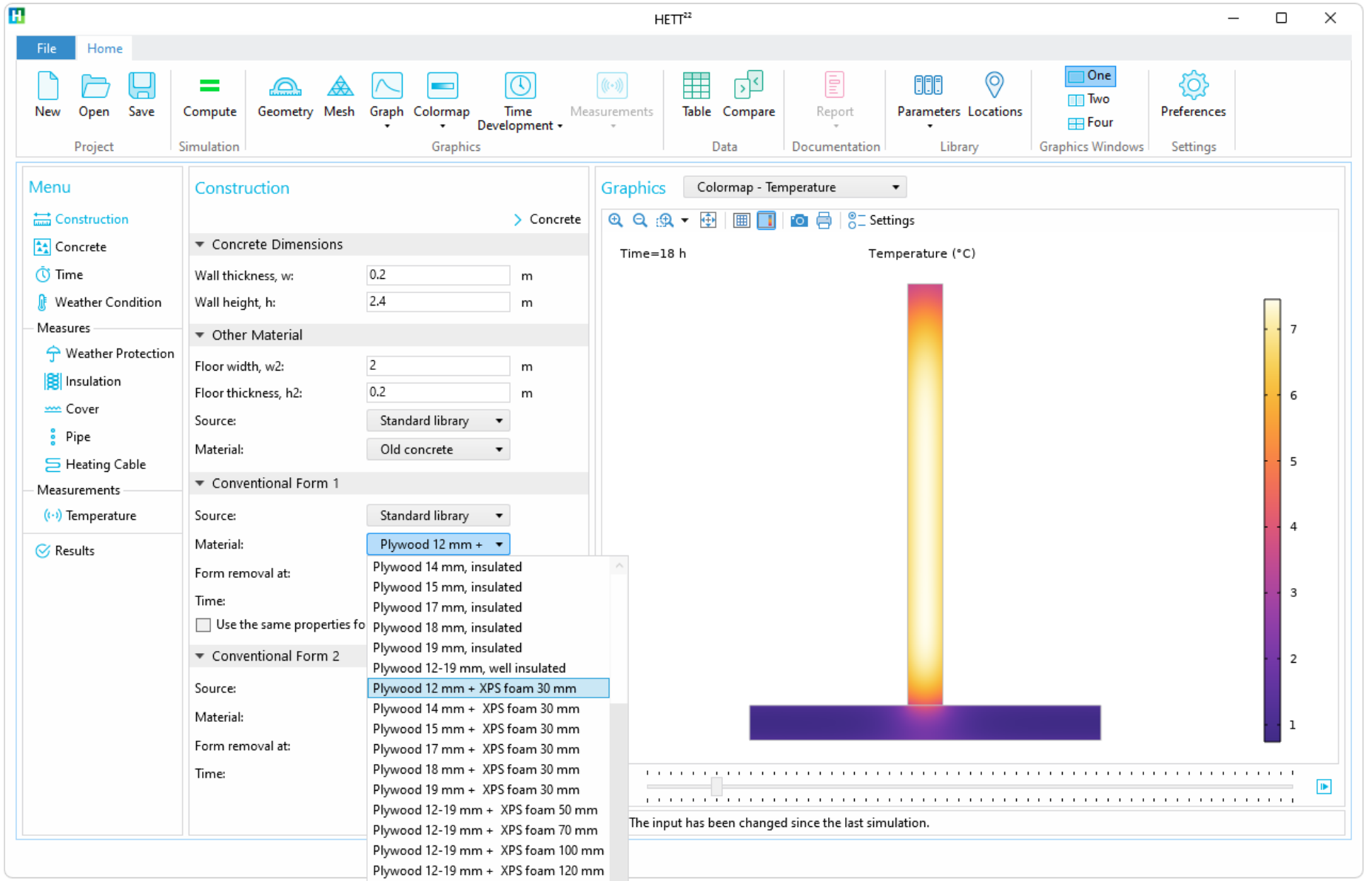
Increasing the Temperature

- Increase the strength of the concrete by elevating the temperature
- One approach to achieve this is by incorporating insulation into the formwork
- Transition from an uninsulated steel form to a Plywood form with 30 mm XPS foam



Select plywood with insulation

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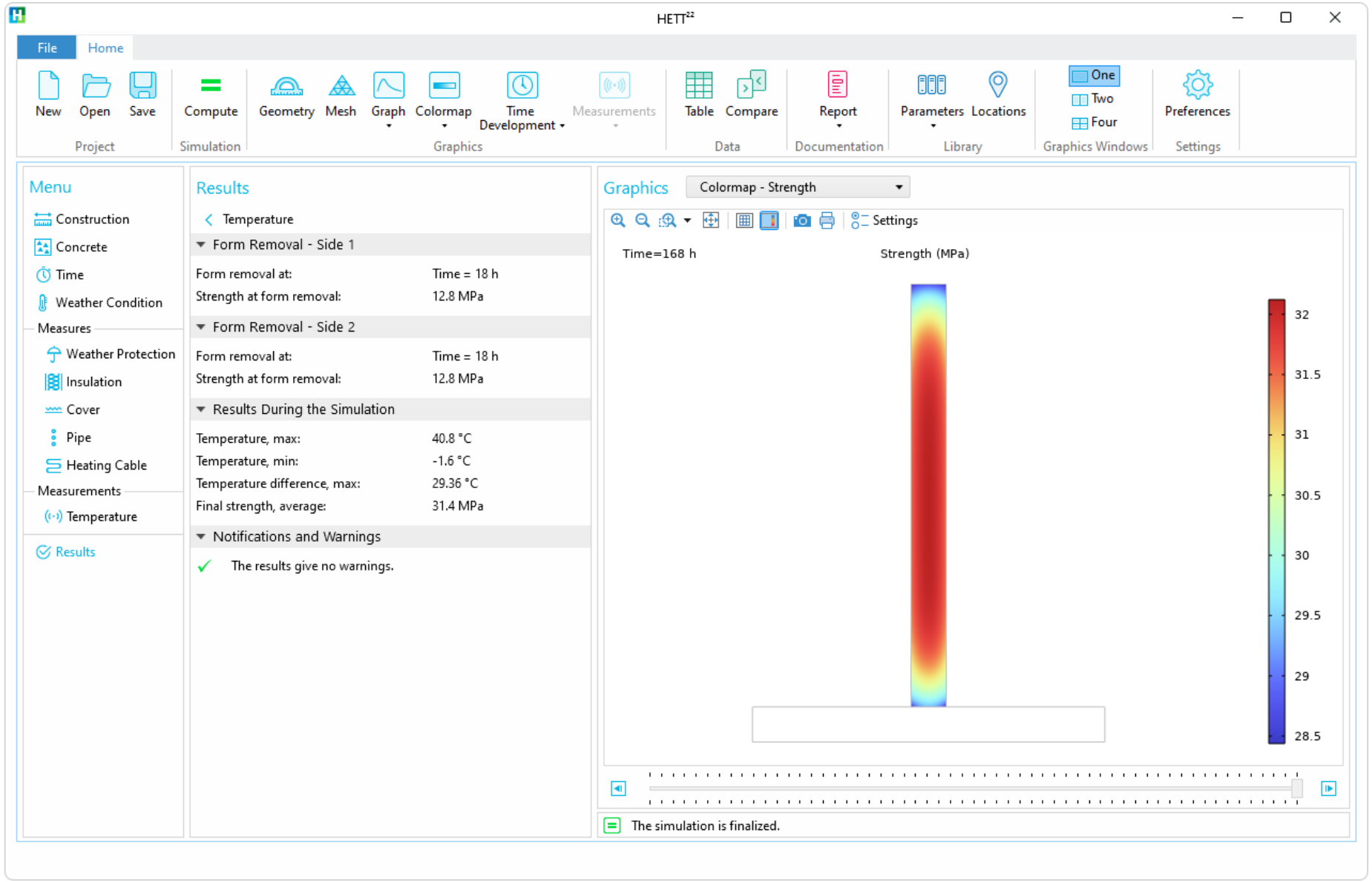

No warnings with the chosen construction and concrete quality

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Lesson Learned

- Using concrete quality C28/35 or C35/45 with an un-insulated form is not sufficient to remove the form after 18 hours
- Concrete C28/35 and C35/45 can be used by changing the construction to an insulated plywood form

Reducing CO_2 emissions

- To reduce emissions, a binder combination with slag can be chosen and this will
  - Decrease the early strength
  - Decrease the environmental impact

Compare

Lösning 1-10

Name	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5	Solution 6	Solution 7	Solution 8	Solution 9	Solution 10
Case	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...		
Results, temperature, max [°C]	15.0	15.0	36.6	41.6	32.7	29.3	38.0	35.6		
Results, temperature, min [°C]	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6		
Results, temperature difference, max [°C]	6.68	6.68	26.30	29.88	23.52	21.04	27.50	25.74		
Results, final strength, average [MPa]	20.6	28.7	22.7	31.7	20.3	17.9	28.8	26.0		
Results, all requirements fulfilled	Warning!	Warning!	OK	OK	OK	Warning!	OK	OK		
Results, risk for early freezing	OK	OK	OK	OK	OK	OK	OK	OK		
Results, risk for high temperature	OK	OK	OK	OK	OK	OK	OK	OK		
Results, risk for no form removal due to low strength	--	--	--	--	--	--	--	--		
Results, risk for low strength (<5MPa) at form removal	Warning!	Warning!	OK	OK	OK	Warning!	OK	OK		
Results, time of form removal [h], side 1	--	--	--	--	--	--	--	--		
Results, strength at form removal [MPa], side 1	0.3	0.7	8.5	14.0	6.1	4.0	11.1	8.3		
Results, time of form removal [h], side 2	--	--	--	--	--	--	--	--		
Results, strength at form removal [MPa], side 2	0.3	0.7	8.5	14.0	6.1	4.0	11.1	8.3		
Construction, concrete dimension wall thickness, w [m]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		
Construction, concrete dimensions, wall height, h [m]	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4		
Construction, other material, floor width, w2 [m]	2	2	2	2	2	2	2	2		
Construction, other material, floor thickness, h2 [m]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		
Construction, other material, source	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...		
Construction, other material, material	Old concrete	Old concrete	Old concrete	Old concrete	Old concrete	Old concrete	Old concrete	Old concrete		
Construction, other material, density [kg/m^3]	2350	2350	2350	2350	2350	2350	2350	2350		
Construction, other material, heat capacity [J/(kg*K)]	950	950	950	950	950	950	950	950		
Construction, other material, thermal conductivity [W/(m*K)]	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7		
Construction, conventional form, source, side 1	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...		
Construction, conventional form, material, side 1	Steel 3 mm,...	Steel 3 mm,...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...		
Construction, conventional form, thickness [m], side 1	0	0	0	0	0	0	0	0		
Construction, conventional form, thermal conductivity [W/(m*...	0	0	0	0	0	0	0	0		
Construction, conventional form, U-value [W/(m^2*K)], side 1	49.8	49.8	1.58	1.58	1.58	1.58	1.58	1.58		
Construction, conventional form, form removal, side 1	Time	Time	Time	Time	Time	Time	Time	Time		
Construction, conventional form, form removal, strength, side 1	--	--	--	--	--	--	--	--		
Construction, conventional form, form removal, time, side 1	18	18	18	18	18	18	18	18		
Construction, conventional form, source, side 2	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...		
Construction, conventional form, material, side 2	Steel 3 mm,...	Steel 3 mm,...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...		
Construction, conventional form, thickness [m], side 2	0	0	0	0	0	0	0	0		
Construction, conventional form, thermal conductivity [W/(m*...	0	0	0	0	0	0	0	0		
Construction, conventional form, U-value [W/(m^2*K)], side 2	49.8	49.8	1.58	1.58	1.58	1.58	1.58	1.58		
Construction, conventional form, form removal, side 2	Time	Time	Time	Time	Time	Time	Time	Time		
Construction, conventional form, form removal, strength, side 2	--	--	--	--	--	--	--	--		
Construction, conventional form, form removal, time, side 2	18	18	18	18	18	18	18	18		
Concrete, source	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...		
Concrete, concrete quality	C28/35	C35/45	C28/35	C35/45	C28/35	C28/35	C35/45	C35/45		
Concrete, cement type	Bascement	Bascement	Bascement	Bascement	Bascement	Bascement	Bascement	Bascement		
Concrete, cement type 2	--	--	--	--	--	--	--	--		
Concrete, additions 1	None	None	None	None	10 % Slagg	20 % Slagg	10 % Slagg	20 % Slagg		
Concrete, additions 2	--	--	--	--	--	--	--	--		
Concrete, setting time [h]	--	--	--	--	--	--	--	--		

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Compare

Lösning 1-10

Name	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5	Solution 6	Solution 7	Solution 8	Solution 9	Solution 10
Case	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...	Wall on Oth...		
Results, temperature, max [°C]	15.0	15.0	36.6	41.6	32.7	29.3	38.0	35.6		
Results, temperature, min [°C]	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6		
Results, temperature difference, max [°C]	6.68	6.68	26.30	29.88	23.52	21.04	27.50	25.74		
Results, final strength, average [MPa]	20.6	28.7	22.7	31.7	20.3	17.9	28.8	26.0		
Results, all requirements fulfilled	Warning!	Warning!	OK	OK	OK	Warning!	OK	OK		
Results, risk for early freezing	OK	OK	OK	OK	OK	OK	OK	OK		
Results, risk for high temperature	OK	OK	OK	OK	OK	OK	OK	OK		
Results, risk for no form removal due to low strength	--	--	--	--	--	--	--	--		
Results, risk for low strength (<5MPa) at form removal	Warning!	Warning!	OK	OK	OK	Warning!	OK	OK		
Results, time of form removal [h], side 1	--	--	--	--	--	--	--	--		
Results, strength at form removal [MPa], side 1	0.3	0.7	8.5	14.0	6.1	4.0	11.1	8.3		
Results, time of form removal [h], side 2	--	--	--	--	--	--	--	--		
Results, strength at form removal [MPa], side 2	0.3	0.7	8.5	14.0	6.1	4.0	11.1	8.3		
Construction, concrete dimension wall thickness, w [m]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		
Construction, concrete dimensions, wall height, h [m]	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4		
Construction, other material, floor width, w2 [m]	2	2	2	2	2	2	2	2		
Construction, other material, floor thickness, h2 [m]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		
Construction, other material, source	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...		
Construction, other material, material	Old concrete	Old concrete	Old concrete	Old concrete	Old concrete	Old concrete	Old concrete	Old concrete		
Construction, other material, density [kg/m^3]	2350	2350	2350	2350	2350	2350	2350	2350		
Construction, other material, heat capacity [J/(kg*K)]	950	950	950	950	950	950	950	950		
Construction, other material, thermal conductivity [W/(m*K)]	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7		
Construction, conventional form, source, side 1	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...		
Construction, conventional form, material, side 1	Steel 3 mm,...	Steel 3 mm,...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...		
Construction, conventional form, thickness [m], side 1	0	0	0	0	0	0	0	0		
Construction, conventional form, thermal conductivity [W/(m*...	0	0	0	0	0	0	0	0		
Construction, conventional form, U-value [W/(m^2*K)], side 1	49.8	49.8	1.58	1.58	1.58	1.58	1.58	1.58		
Construction, conventional form, form removal, side 1	Time	Time	Time	Time	Time	Time	Time	Time		
Construction, conventional form, form removal, strength, side 1	--	--	--	--	--	--	--	--		
Construction, conventional form, form removal, time, side 1	18	18	18	18	18	18	18	18		
Construction, conventional form, source, side 2	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...		
Construction, conventional form, material, side 2	Steel 3 mm,...	Steel 3 mm,...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...	Plywood 12...		
Construction, conventional form, thickness [m], side 2	0	0	0	0	0	0	0	0		
Construction, conventional form, thermal conductivity [W/(m*...	0	0	0	0	0	0	0	0		
Construction, conventional form, U-value [W/(m^2*K)], side 2	49.8	49.8	1.58	1.58	1.58	1.58	1.58	1.58		
Construction, conventional form, form removal, side 2	Time	Time	Time	Time	Time	Time	Time	Time		
Construction, conventional form, form removal, strength, side 2	--	--	--	--	--	--	--	--		
Construction, conventional form, form removal, time, side 2	18	18	18	18	18	18	18	18		
Concrete, source	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...	Standard lib...		
Concrete, concrete quality	C28/35	C35/45	C28/35	C35/45	C28/35	C28/35	C35/45	C35/45		
Concrete, cement type	Bascement	Bascement	Bascement	Bascement	Bascement	Bascement	Bascement	Bascement		
Concrete, cement type 2	--	--	--	--	--	--	--	--		
Concrete, additions 1	None	None	None	None	10 % Slagg	20 % Slagg	10 % Slagg	20 % Slagg		
Concrete, additions 2	--	--	--	--	--	--	--	--		
Concrete, setting time [h]	--	--	--	--	--	--	--	--		

Close

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Simulations show that two setups work

C28/35 with 10% slag

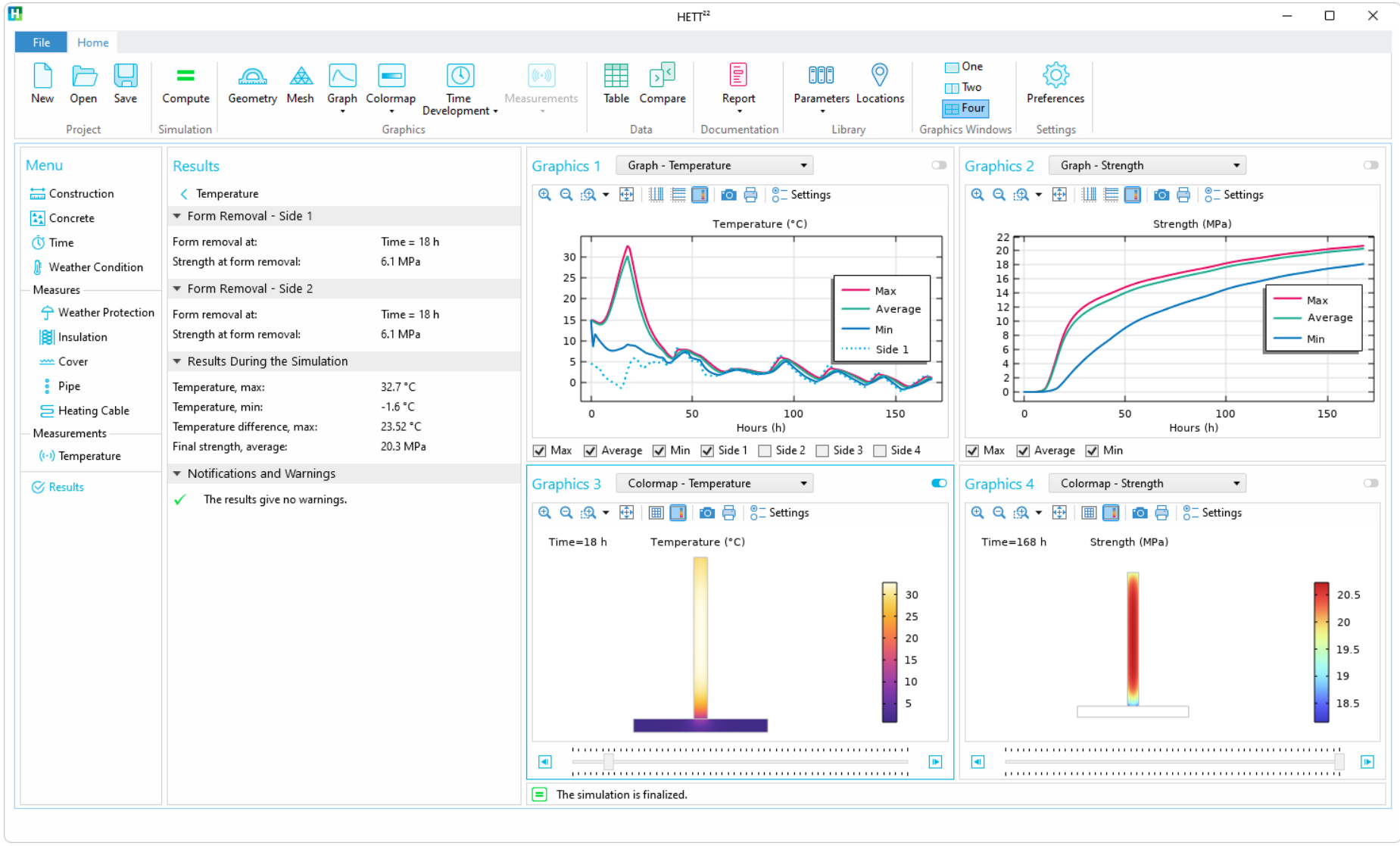
C35/45 with 20% slag

Which is the most environmentally friendly option?

Comparison

Concrete Quality	Form	Time for 5 MPa (h)	CO_2 Measure (kg/m^3)
C28/35	Uninsulated steel	≥ 30	208
C35/45	Uninsulated steel	≥ 25	241
C28/35	Insulated plywood	≥ 15	208
C35/45	Insulated plywood	≥ 13	241
C28/35 + 10 % slag	Insulated plywood	≥ 17	189
C28/35 + 20 % slag	Insulated plywood	≥ 20	170
C35/45 + 10 % slag	Insulated plywood	≥ 14	218
C35/45 + 20 % slag	Insulated plywood	≥ 15	196

C28/35 + 10 % slag and Insulated Form



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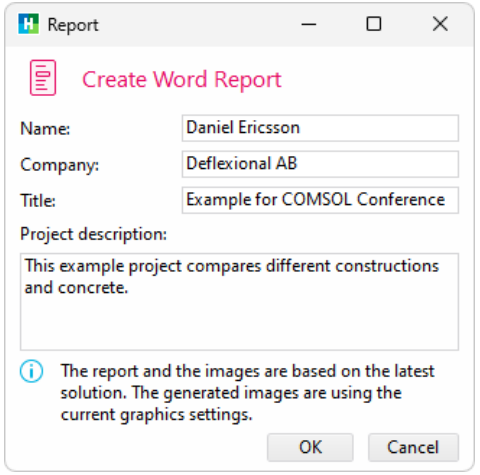
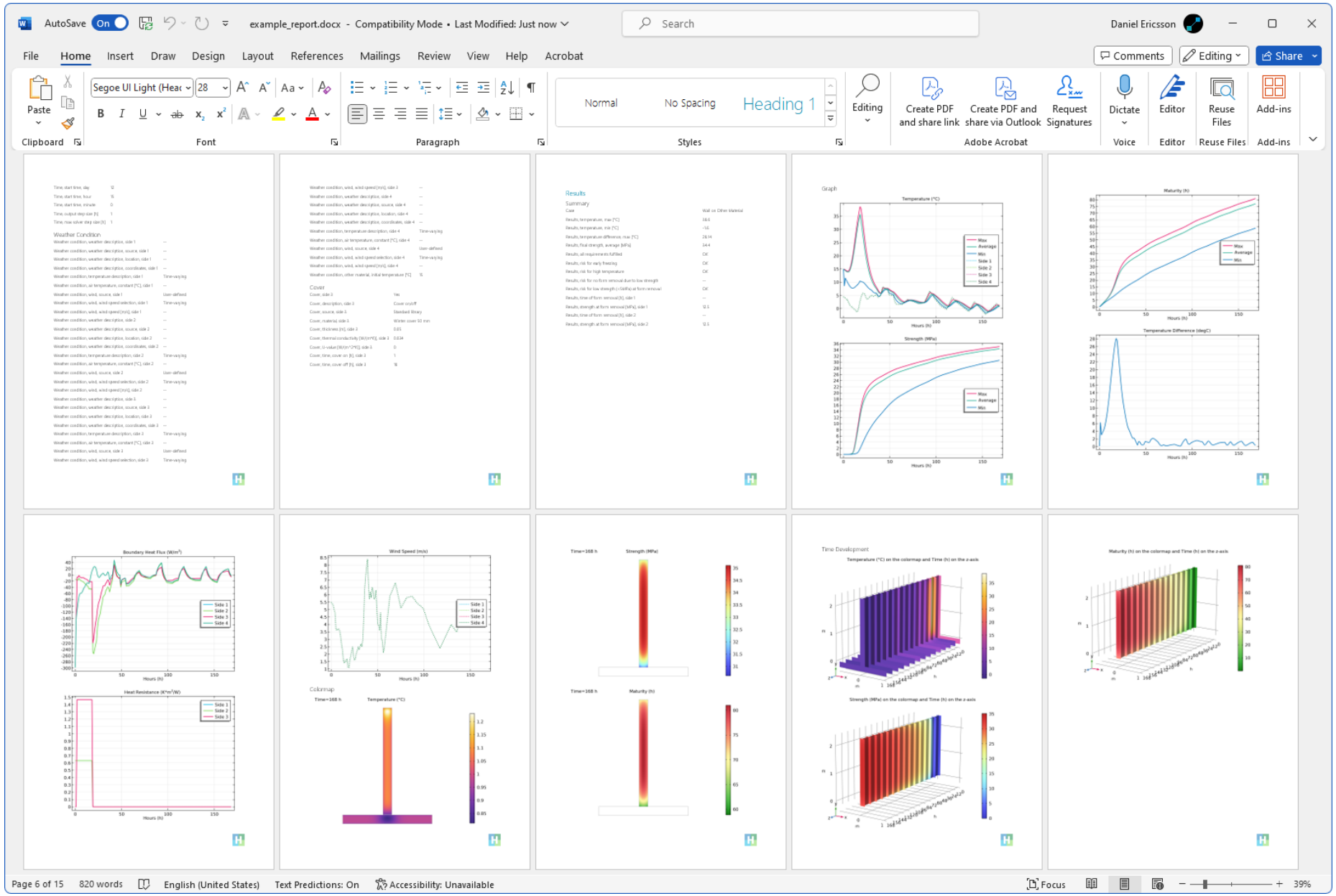
Reports





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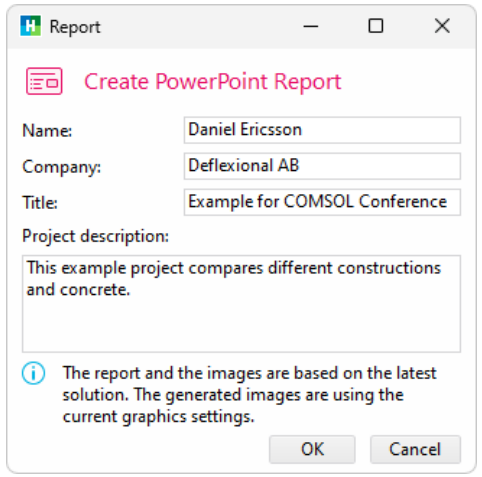
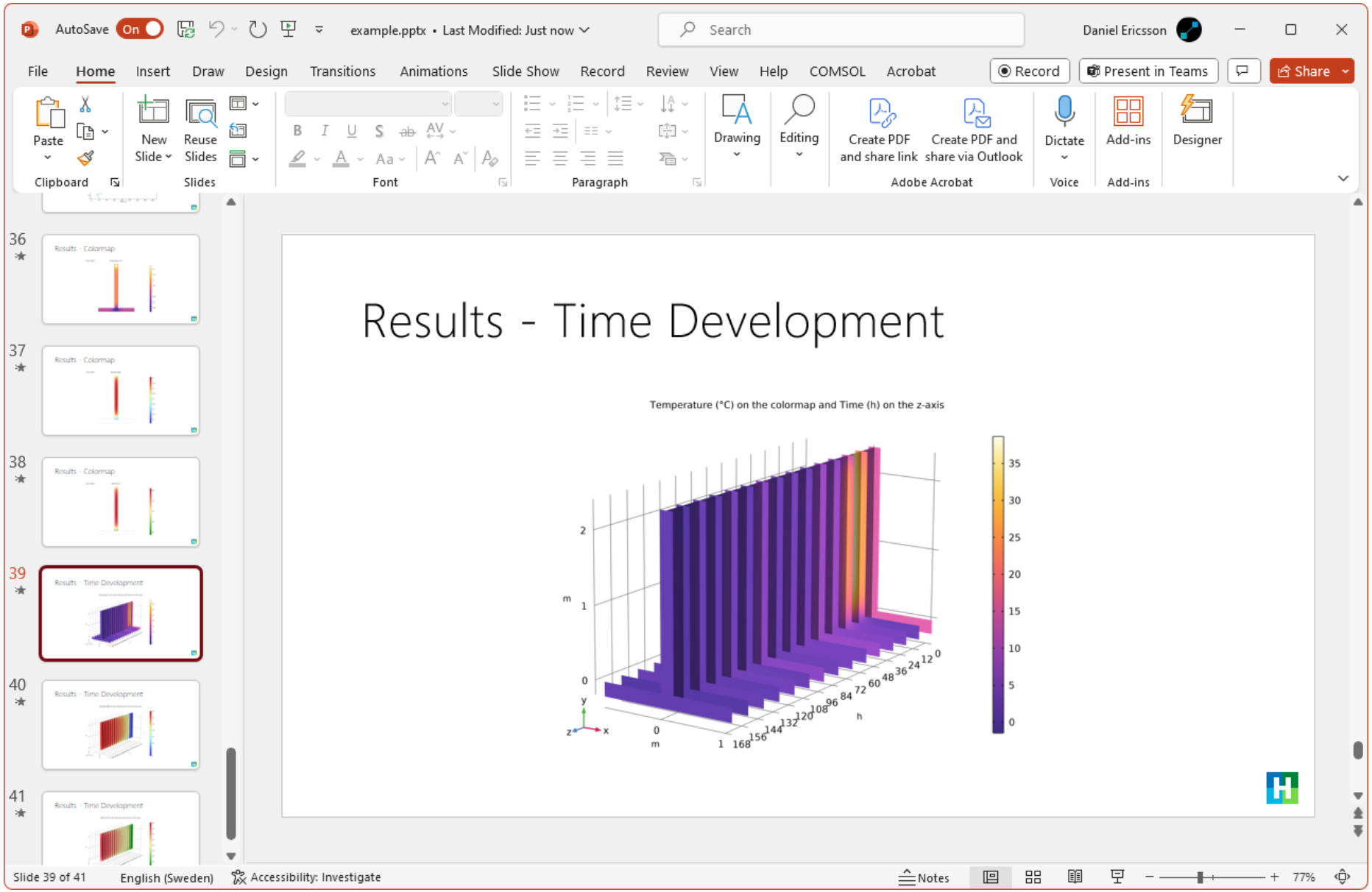
Reports





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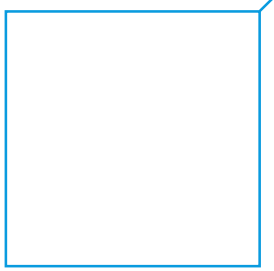
The Underlying COMSOL Model

Combining the Model Builder with methods



Geometry

- The geometry is dynamically generated using methods in the Application Builder based on the selected construction case
- A second *2D Component* is used to visualize the construction drawing with dimensions, colors, and textual elements

Physics Interfaces

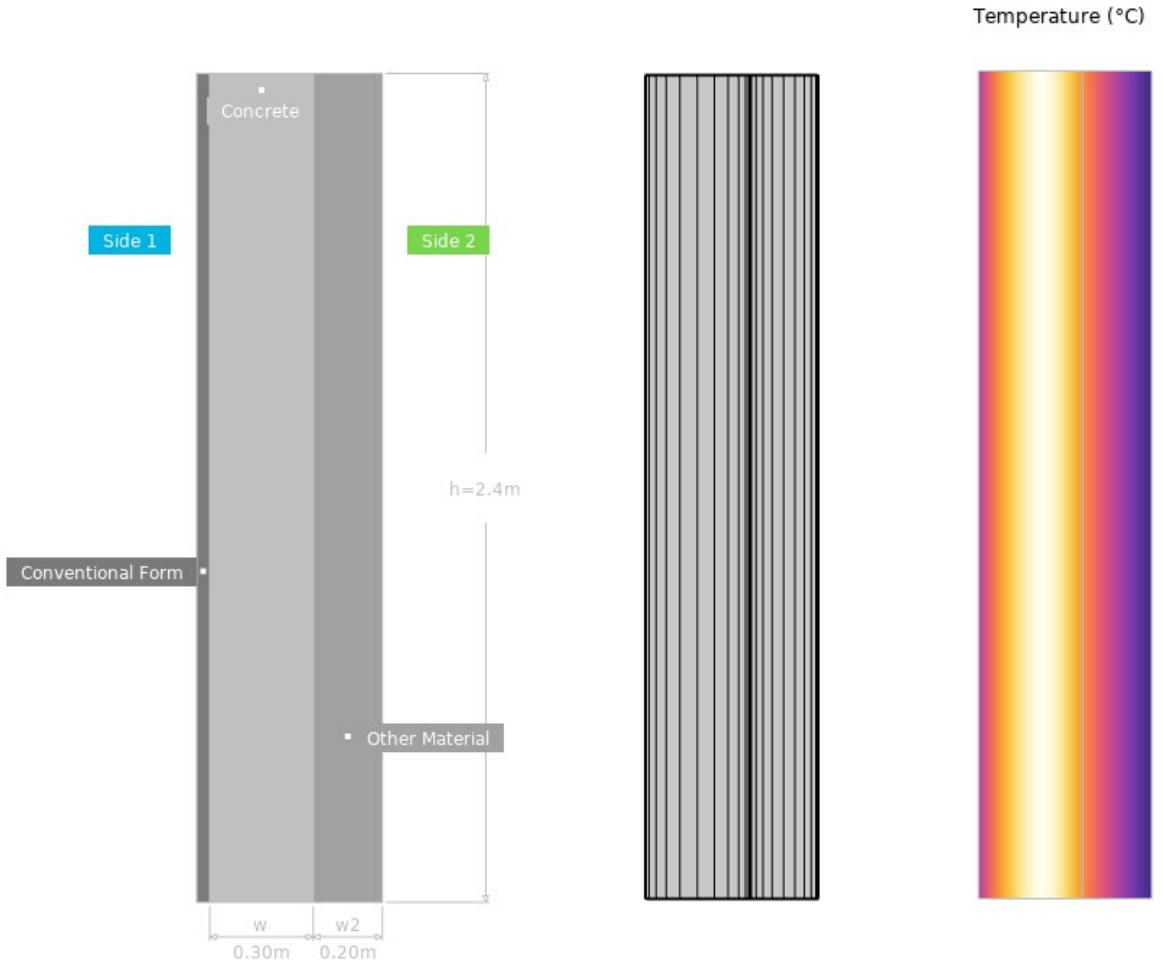
- Heat Transfer in Solids
  - Heat Source
  - Heat Flux
  - Thin Layer
- Domain ODEs and DAEs
  - Calculate the equivalent time (maturity) and concrete strength
- Events
  - Efficiently manages dynamic changes in the model such as formwork removal, cover additions, or the activation/deactivation of heating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

Mesh

- The mesh is automatically adjusted for the specific construction cases
- Can be a mix of triangular elements and mapped meshes
- Boundary layer meshing ensures that temperature gradients are resolved close to important areas
- The discretization is set to quadratic lagrange for the *Heat Transfer in Solids* physics interface

Mesh Example #1

- The heat flux condition (the temperature and wind) are not varying in the y-direction
- The model could be solved in 1D
- The 2D model uses only one element in the y-direction to save computational time
- The mesh is refined close to the walls and interfaces



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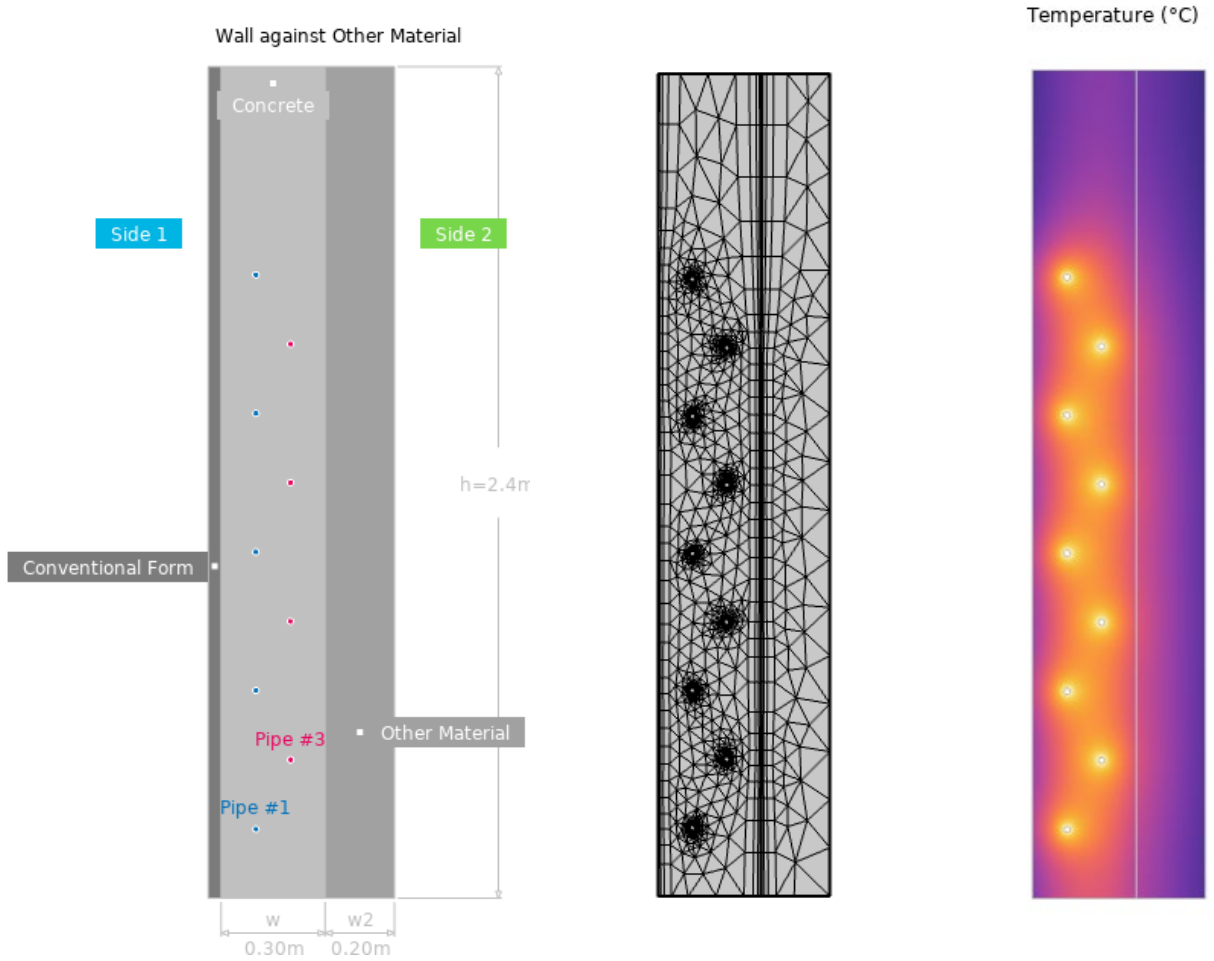
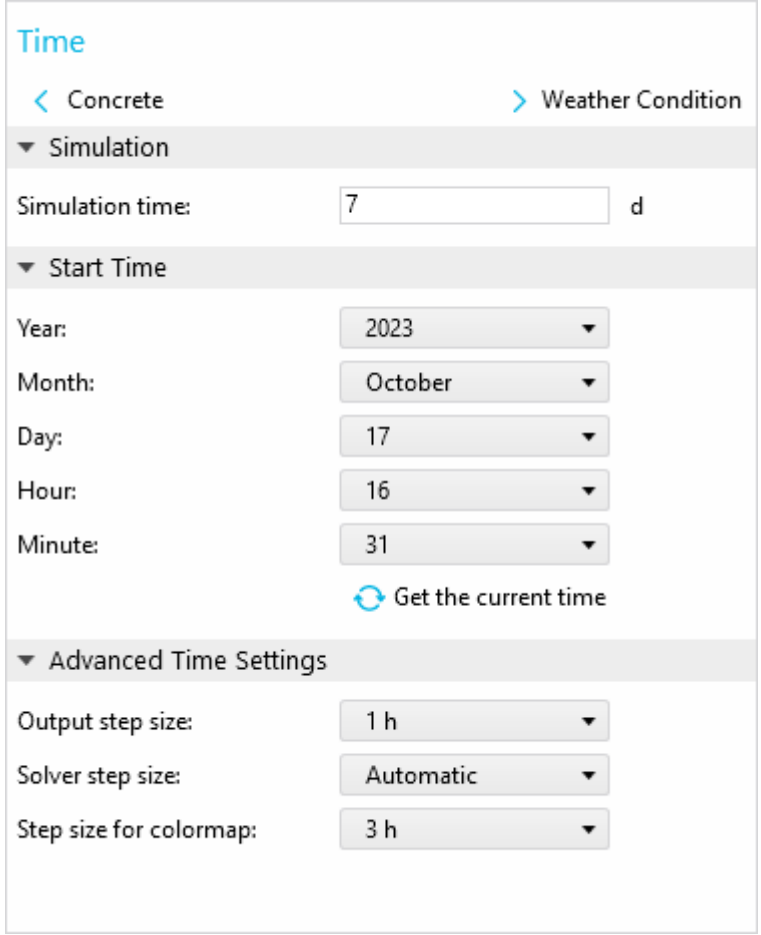
Mesh Example #2

- Pipes with hot water are introduced, and the model must be solved in 2D
- The mesh is refined with boundary layers:
  - Close to the walls
  - Around the pipes



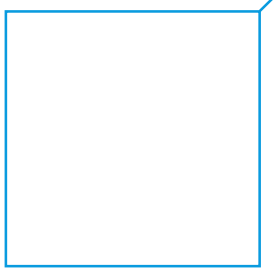
Solver Settings

- The solver uses MUMPS
- The time stepping method is set to BDF
- The app users can control
  - The output step size
  - The solver step size
    - Automatic
    - Manual with a maximum step size
  - Step size for colormap
    - Sets the step size for 2D visualizations



Application Features

Encompasses functionalities that are likely unique



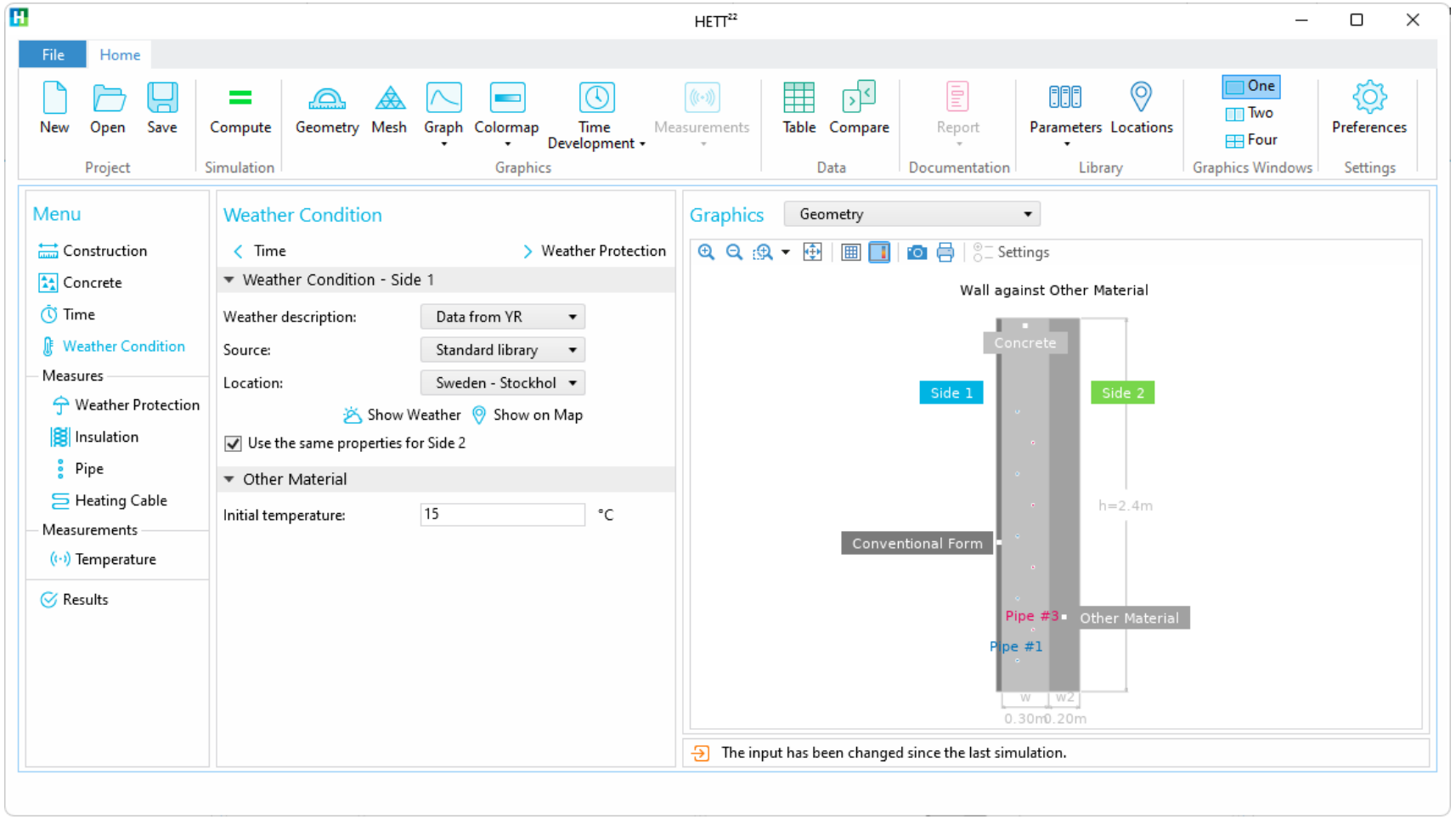
Weather Forecasts

Automatically transform forecast into appropriate boundary conditions

Weather Forecasts

- The way concrete matures is highly dependent on the surrounding air temperature and wind speed
- To improve the prediction of near-future conditions, HETT[22] can automatically download weather forecasts from smhi.se and yr.no through JSON document retrieval
- The data is automatically transformed into the appropriate boundary conditions

Weather Condition



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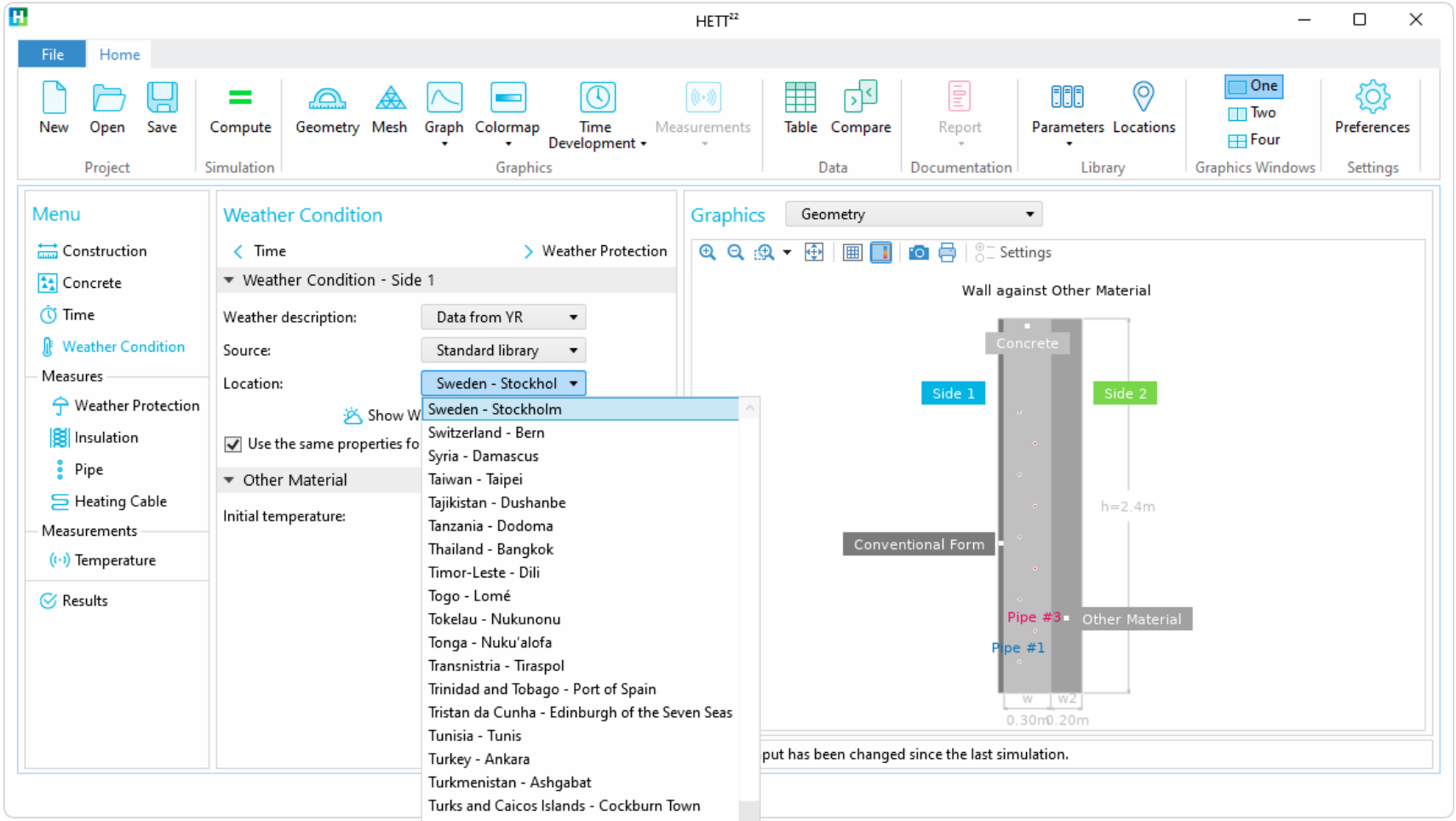
Weather Condition



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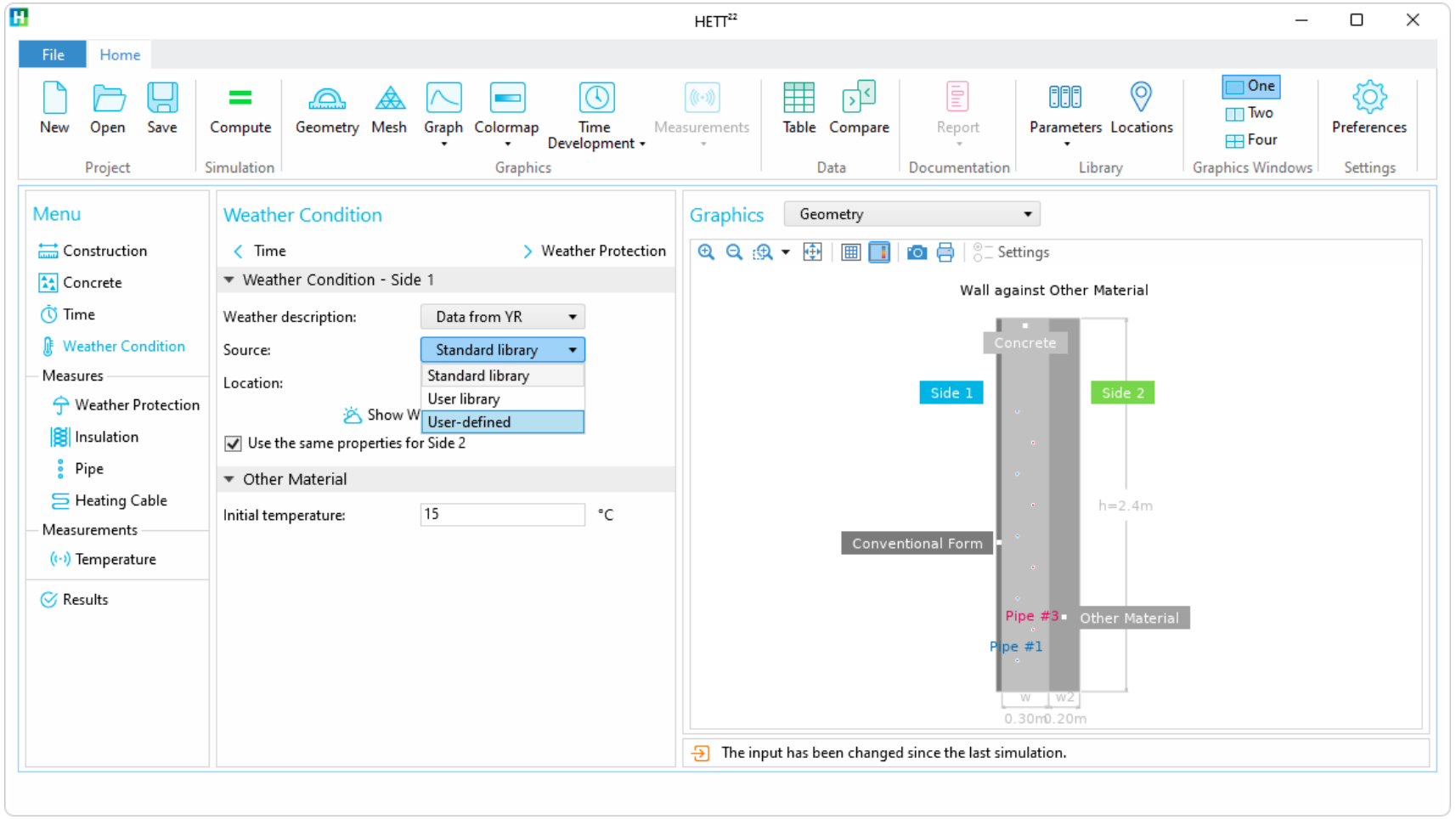
Weather Condition



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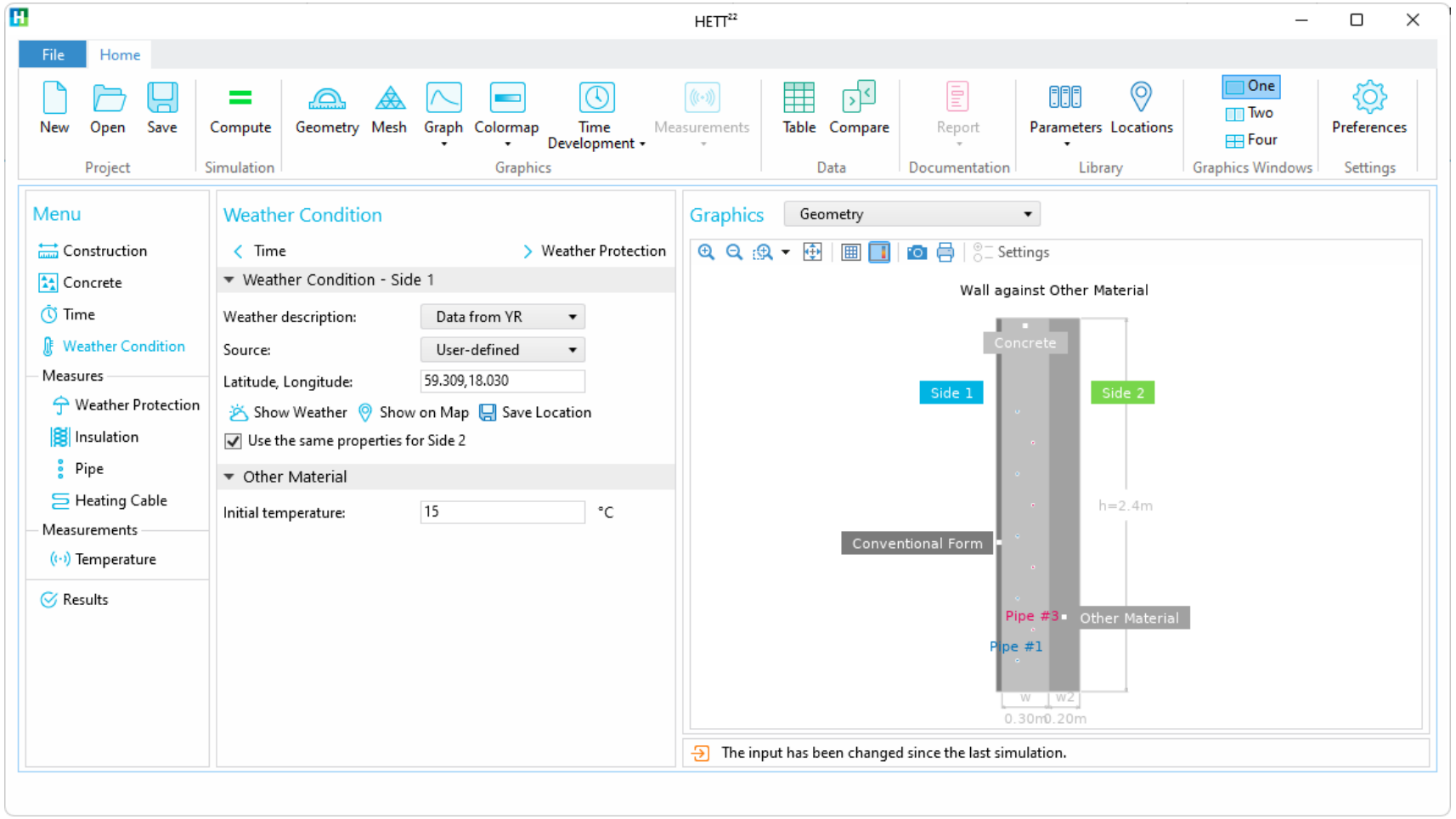
Weather Condition



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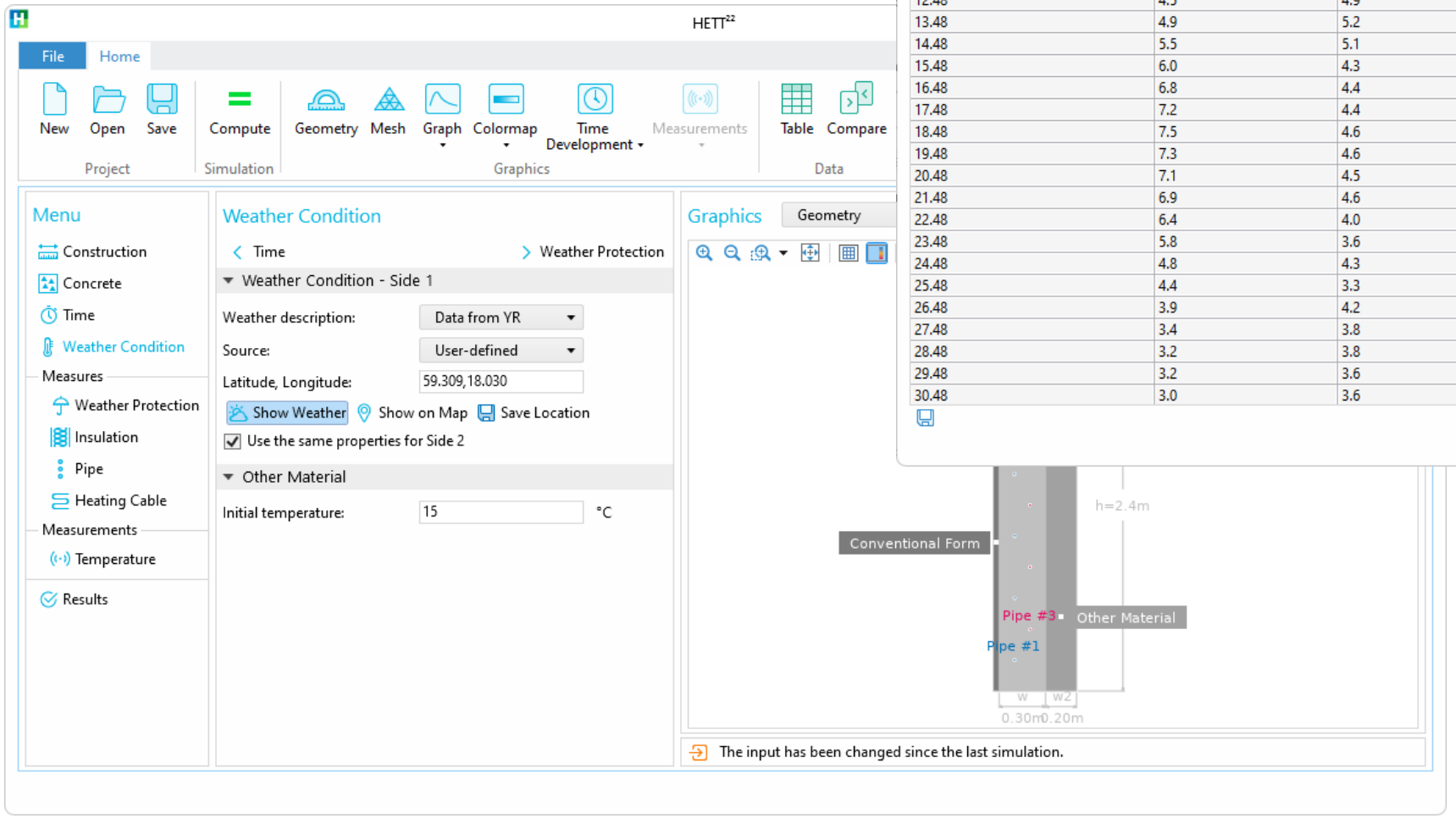
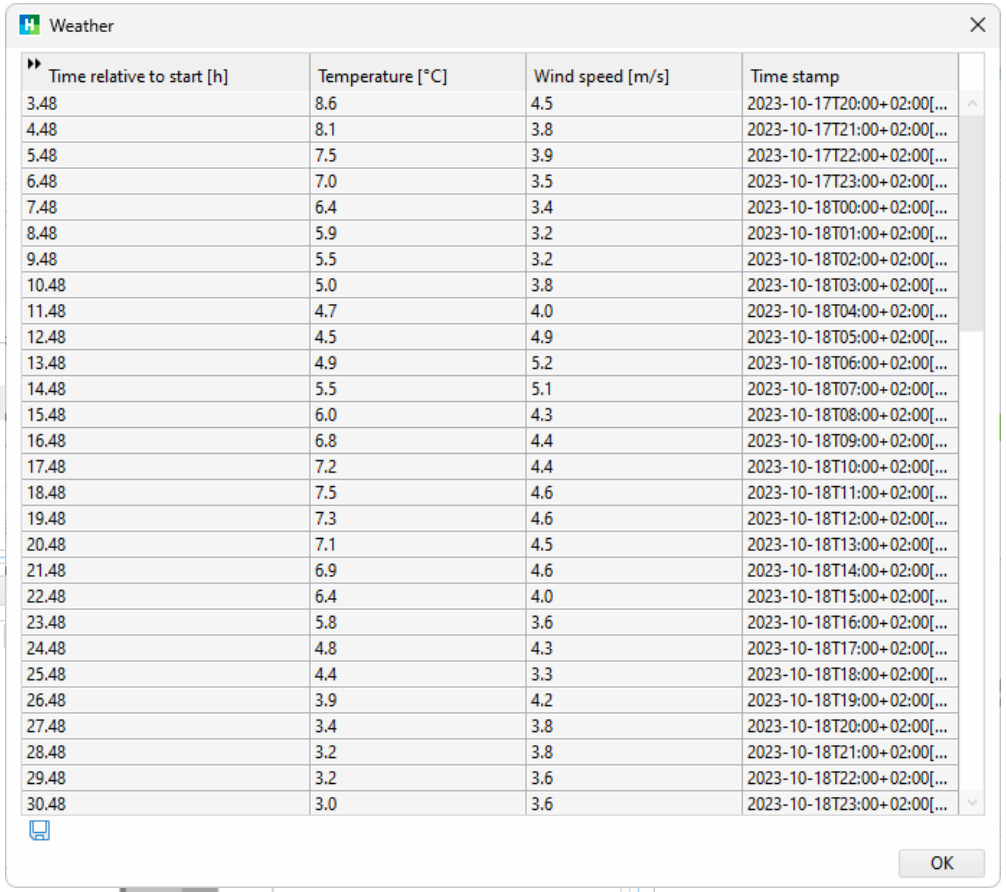
Forecasts





Time relative to start [h]	Temperature [°C]	Wind speed [m/s]	Time stamp
3.48	8.6	4.5	2023-10-17T20:00+02:00[...
4.48	8.1	3.8	2023-10-17T21:00+02:00[...
5.48	7.5	3.9	2023-10-17T22:00+02:00[...
6.48	7.0	3.5	2023-10-17T23:00+02:00[...
7.48	6.4	3.4	2023-10-18T00:00+02:00[...
8.48	5.9	3.2	2023-10-18T01:00+02:00[...
9.48	5.5	3.2	2023-10-18T02:00+02:00[...
10.48	5.0	3.8	2023-10-18T03:00+02:00[...
11.48	4.7	4.0	2023-10-18T04:00+02:00[...
12.48	4.5	4.9	2023-10-18T05:00+02:00[...
13.48	4.9	5.2	2023-10-18T06:00+02:00[...
14.48	5.5	5.1	2023-10-18T07:00+02:00[...
15.48	6.0	4.3	2023-10-18T08:00+02:00[...
16.48	6.8	4.4	2023-10-18T09:00+02:00[...
17.48	7.2	4.4	2023-10-18T10:00+02:00[...
18.48	7.5	4.6	2023-10-18T11:00+02:00[...
19.48	7.3	4.6	2023-10-18T12:00+02:00[...
20.48	7.1	4.5	2023-10-18T13:00+02:00[...
21.48	6.9	4.6	2023-10-18T14:00+02:00[...
22.48	6.4	4.0	2023-10-18T15:00+02:00[...
23.48	5.8	3.6	2023-10-18T16:00+02:00[...
24.48	4.8	4.3	2023-10-18T17:00+02:00[...
25.48	4.4	3.3	2023-10-18T18:00+02:00[...
26.48	3.9	4.2	2023-10-18T19:00+02:00[...
27.48	3.4	3.8	2023-10-18T20:00+02:00[...
28.48	3.2	3.8	2023-10-18T21:00+02:00[...
29.48	3.2	3.6	2023-10-18T22:00+02:00[...
30.48	3.0	3.6	2023-10-18T23:00+02:00[...

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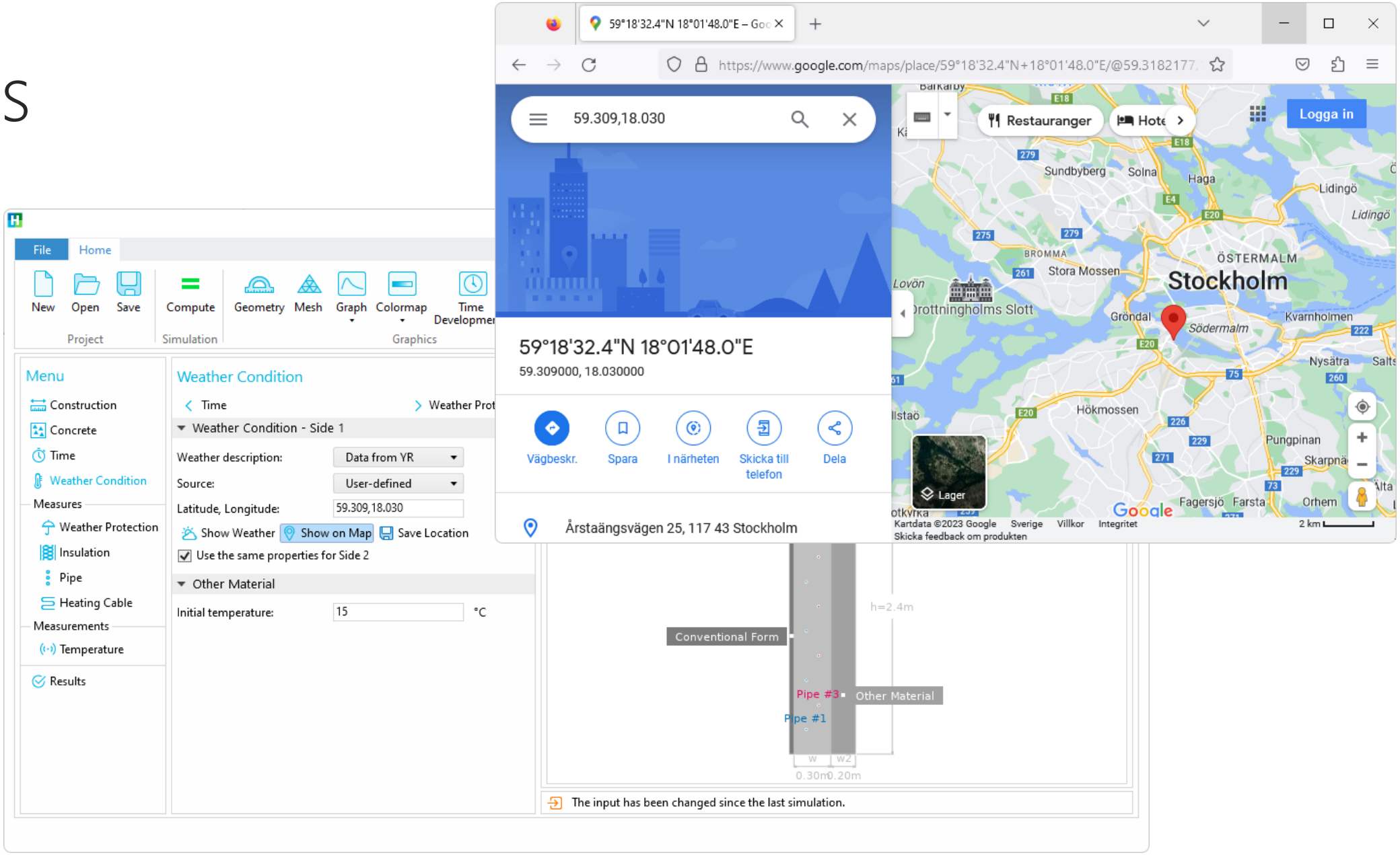
Maps



Tip: Right-click in Google Maps to get the location's coordinate!

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Sensor Data Import

Comparing simulations with measurements from construction sites

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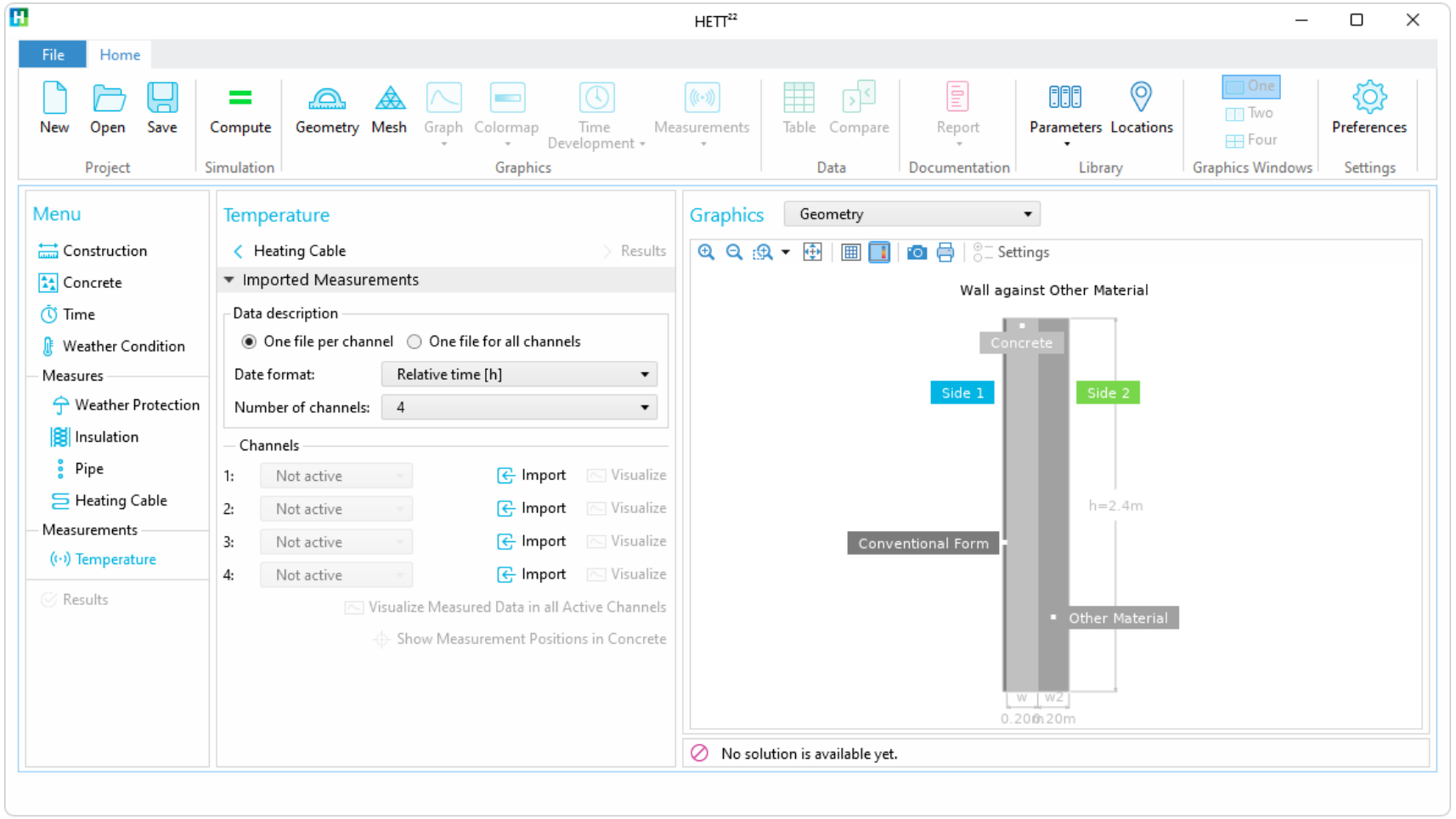
Sensor Data Import

- For improved accuracy and validation, HETT[22] enables users to import sensor data measurements from construction sites, facilitating a direct comparison between simulation and real-world observations
- Supports multiple sensor data formats and importing data from a Microsoft® Excel® file is straightforward
- Sensors can be placed both in the air and inside the concrete
  - If a temperature sensor is situated inside the concrete, a 1D simulation will convert the temperature data to strength, allowing for comparison with the results generated by the 2D simulation

Sensor Data Import



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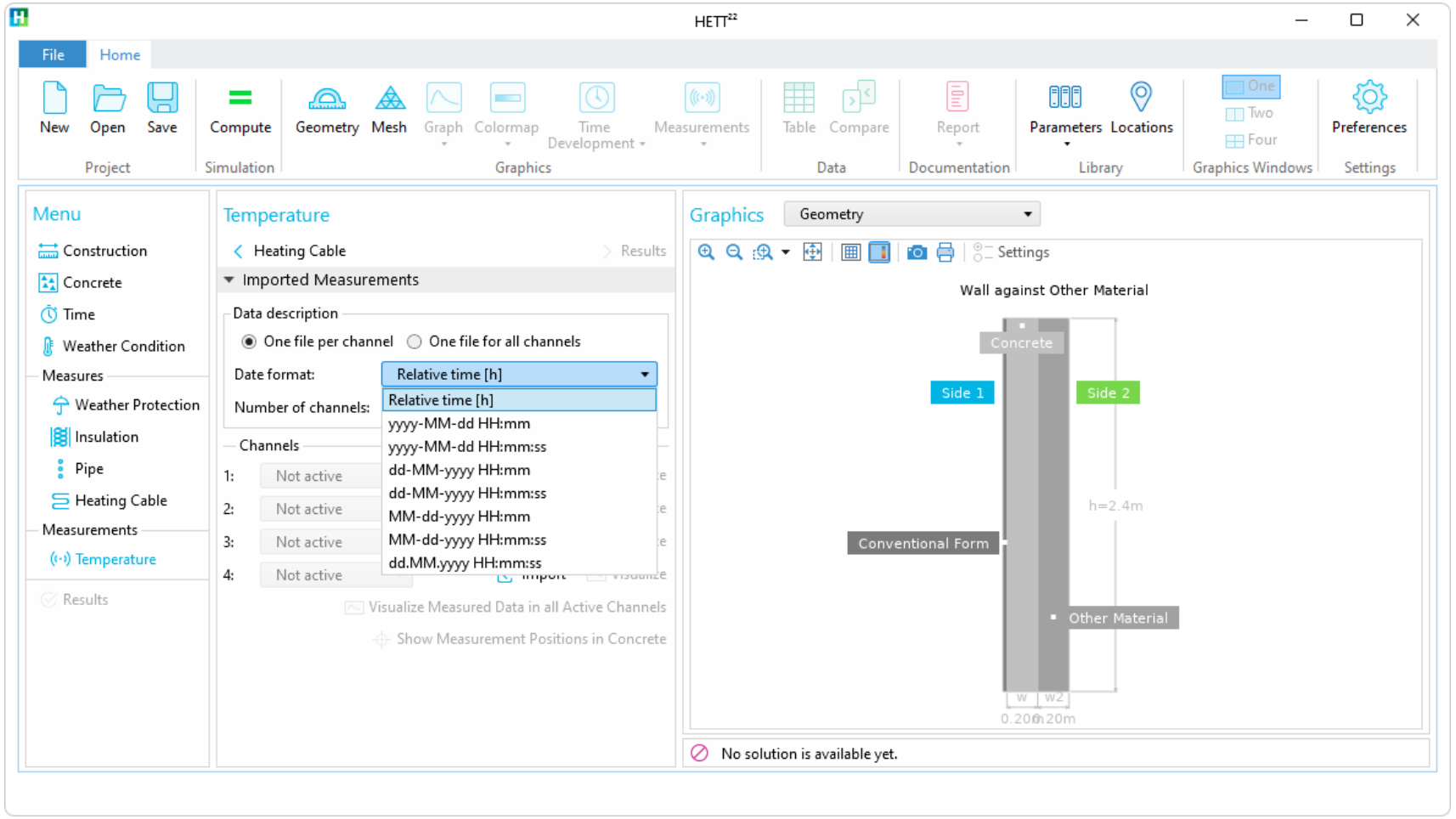
Sensor Data Import



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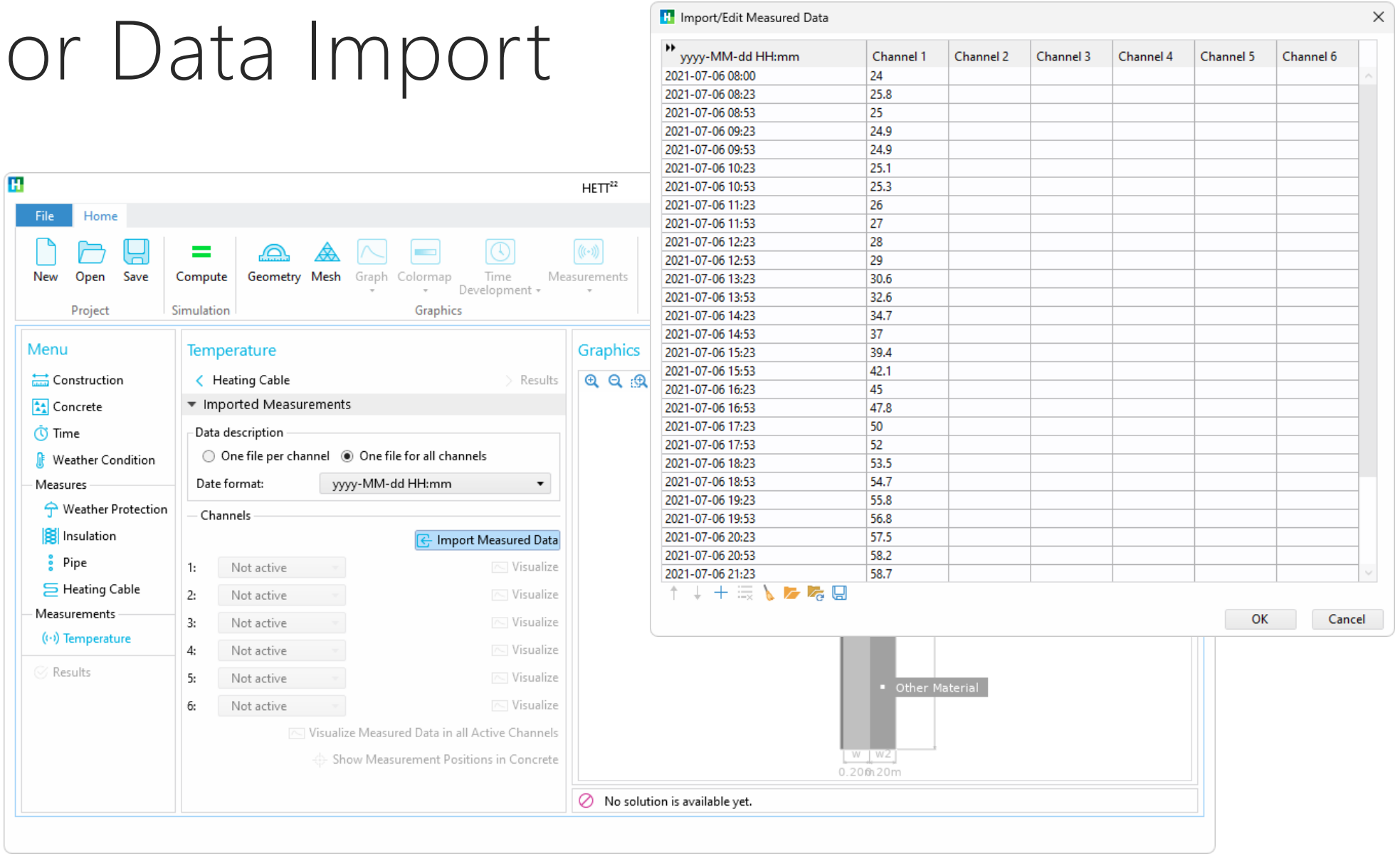
Sensor Data Import



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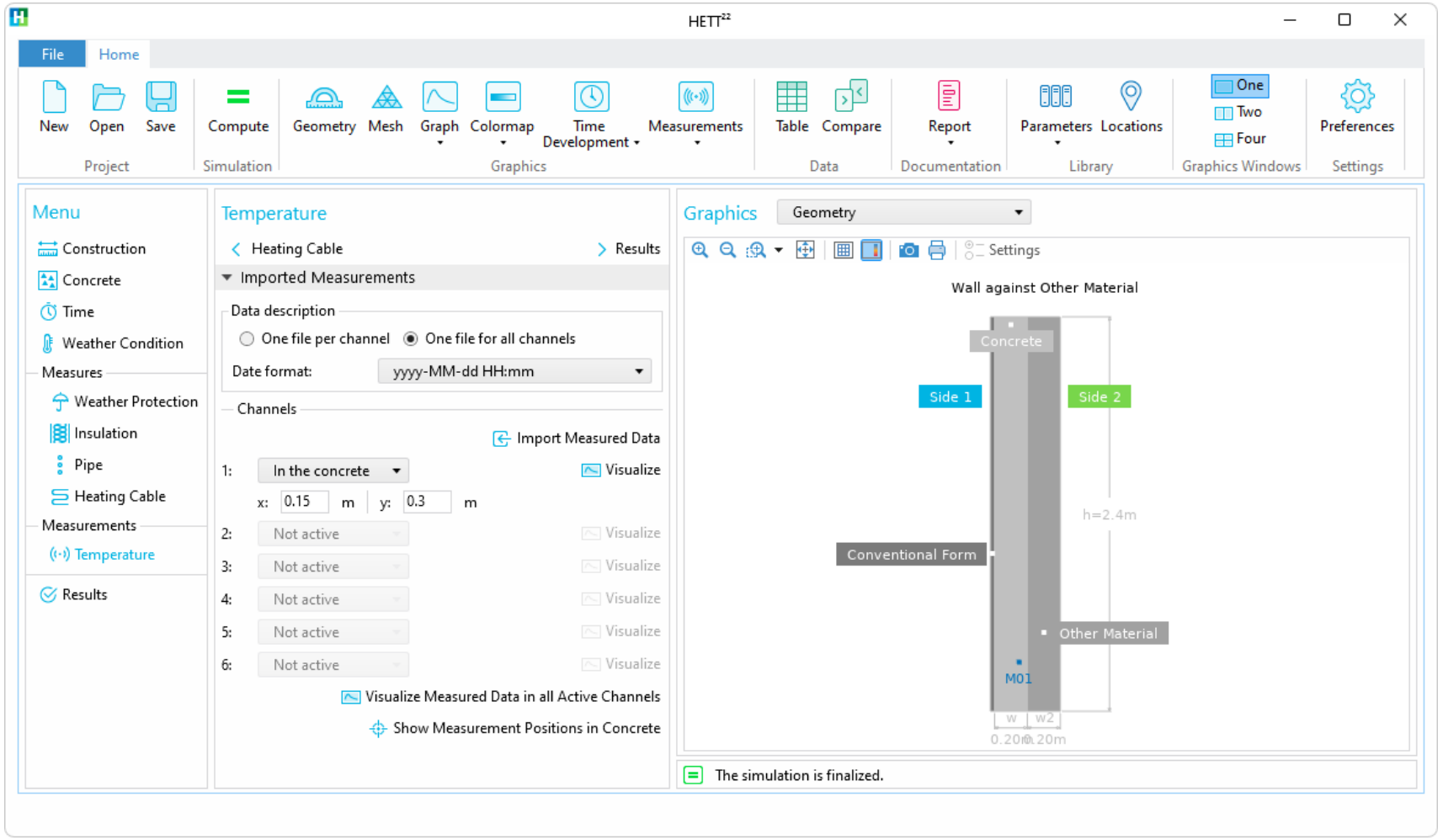
Sensor Positions



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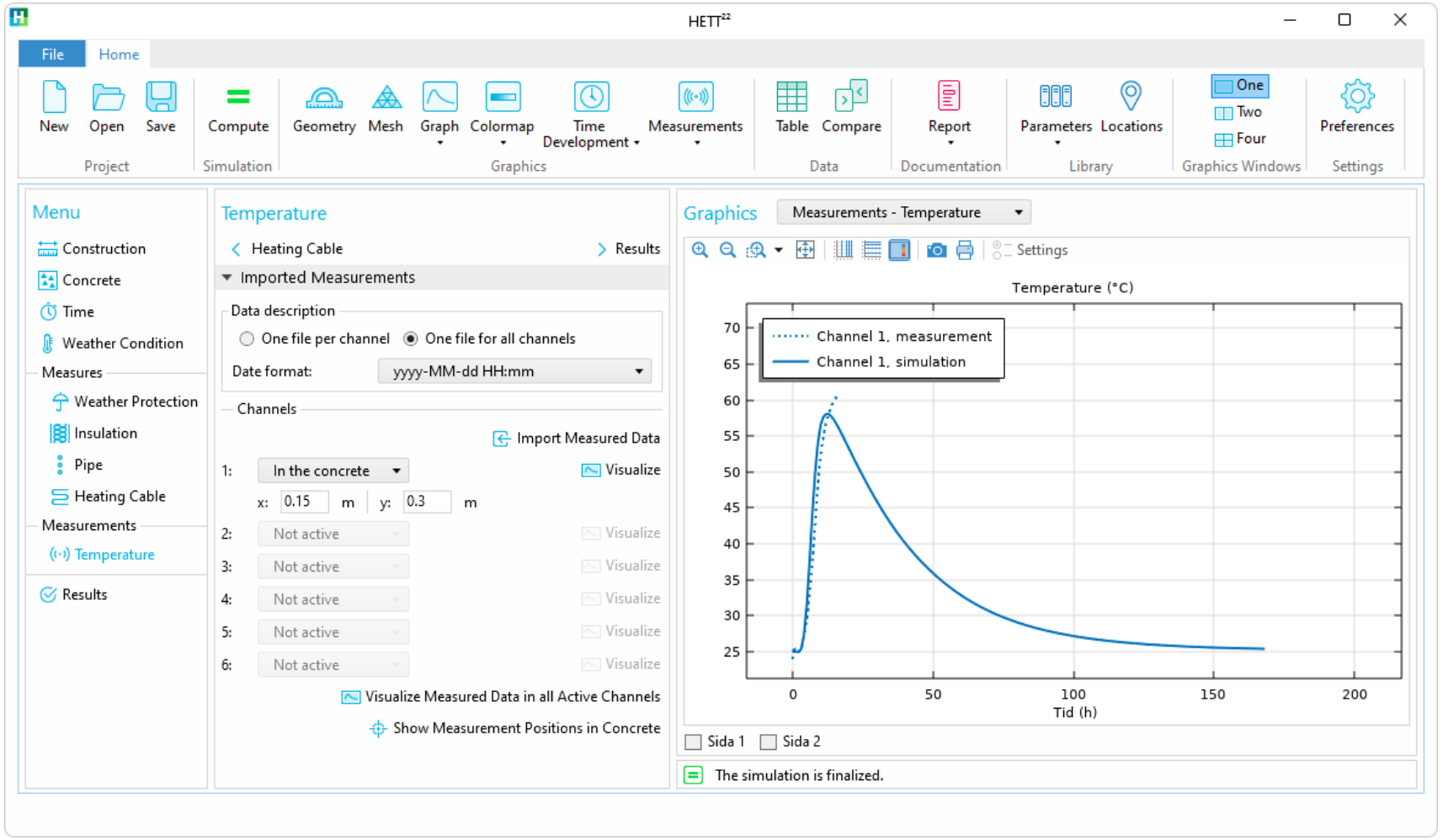
Measurements & Simulation



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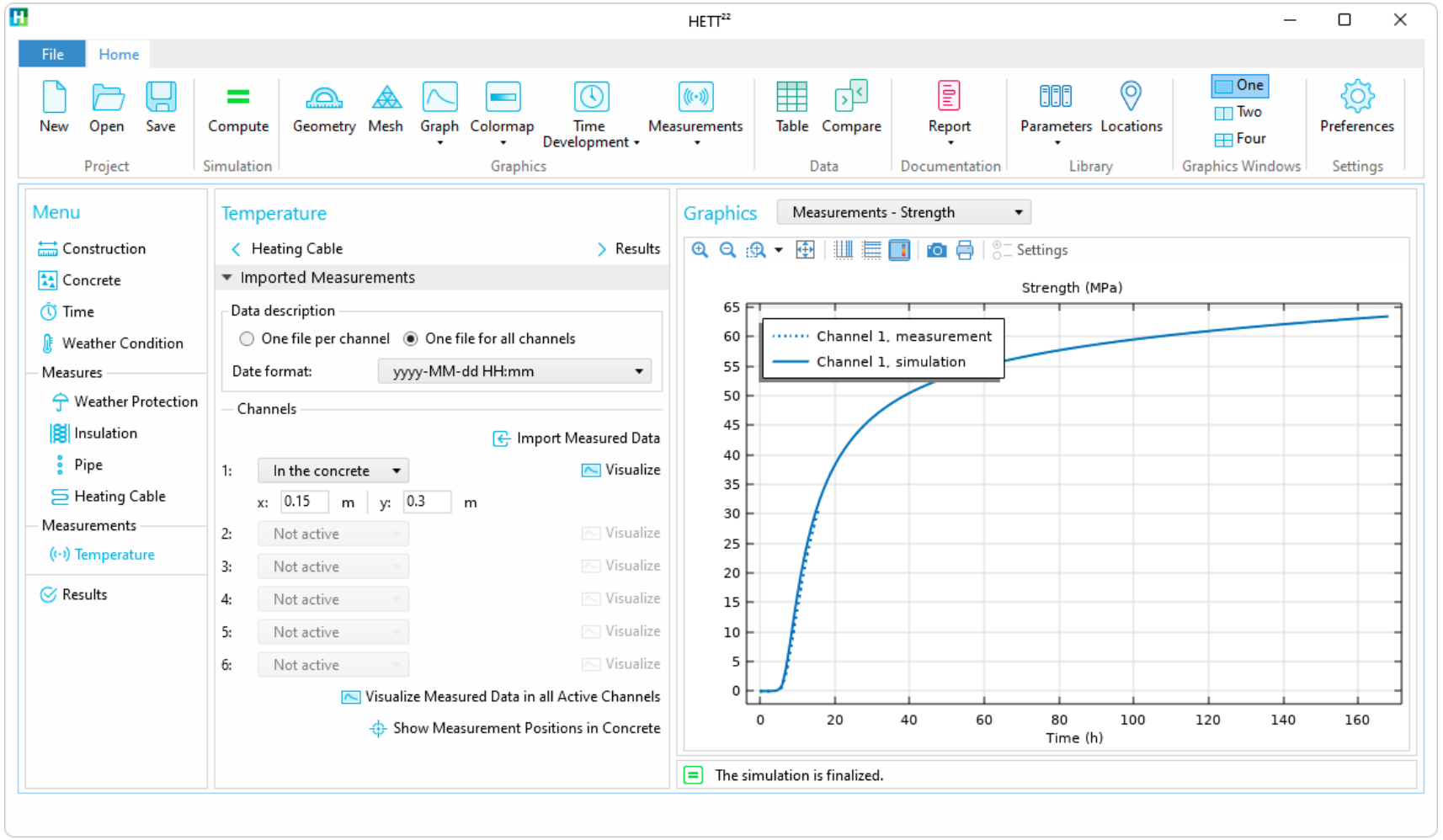
Measurements & Simulation



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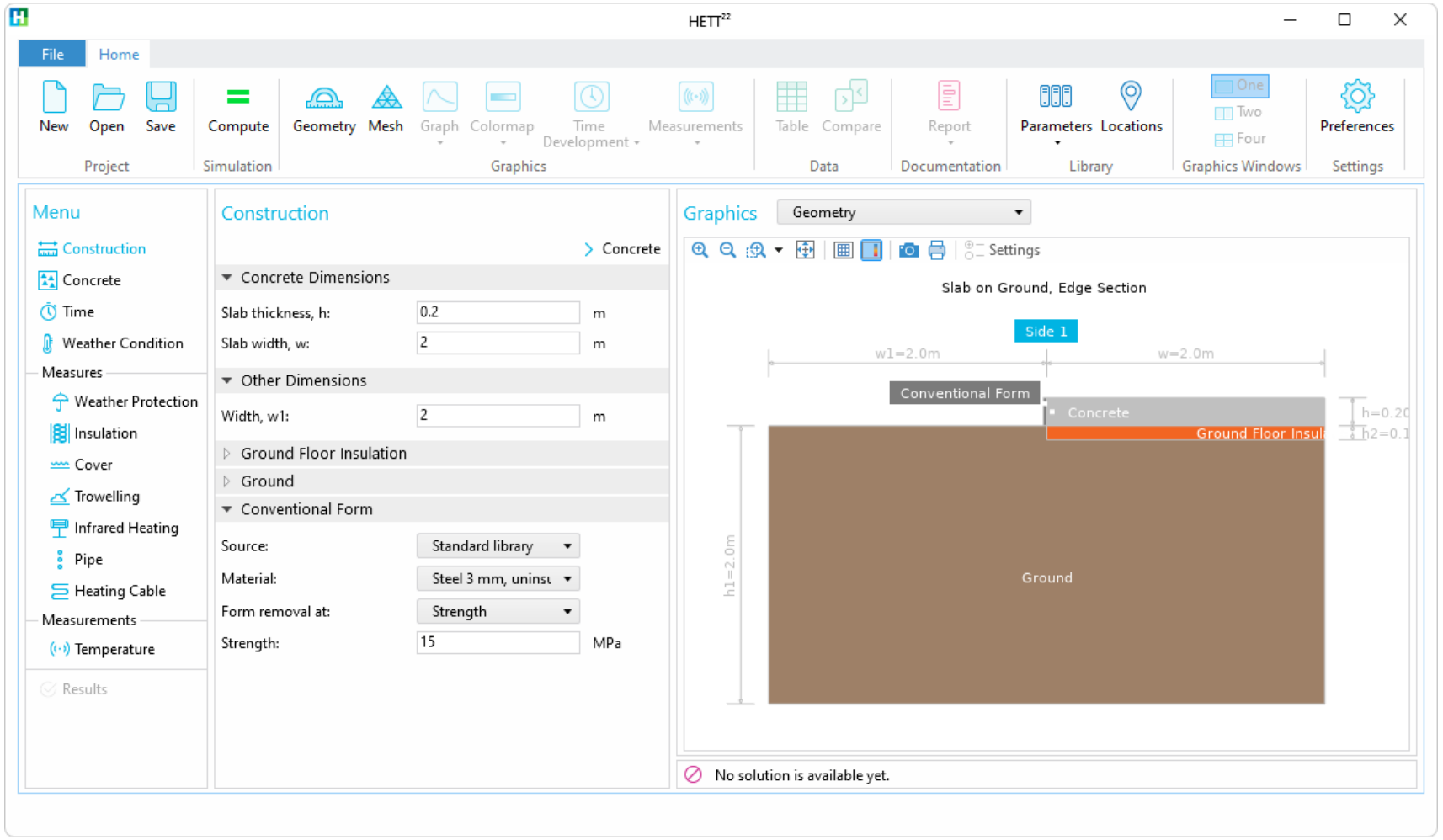
Libraries

An extensive library of construction materials and more

Libraries

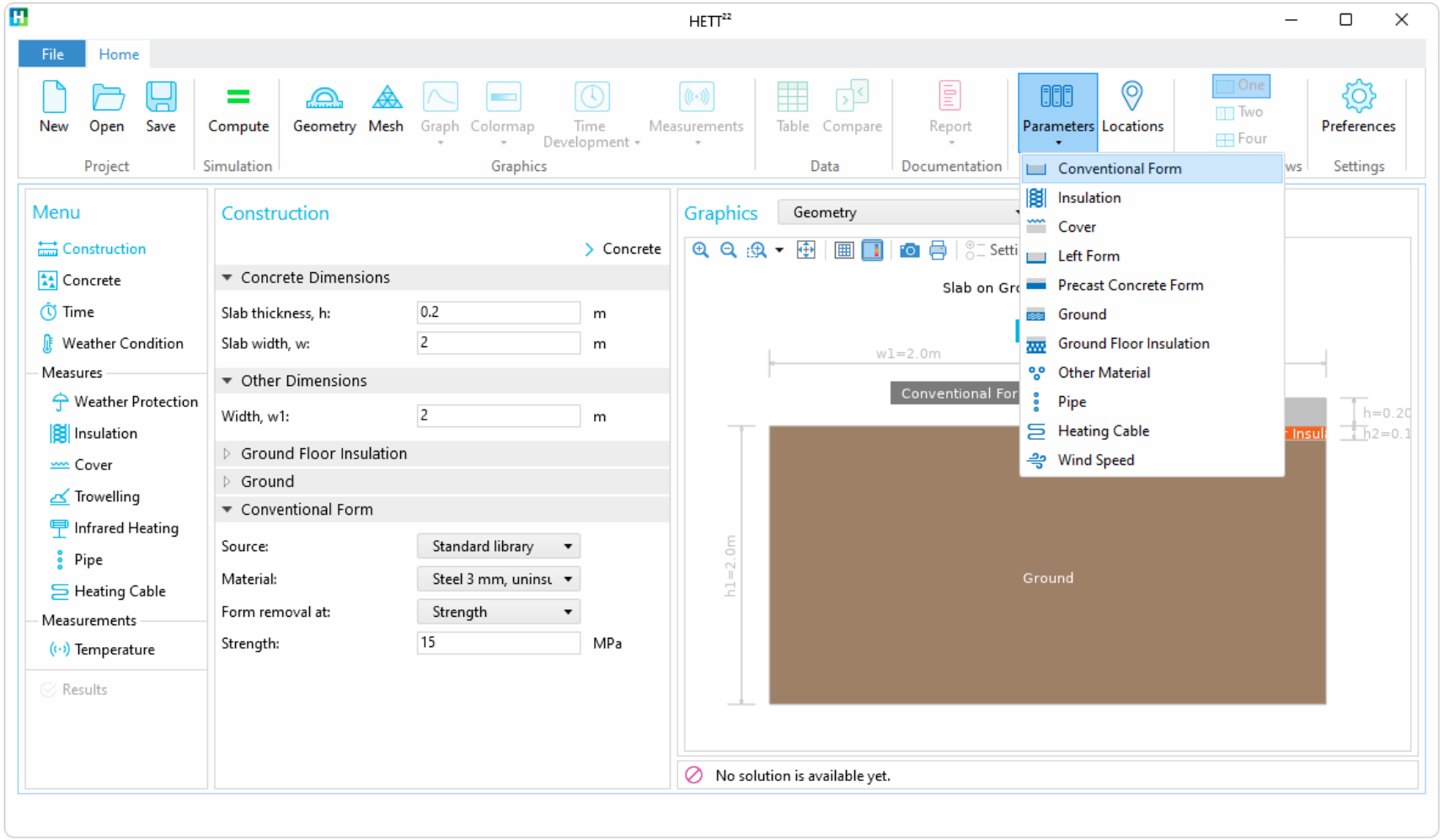
- Features an extensive library of construction materials
- Rather than manually inputting e.g., thermal conductivity, density, and heat capacity for specific materials, users can conveniently select materials from combo-boxes
- Besides the pre-installed standard library, users have the option to expand their library
- Also contains a library for construction site locations

Material Library



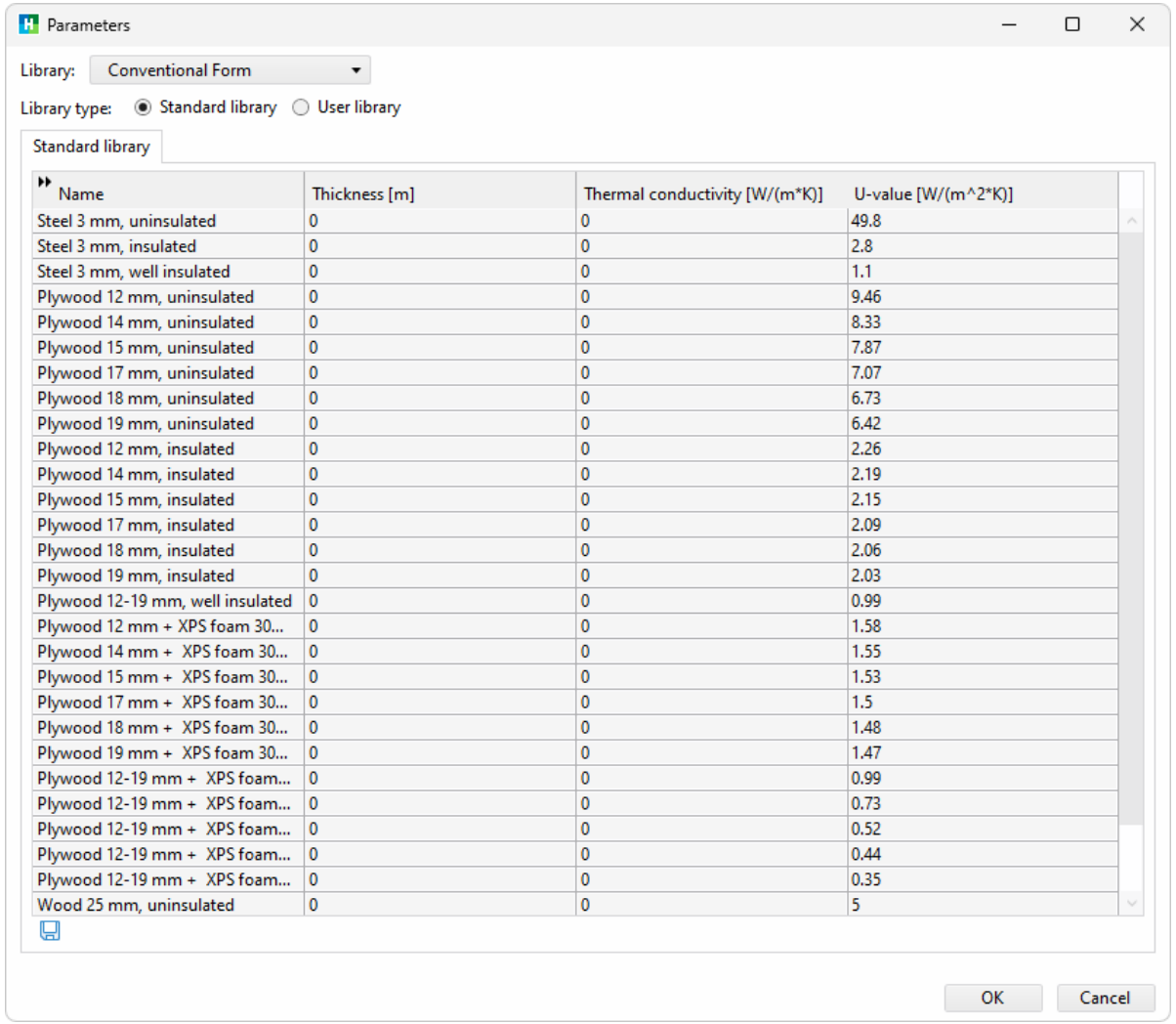
deflexional

Material Library



deflexional

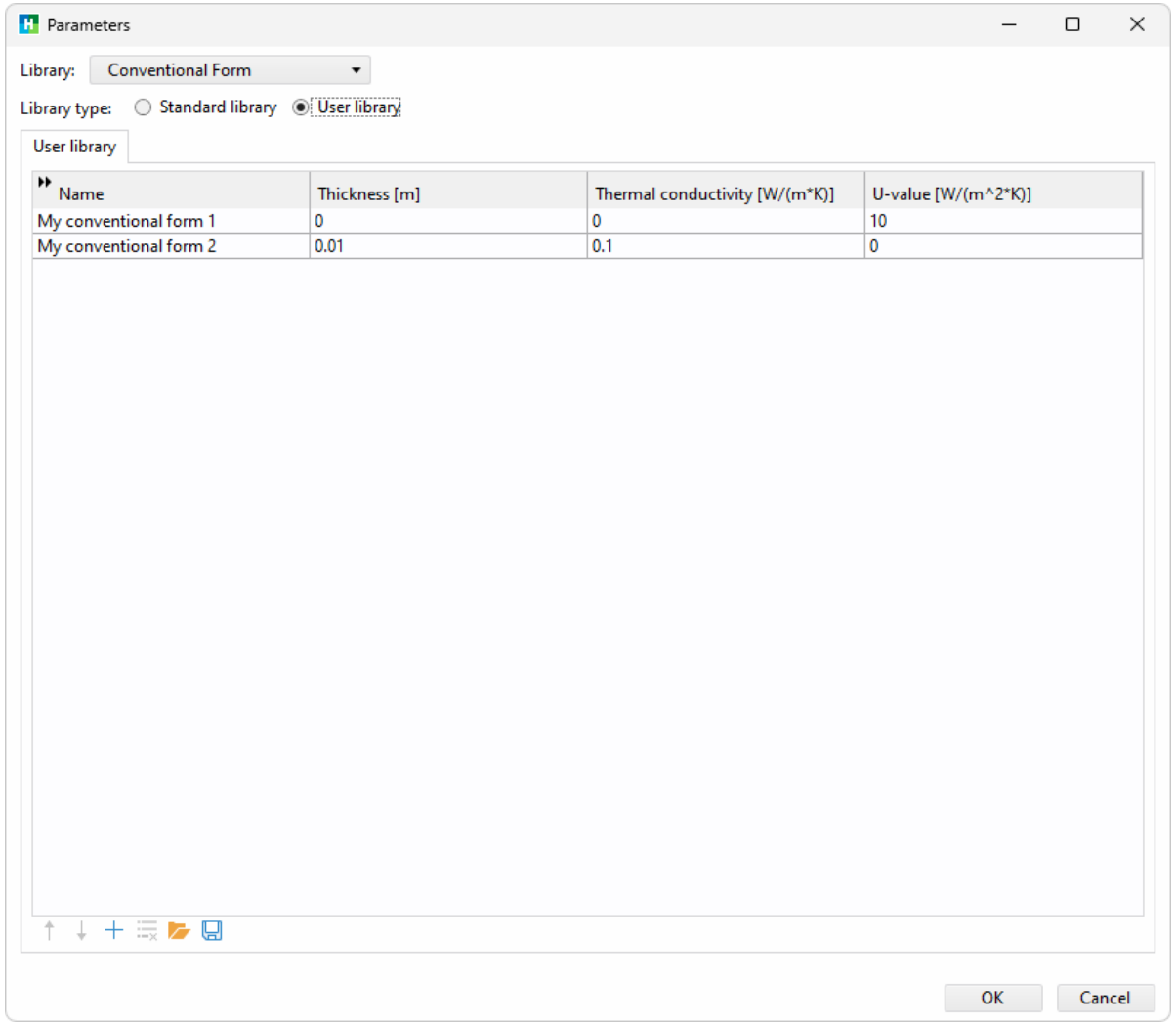
Material Library



Name	Thickness [m]	Thermal conductivity [W/(m*K)]	U-value [W/(m^2*K)]
Steel 3 mm, uninsulated	0	0	49.8
Steel 3 mm, insulated	0	0	2.8
Steel 3 mm, well insulated	0	0	1.1
Plywood 12 mm, uninsulated	0	0	9.46
Plywood 14 mm, uninsulated	0	0	8.33
Plywood 15 mm, uninsulated	0	0	7.87
Plywood 17 mm, uninsulated	0	0	7.07
Plywood 18 mm, uninsulated	0	0	6.73
Plywood 19 mm, uninsulated	0	0	6.42
Plywood 12 mm, insulated	0	0	2.26
Plywood 14 mm, insulated	0	0	2.19
Plywood 15 mm, insulated	0	0	2.15
Plywood 17 mm, insulated	0	0	2.09
Plywood 18 mm, insulated	0	0	2.06
Plywood 19 mm, insulated	0	0	2.03
Plywood 12-19 mm, well insulated	0	0	0.99
Plywood 12 mm + XPS foam 30...	0	0	1.58
Plywood 14 mm + XPS foam 30...	0	0	1.55
Plywood 15 mm + XPS foam 30...	0	0	1.53
Plywood 17 mm + XPS foam 30...	0	0	1.5
Plywood 18 mm + XPS foam 30...	0	0	1.48
Plywood 19 mm + XPS foam 30...	0	0	1.47
Plywood 12-19 mm + XPS foam...	0	0	0.99
Plywood 12-19 mm + XPS foam...	0	0	0.73
Plywood 12-19 mm + XPS foam...	0	0	0.52
Plywood 12-19 mm + XPS foam...	0	0	0.44
Plywood 12-19 mm + XPS foam...	0	0	0.35
Wood 25 mm, uninsulated	0	0	5

deflexional

Material Library



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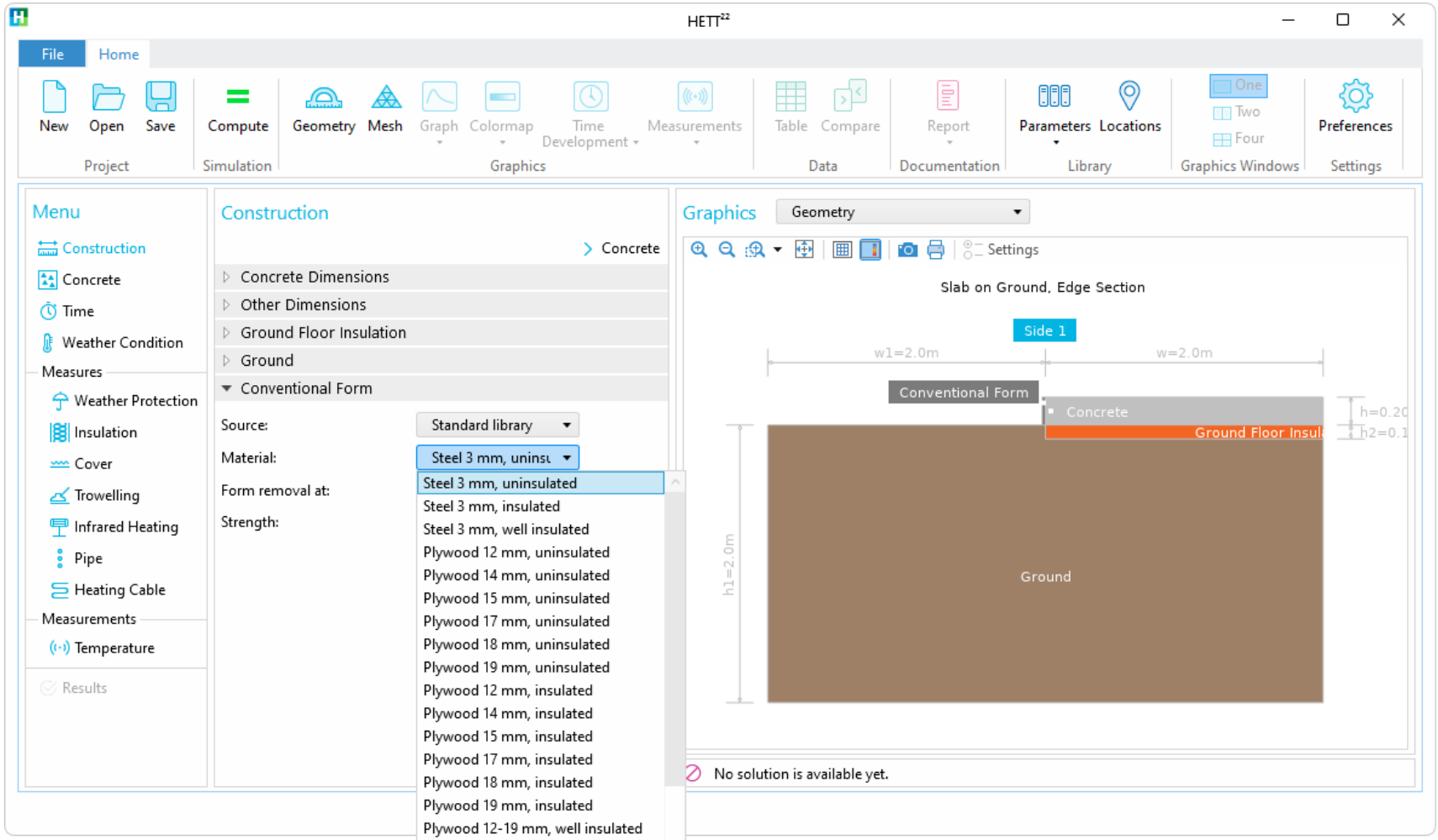

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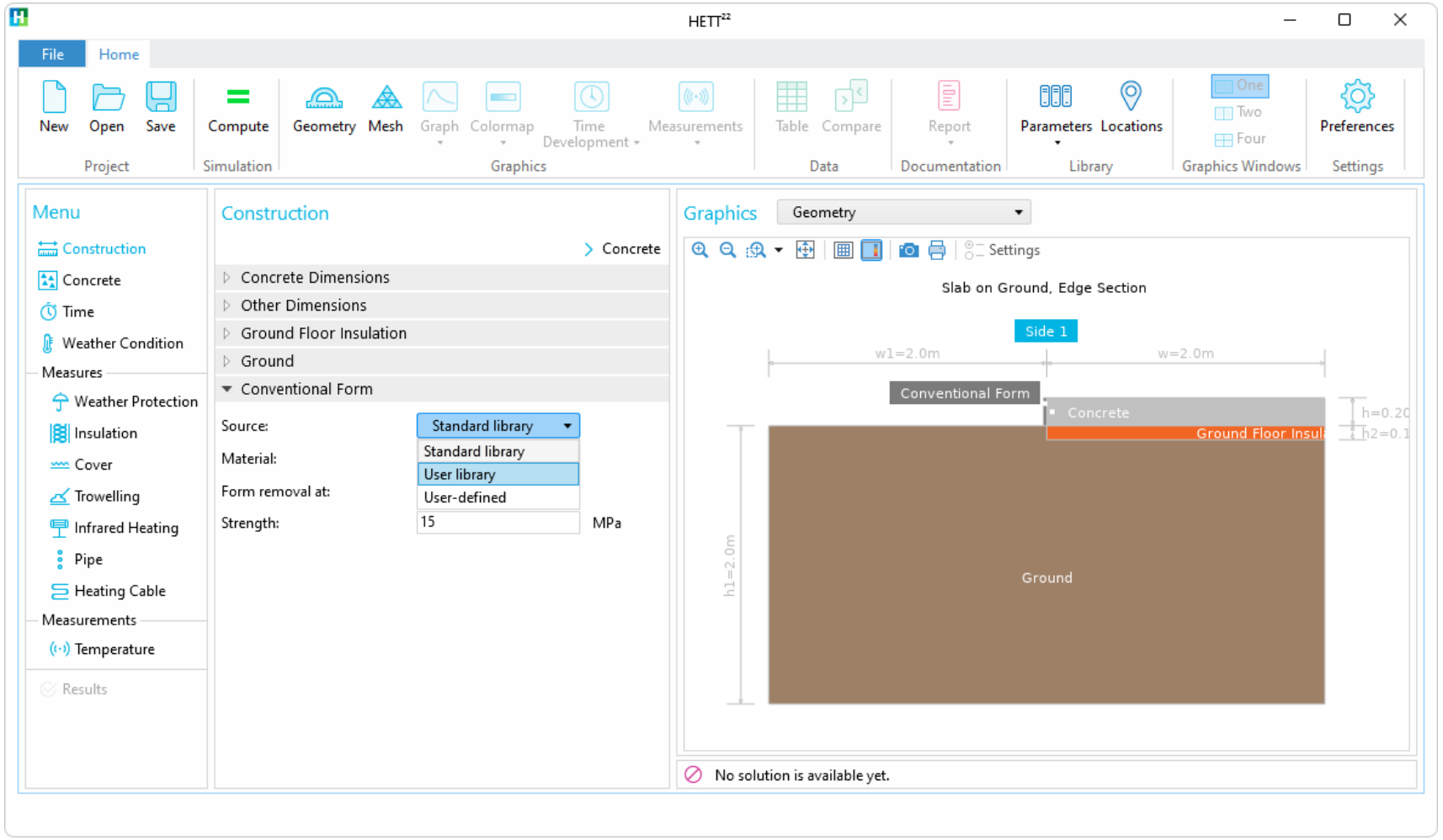

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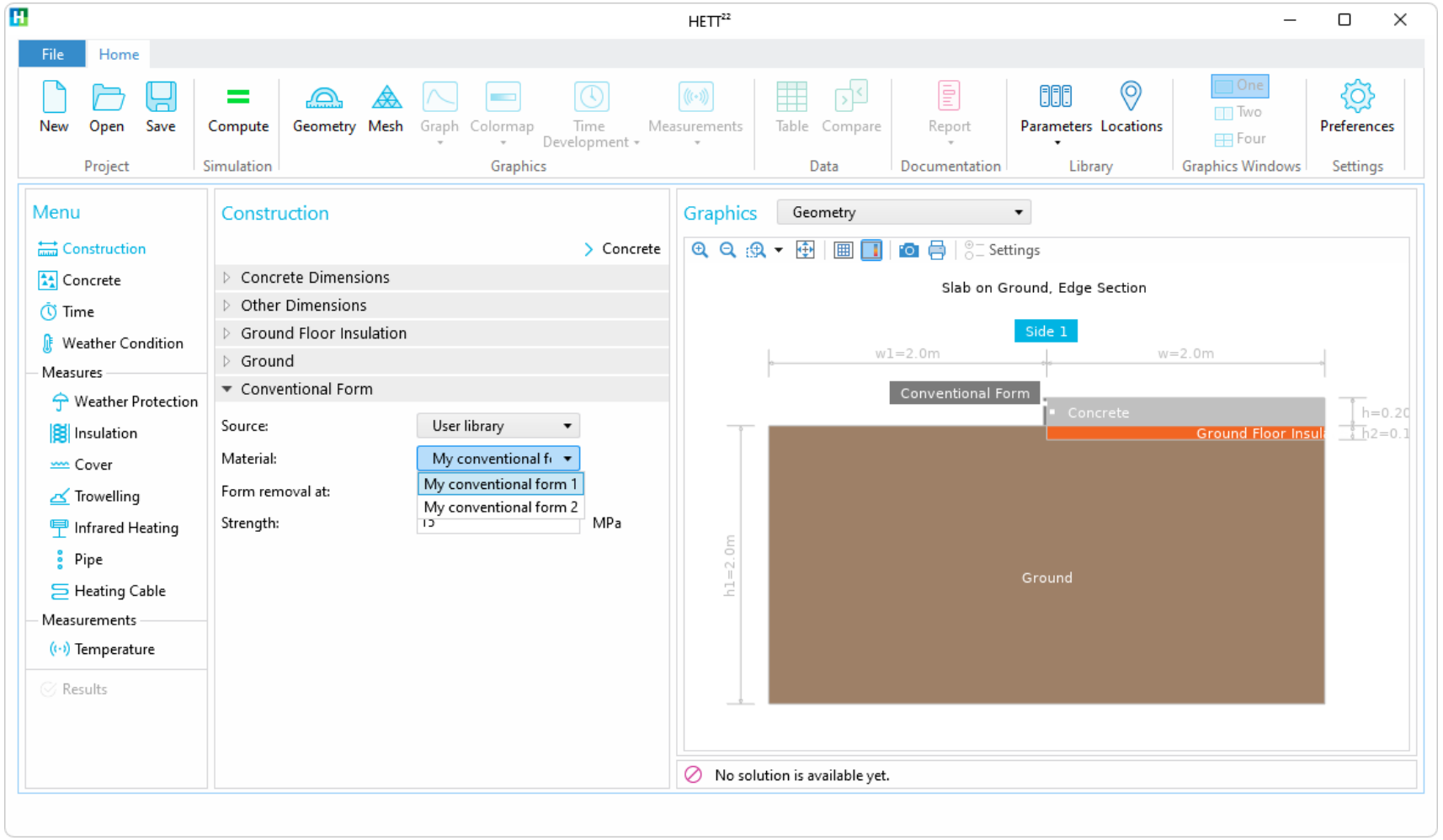

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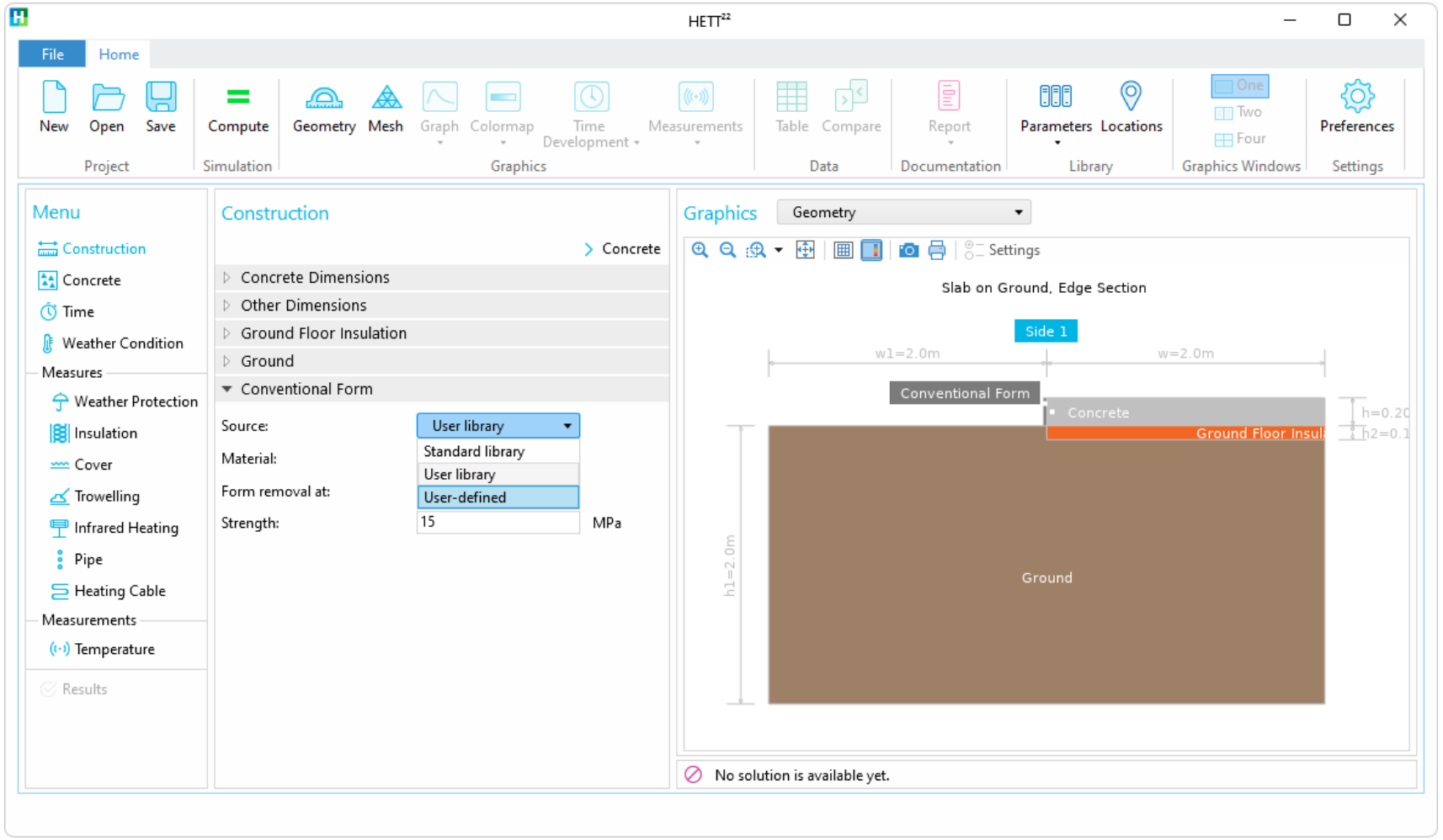

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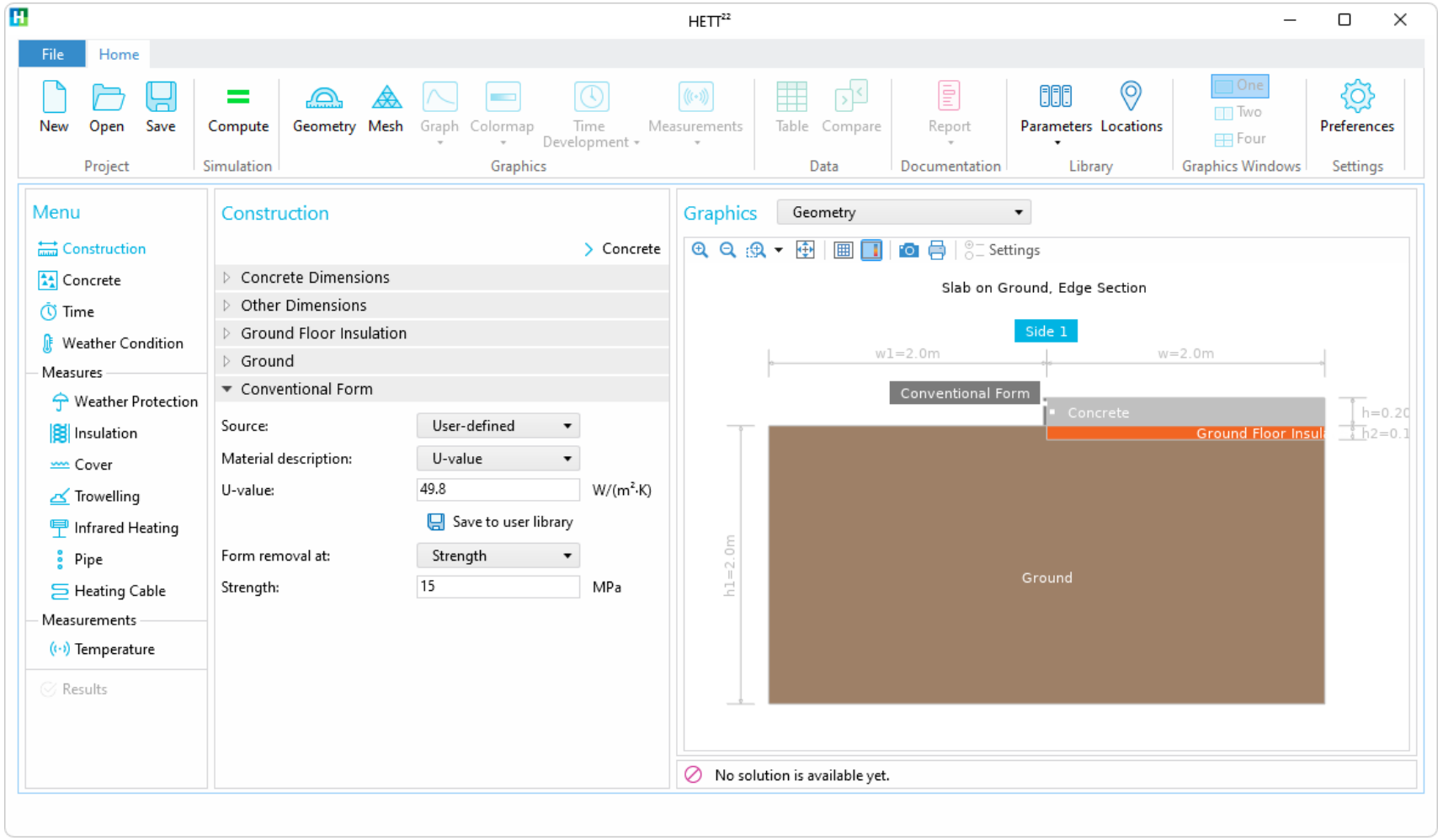

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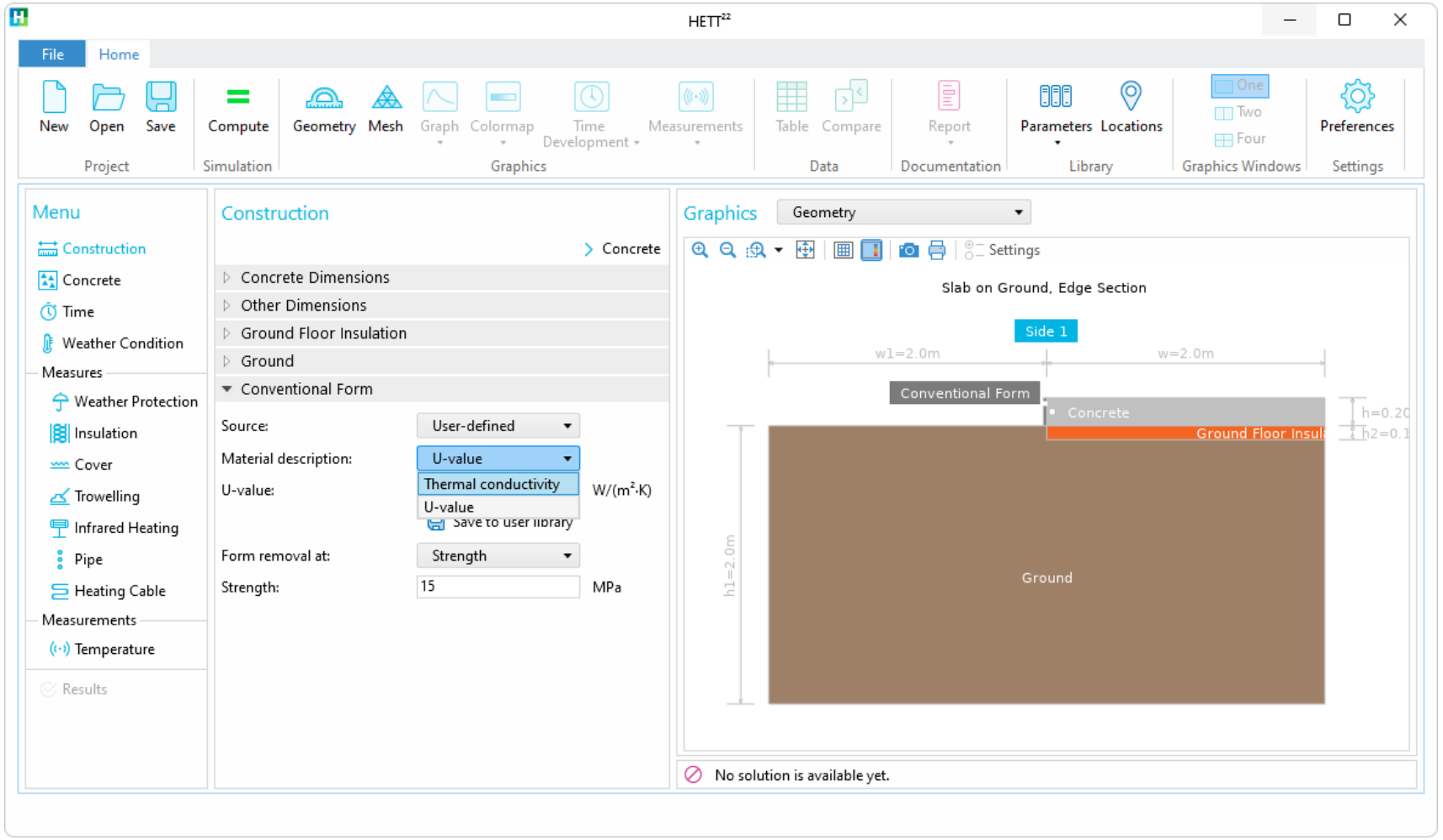

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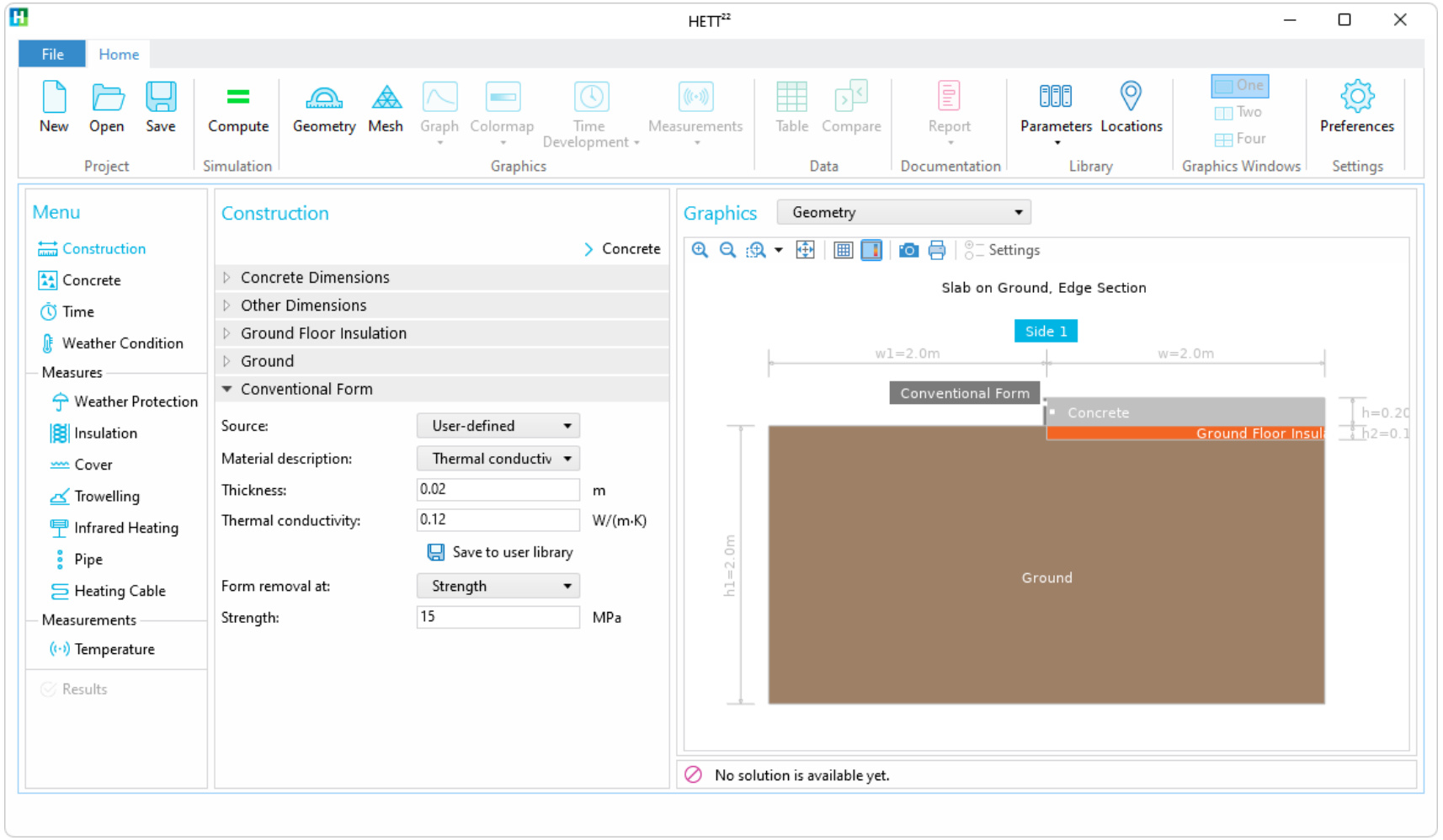

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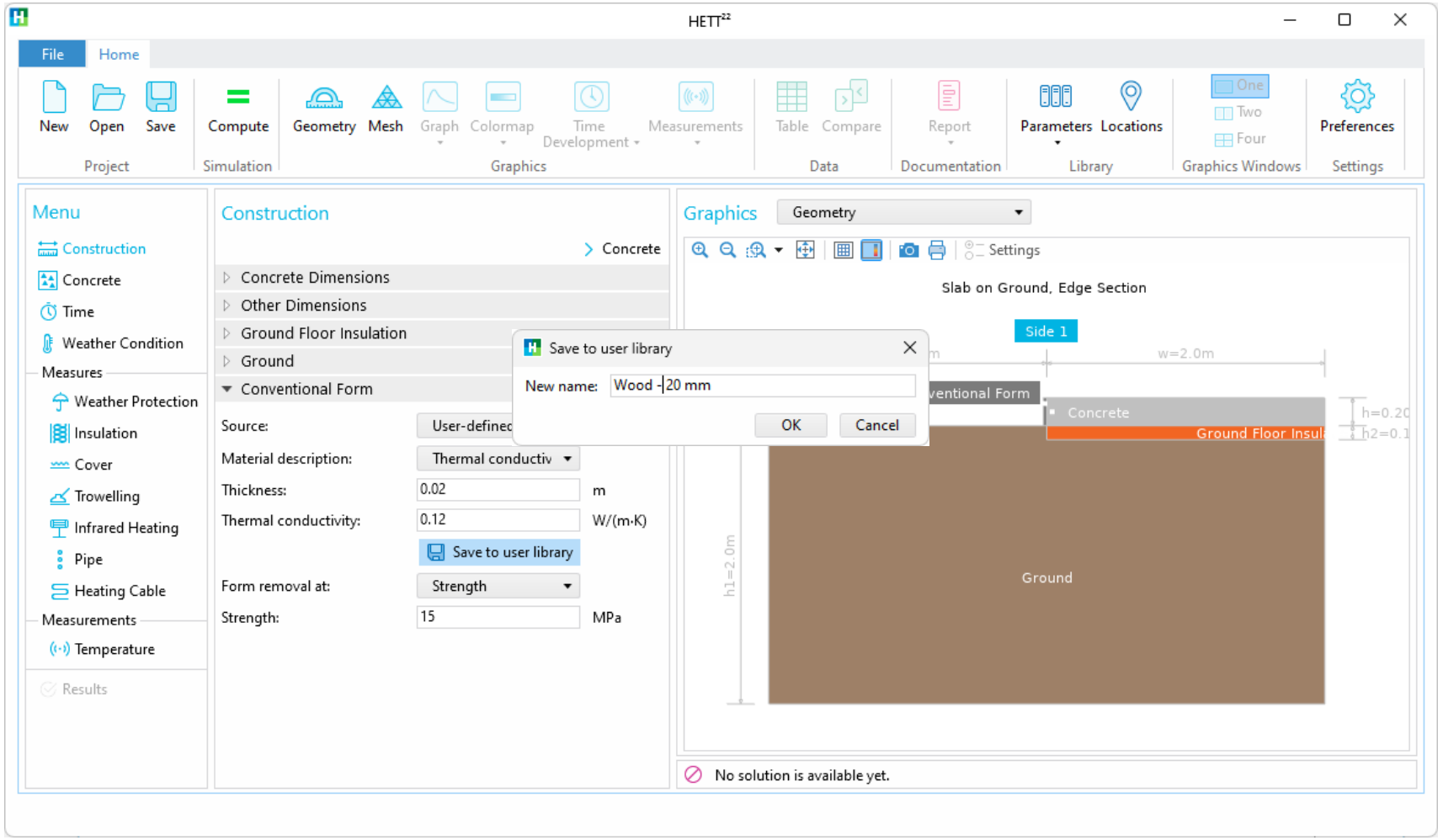

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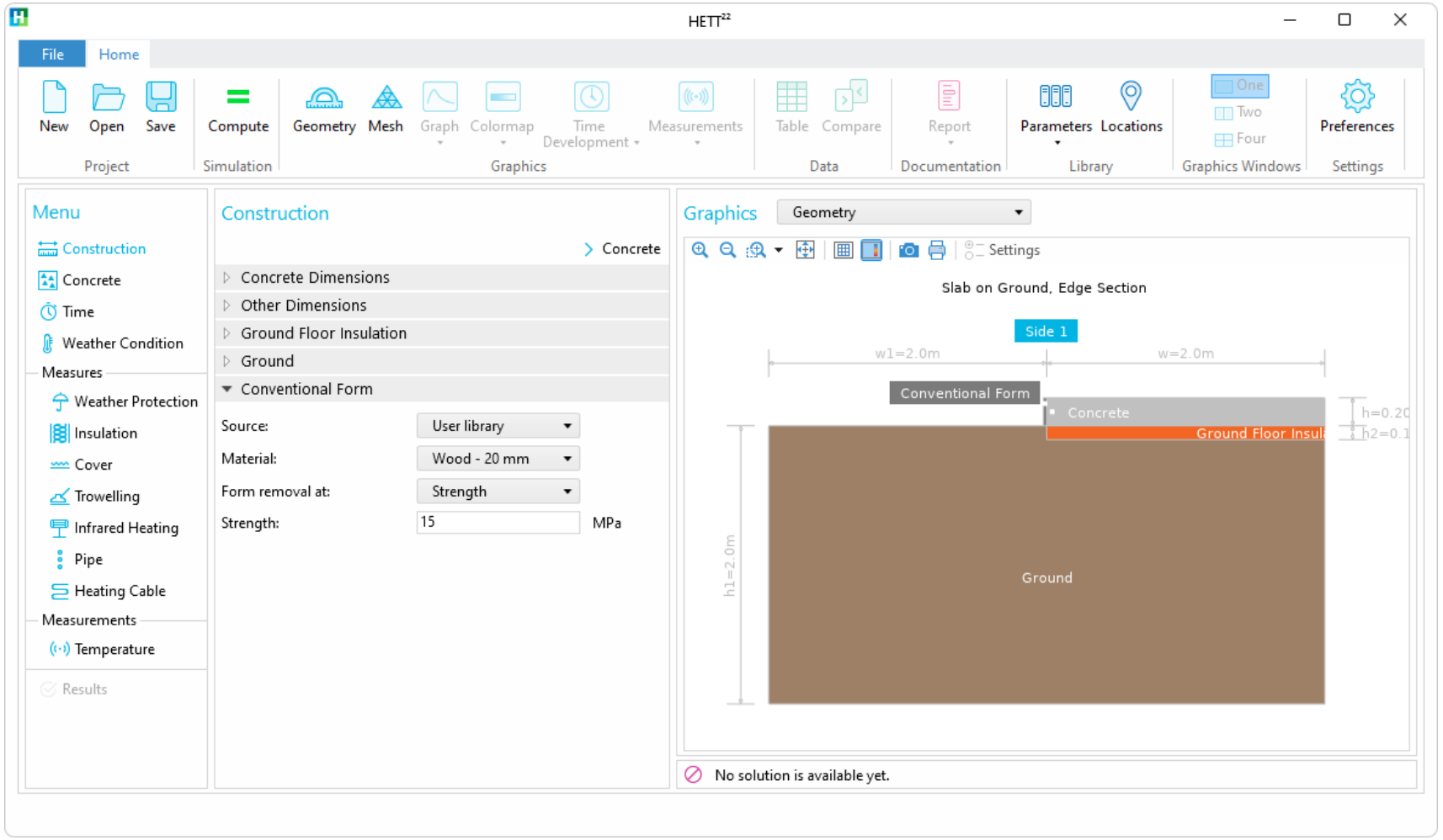

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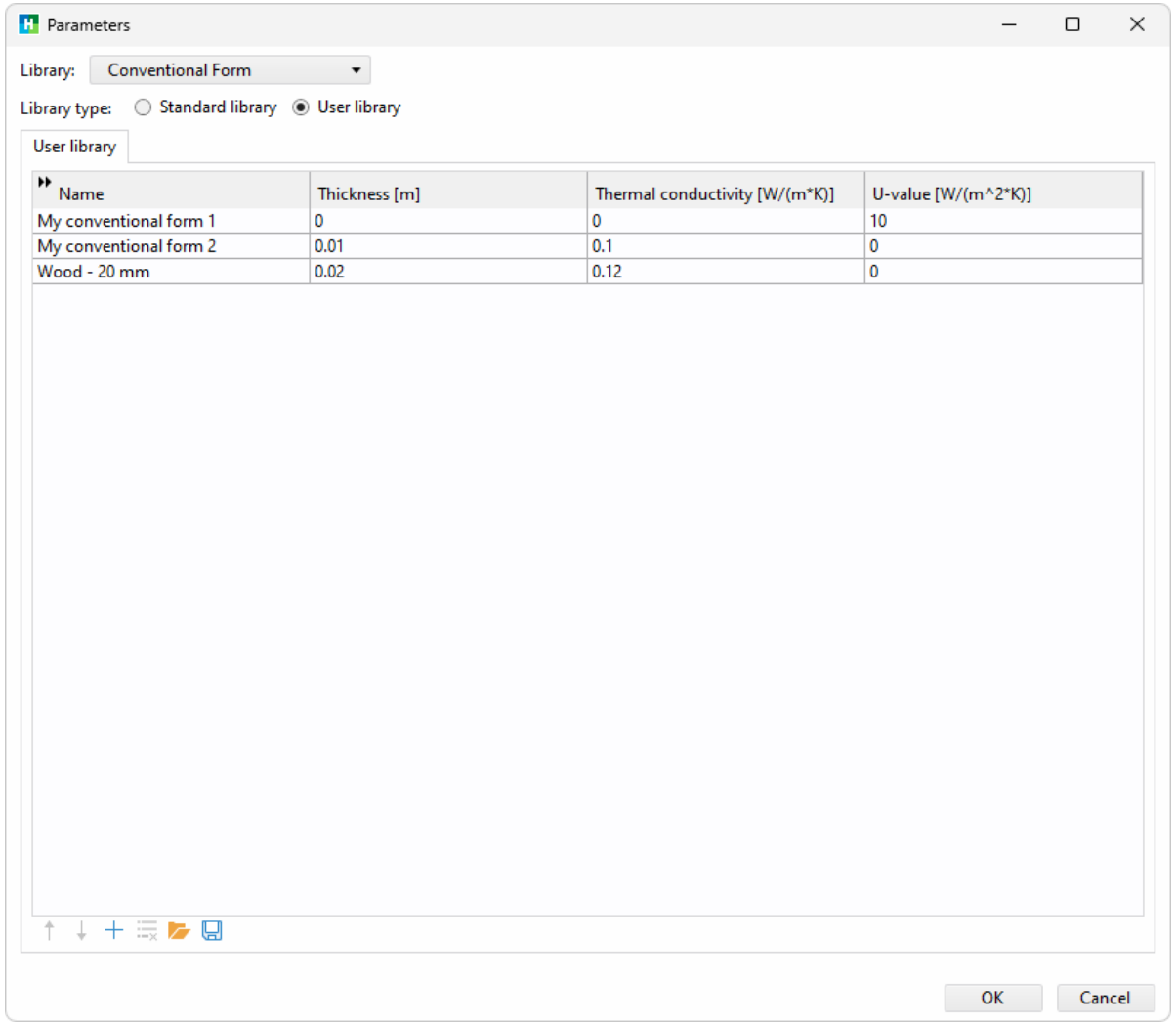

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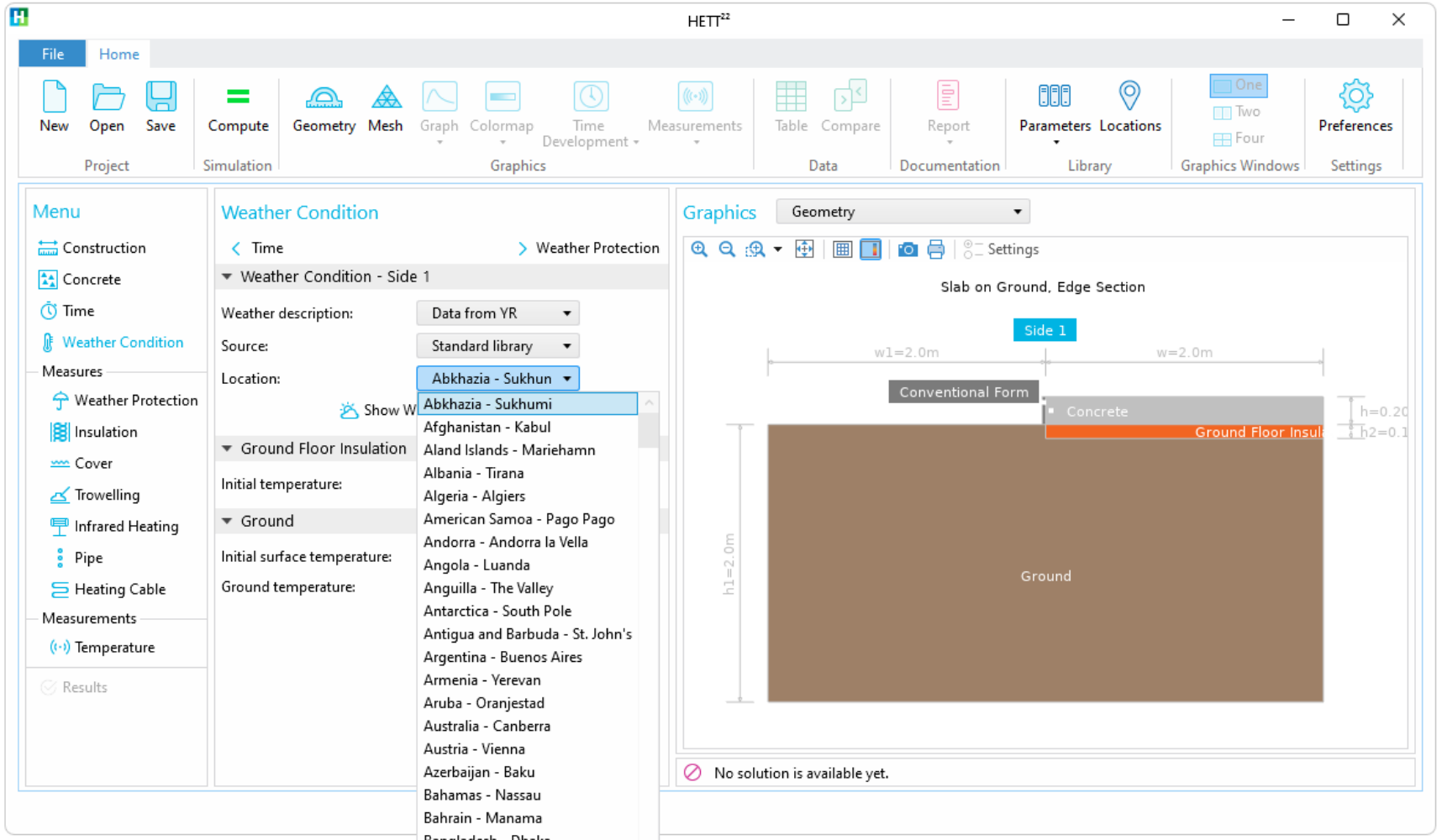
Locations



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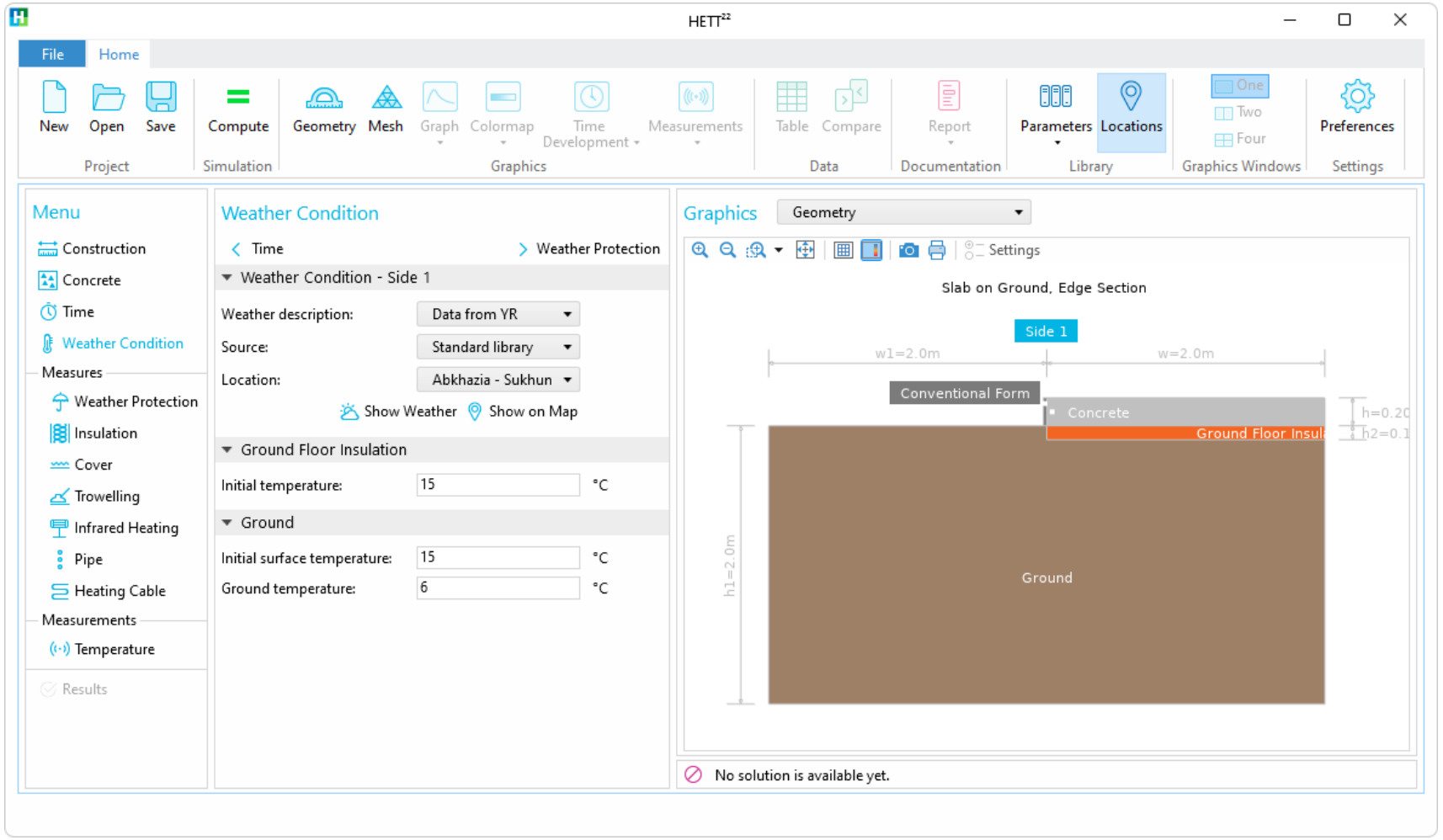
Locations



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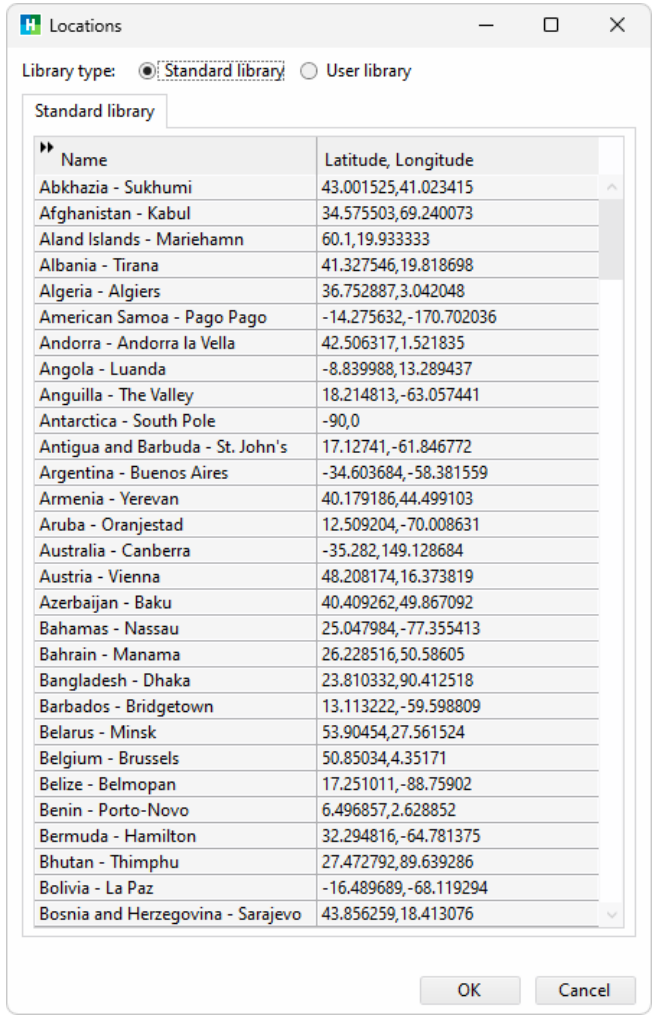
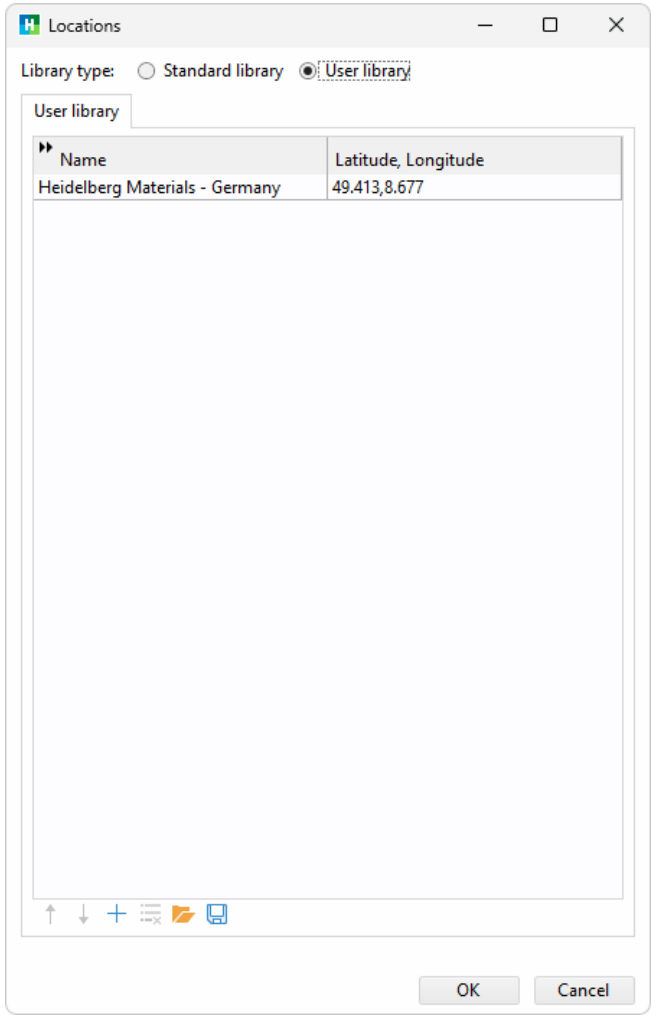
Locations





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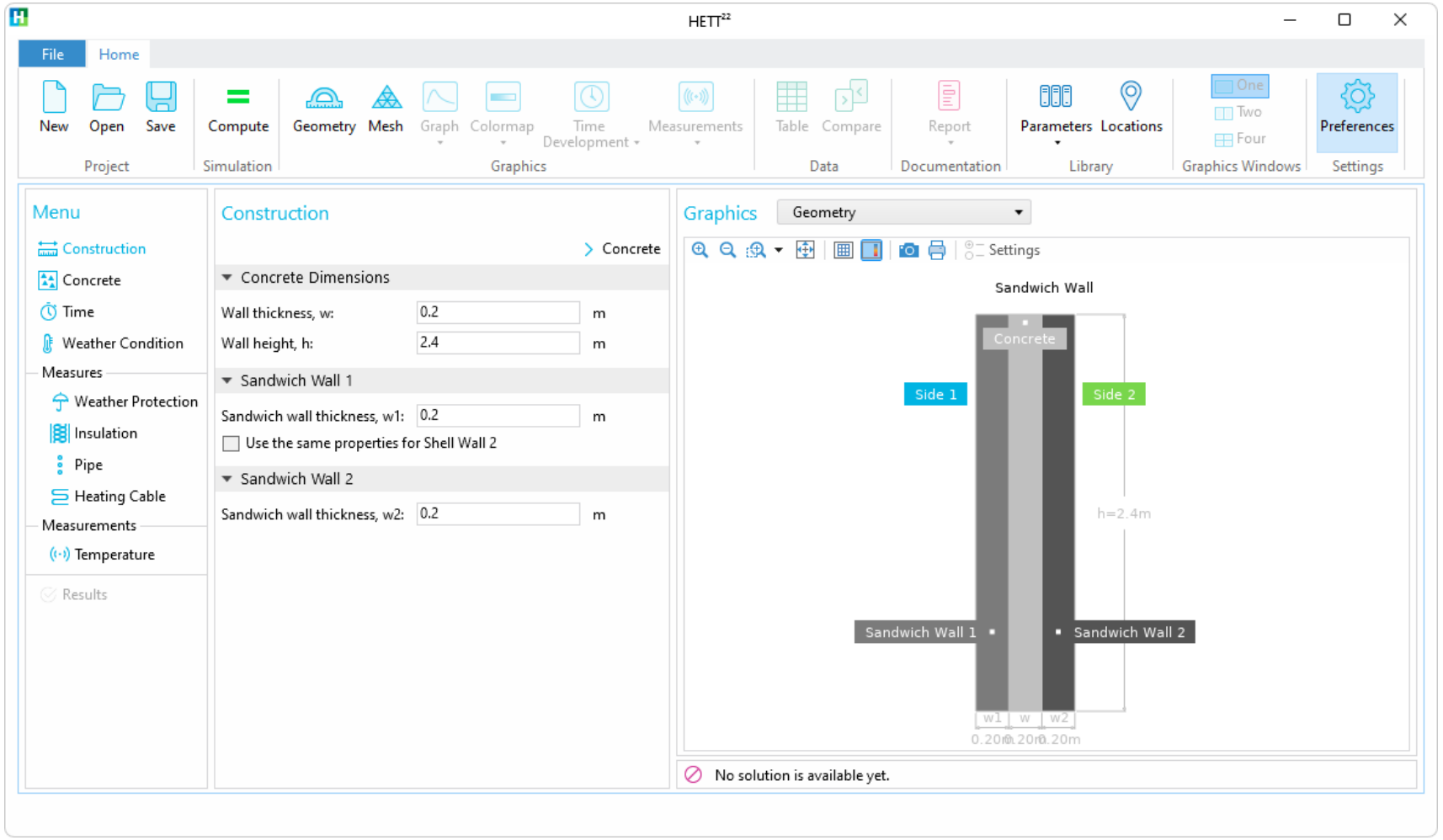
Regional Support

Supported languages include Swedish, Norwegian, and English

Languages

- The translations are integrated as an Excel file, making it easy to add additional languages in the future
- Apart from language support, it's worth noting that the background equations differ somewhat for the two type of concrete libraries supported in HETT[22]

Preferences



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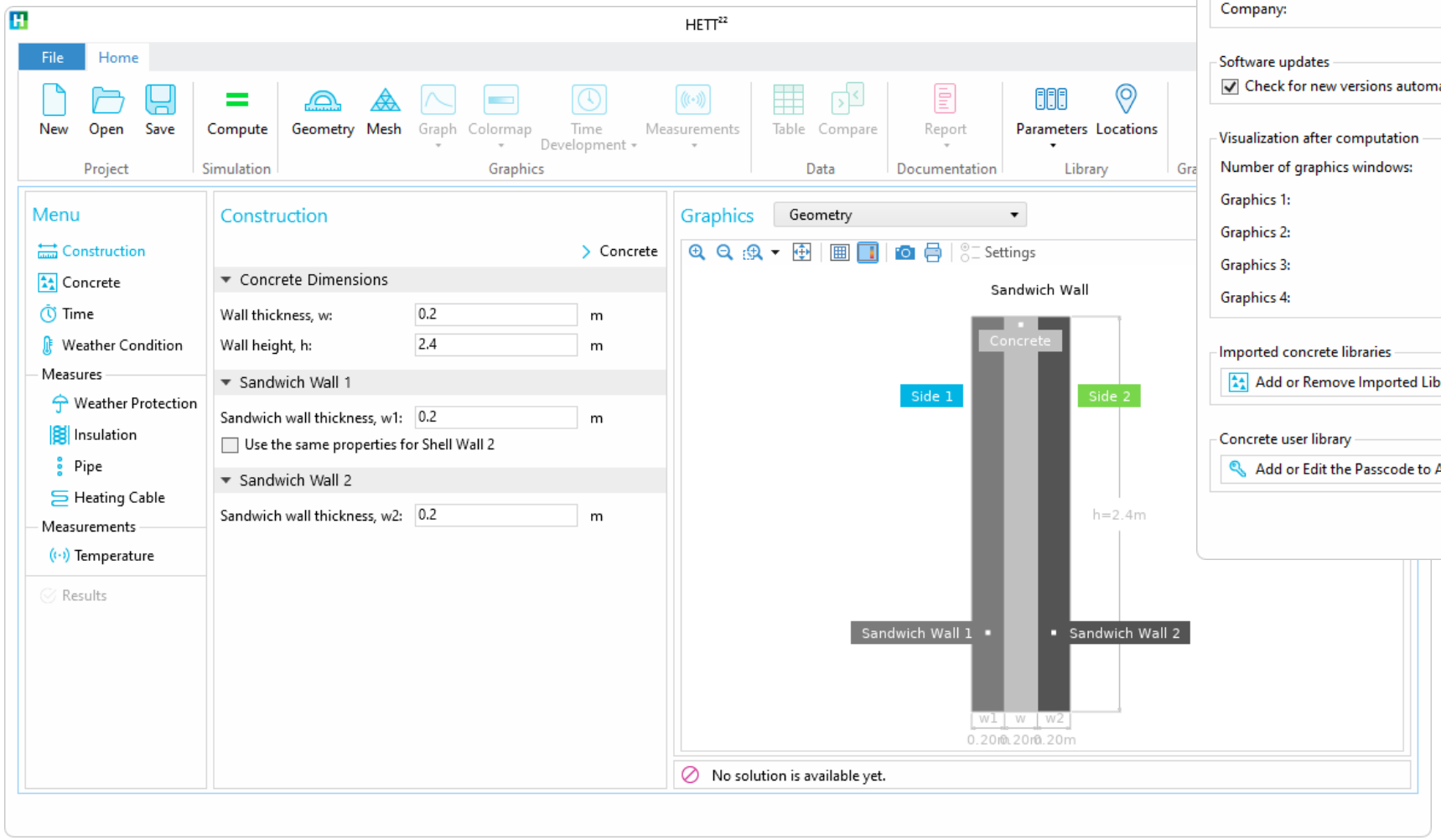
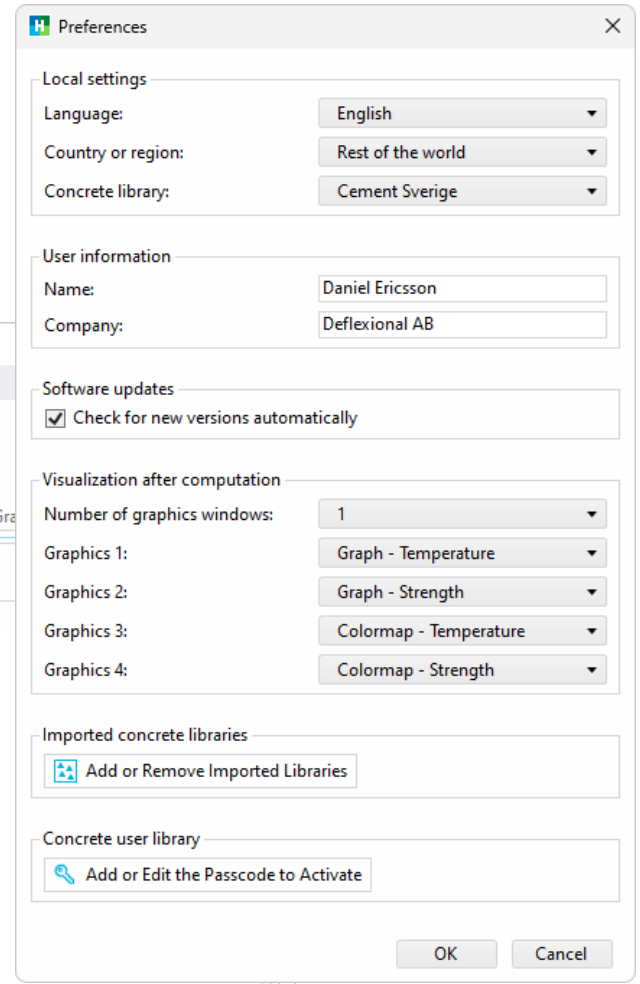
Preferences





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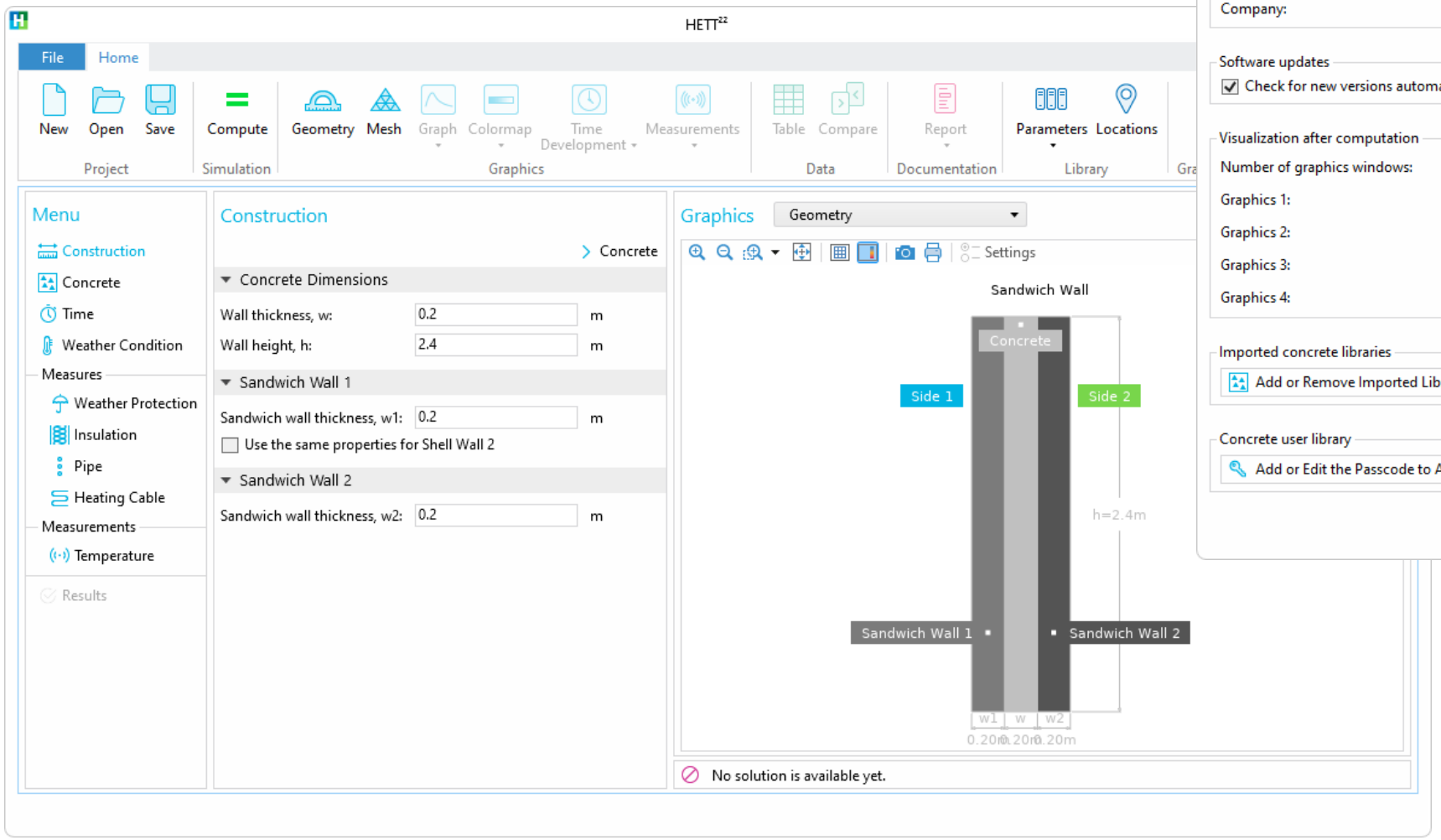
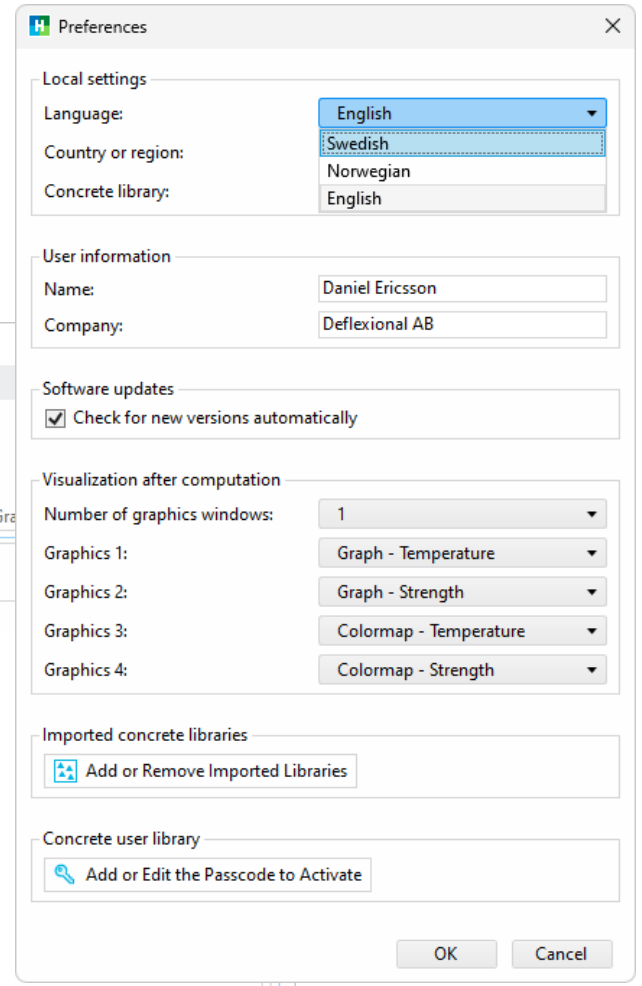
Language





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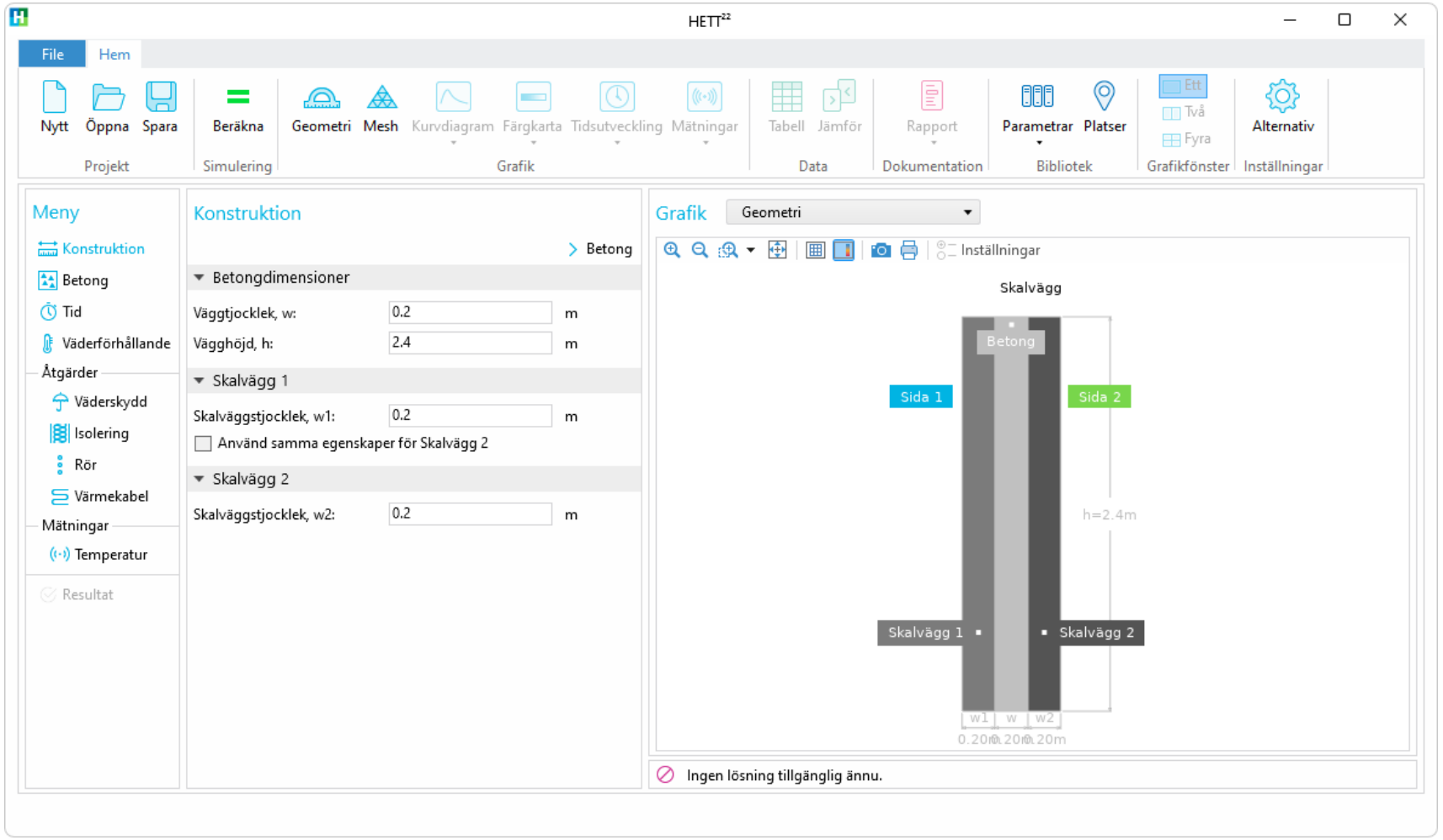
Language



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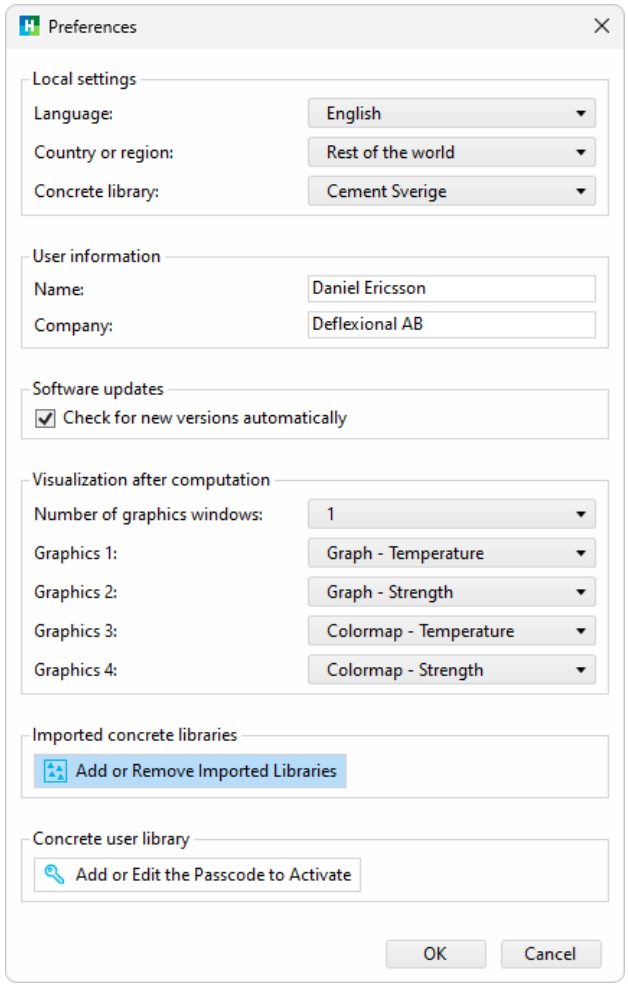
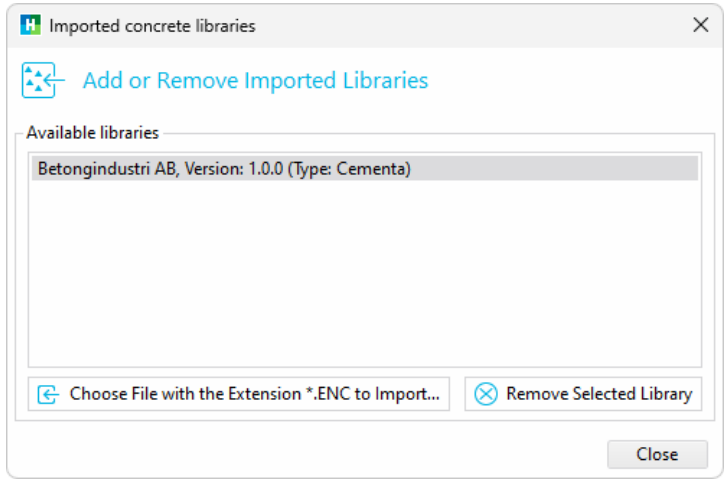
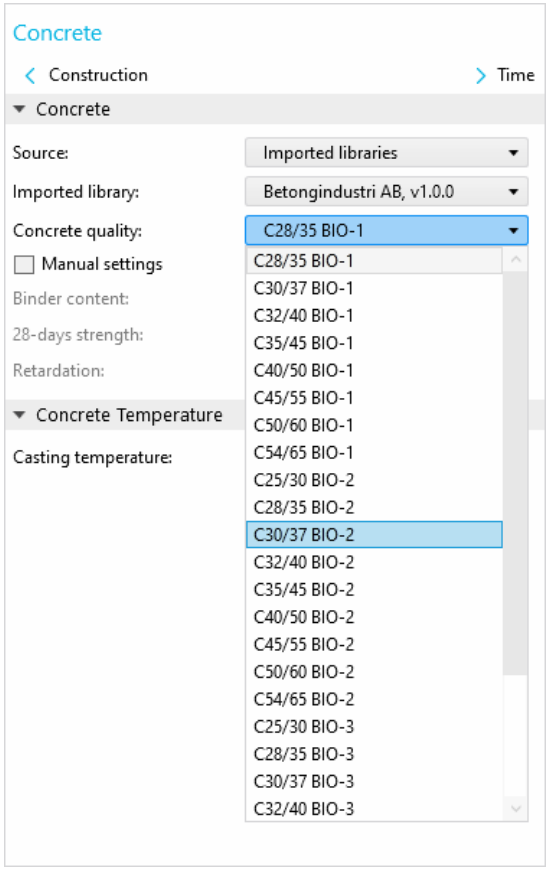
Imported Concrete Libraries

Concrete producers can include and share their encrypted concrete data

Imported Concrete Libraries







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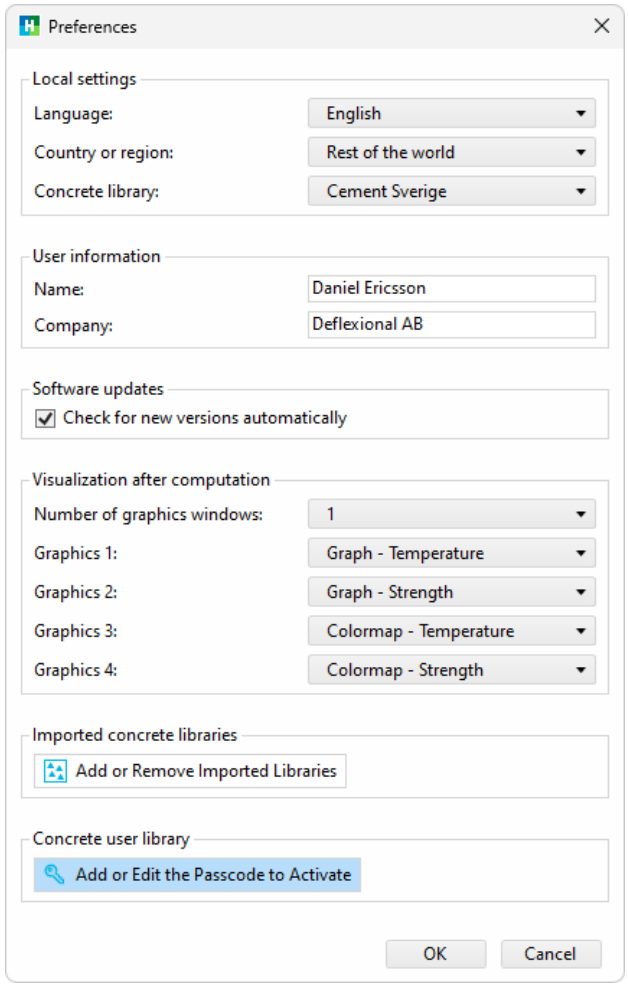
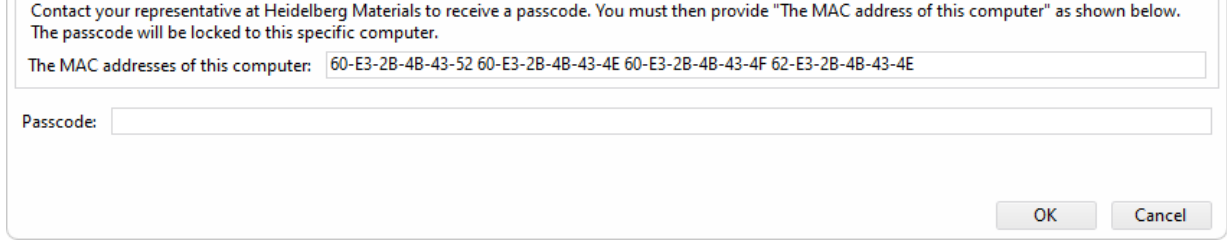
Access to Specific Functionality

A portion allocated for advanced users and researchers

Concrete User Library





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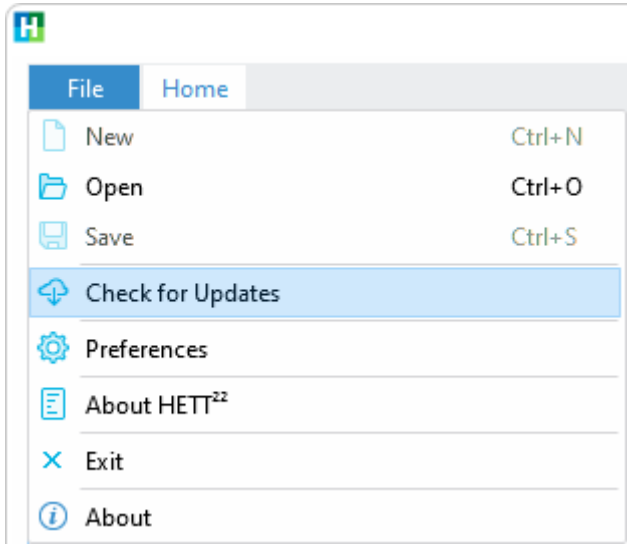
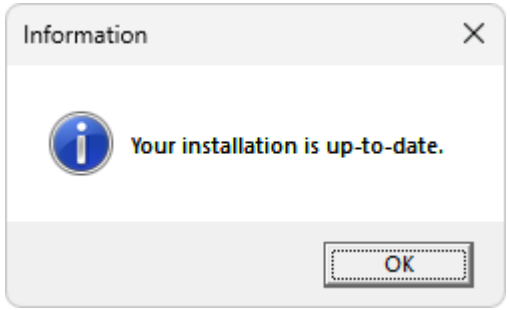
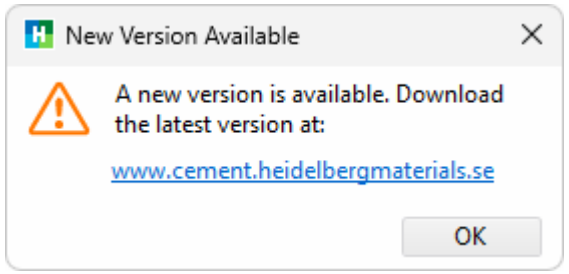
Check For Updates

When a new version is released, users will receive notifications

Check For Updates







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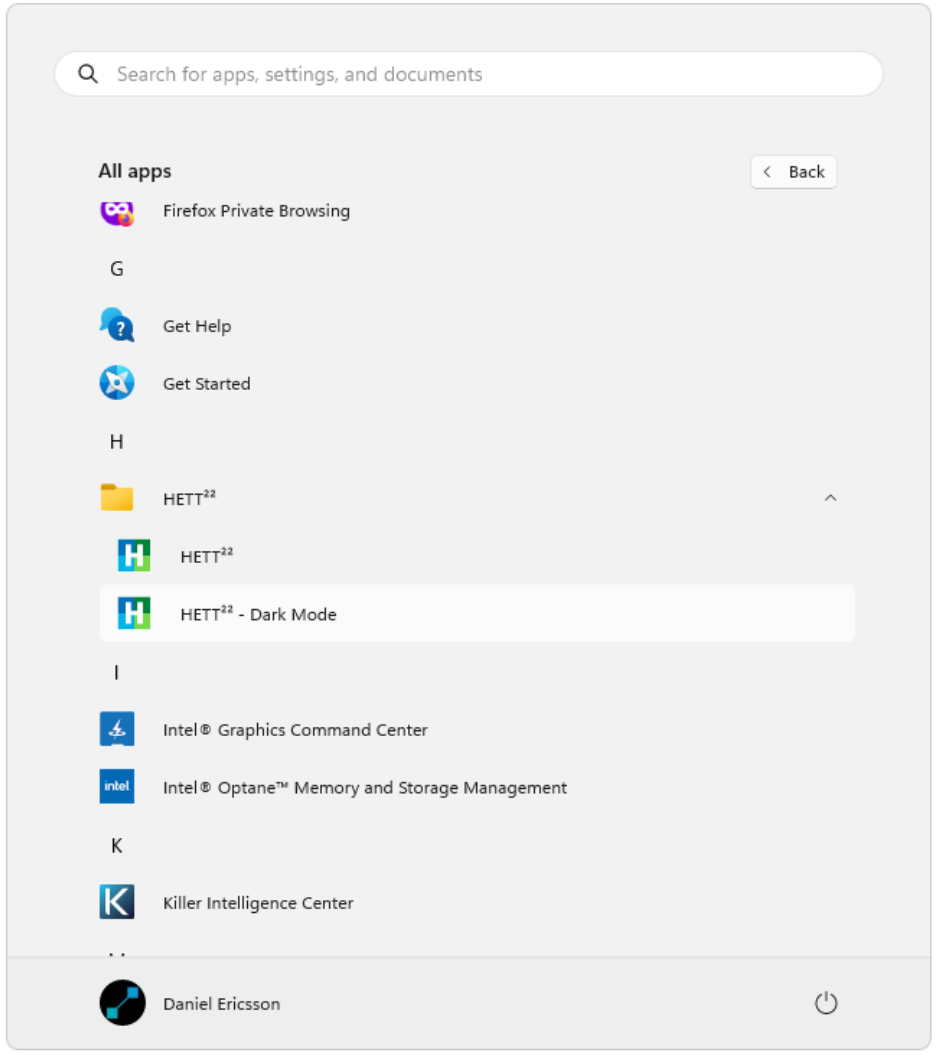
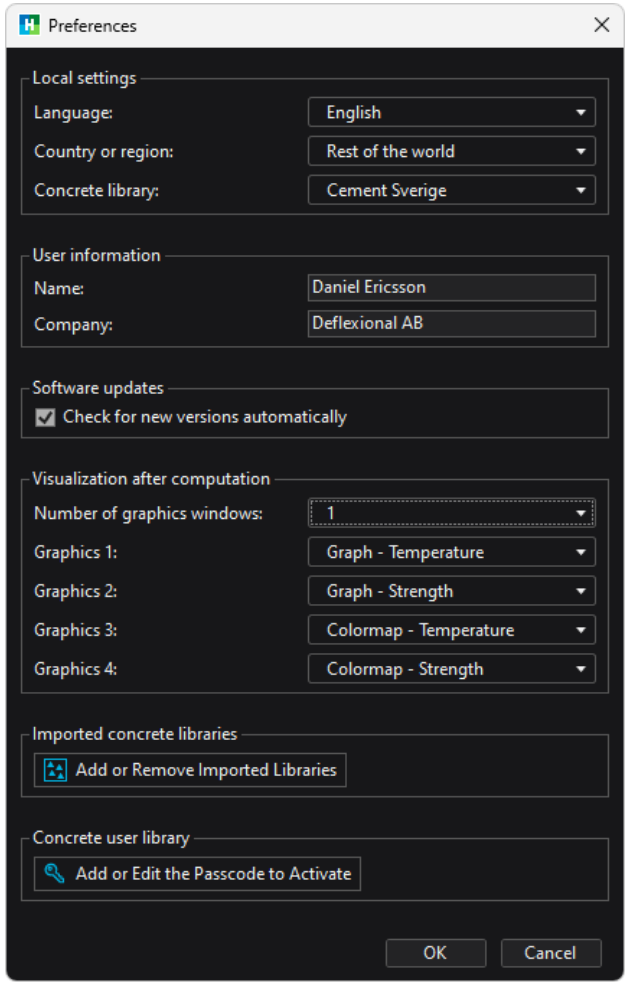
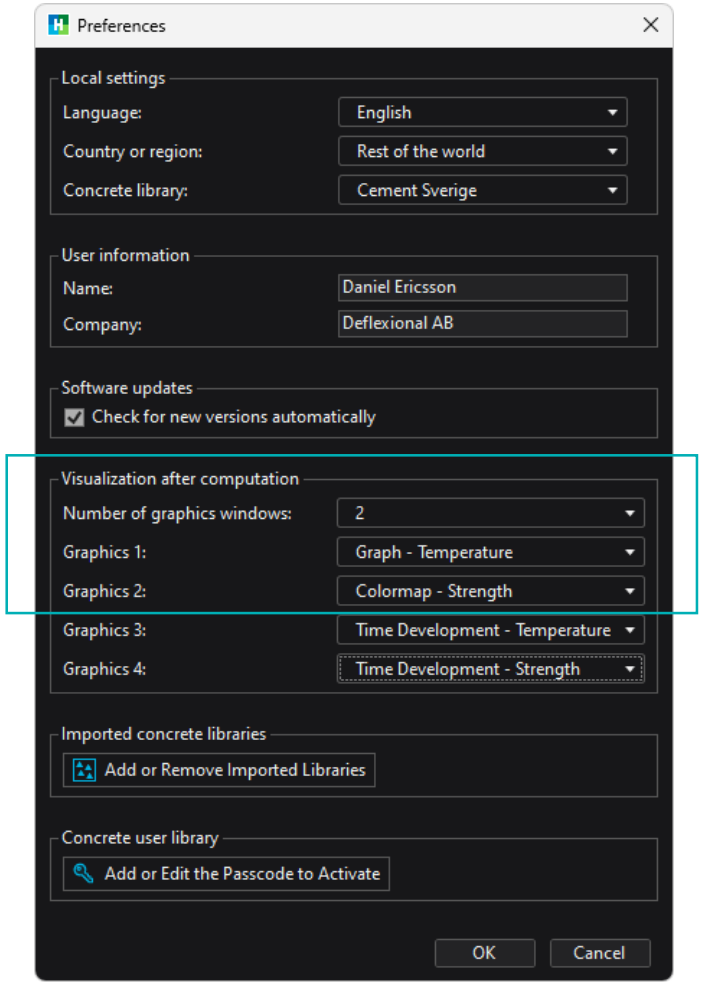
Visual Preferences

Match the individual visual preferences

Dark Mode







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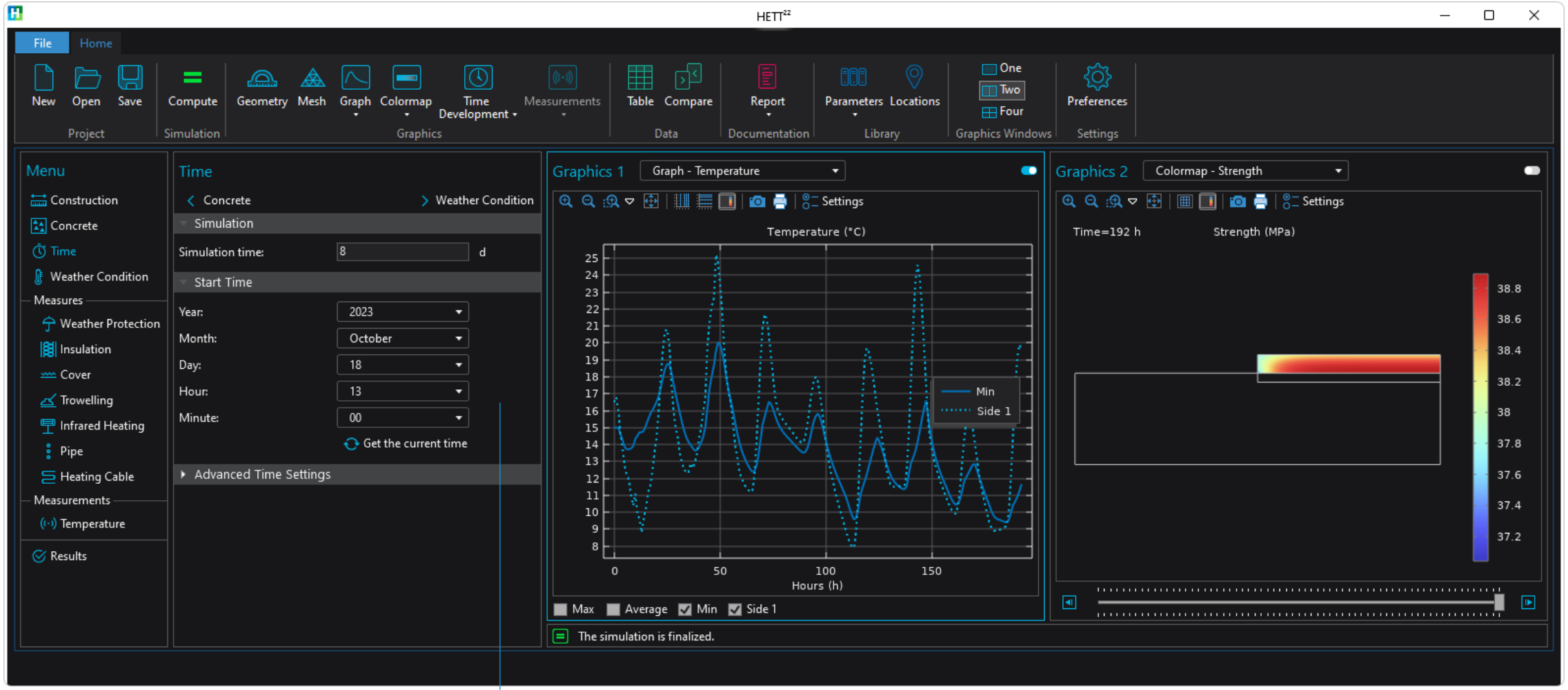
Dark Mode



From October 18th to October 26th

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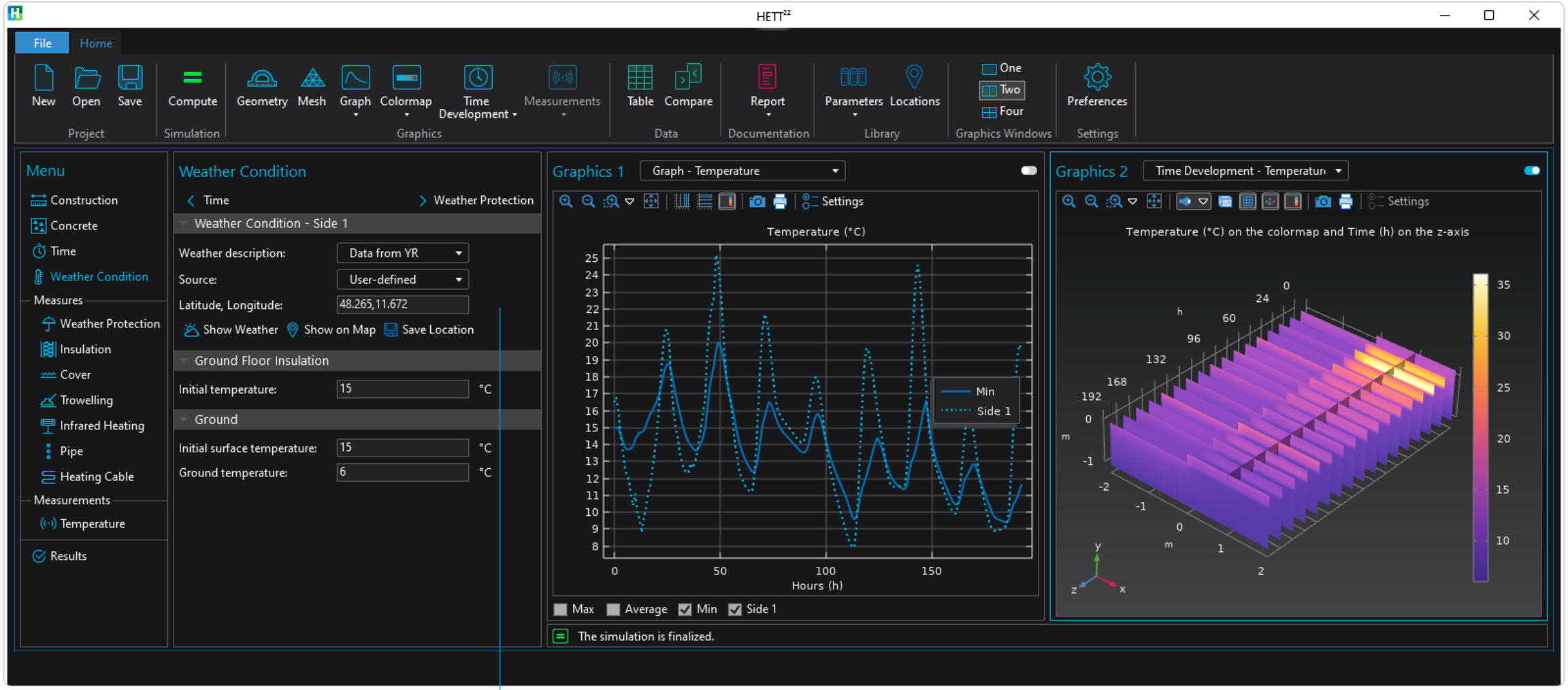
Dark Mode



Location, Science Congress Center Munich

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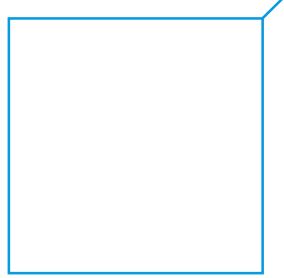
Conclusions

HETT[22] streamlines the construction process



Conclusions

- Cost savings and environmental benefits can be realized by choosing the right concrete and construction
- The maturity method has been incorporated into the COMSOL® platform
- To make this powerful tool accessible to contractors without requiring expertise in numerical analysis, the Application Builder and COMSOL Compiler™ were used to develop HETT[22]
- Any contractor can now harness the capabilities of COMSOL Multiphysics®

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