Control of Hardening Concrete

- b4cast

  simulation of temperatures, strengths and stresses

- Heat-Box

  Measuring of Heat of Development

- HeatWatch

  Monitoring temperatures, maturities and strengths on site

Durability/Serviceability/ Appearance

It is very important to be careful about the hardening process of concrete. Inappropiate construction methods can cause:

- Freezing before the concrete is strong enough
- Too early evaporation leading to a weak cover layer
- Too high temperature differences leading to crack-formation
- Lack of final strength due to too high temperatures
- Lack of strength at form-removal, prestressing or loading

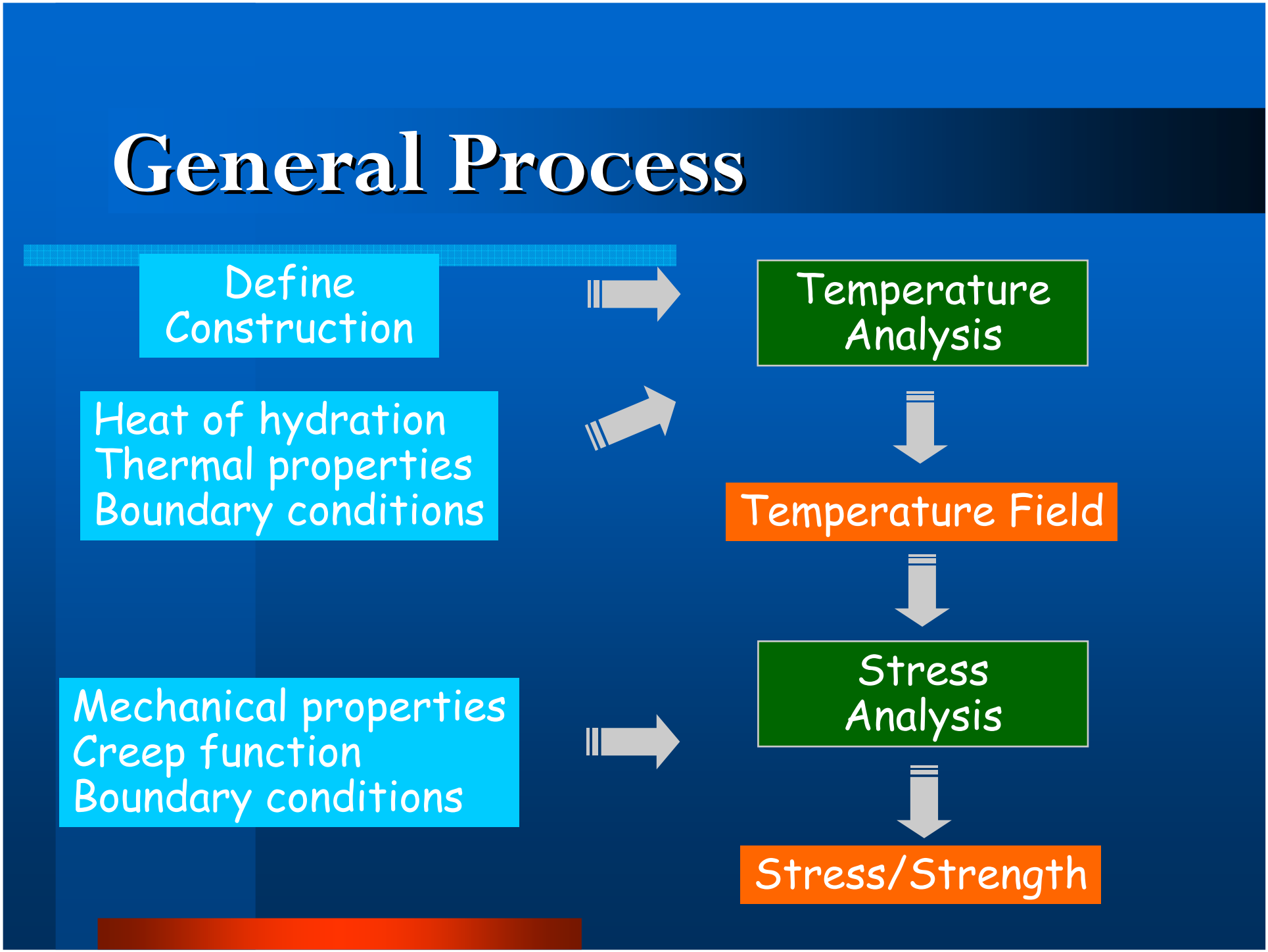
Construction Method

- In all cases the concrete structure will be directly damaged and the durability, functionality and appearance will be substantially reduced.
- On the other hand it is also important not to make more arrangements than neccesary.
- By making a simulation prior to start-up of a project the risk of damages are reduced or eliminated.

Objectives

- Thermal Analysis (freezing, early evaporation, strength)
- Stress Analysis (crack-formation)
- Evaluate alternatives
  - Concrete mixtures
  - Placing sequence
  - Artificial cooling
  - Thermal protection

General Process



Thermal Analysis

- Heat of Hydration (Heat-Box)
- Initial Temperatures
- Thermal Boundary Conditions

Thermal Analysis - Results

History and distribution of:

- Temperature
- Maturity
- Material Properties for evaluation and as input for stress analysis
- Thermal strains as input for stress analysis

Stress Analysis

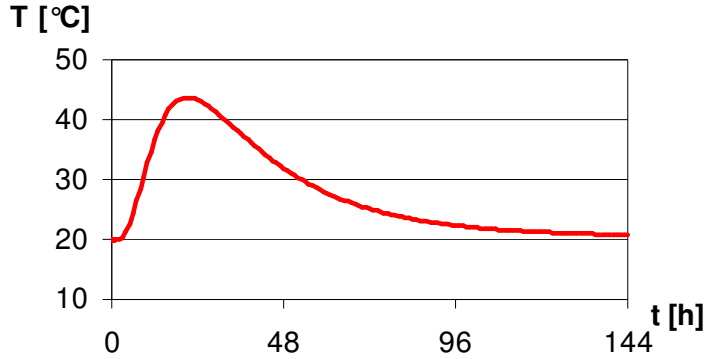
- Thermal Strains
- Mechanical properties
  as thermal expansion, E-modulus, autogenous shrinkage, creep (functions of temperature history)
- External supports
- Self weigth

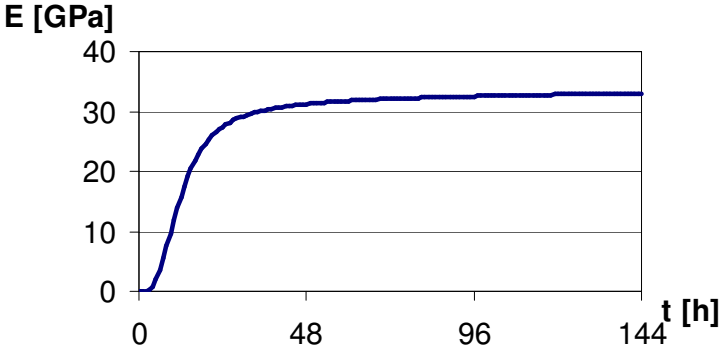
Stress Analysis - Results

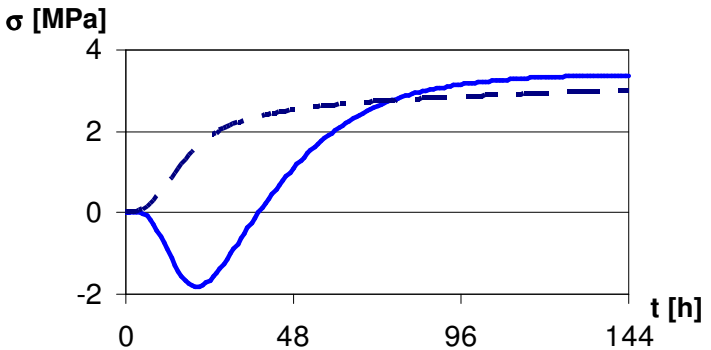
History and distribution of:

- Stress-components
- Ratio between maximum principal and actual tensile strength (exploitation)

External restraining

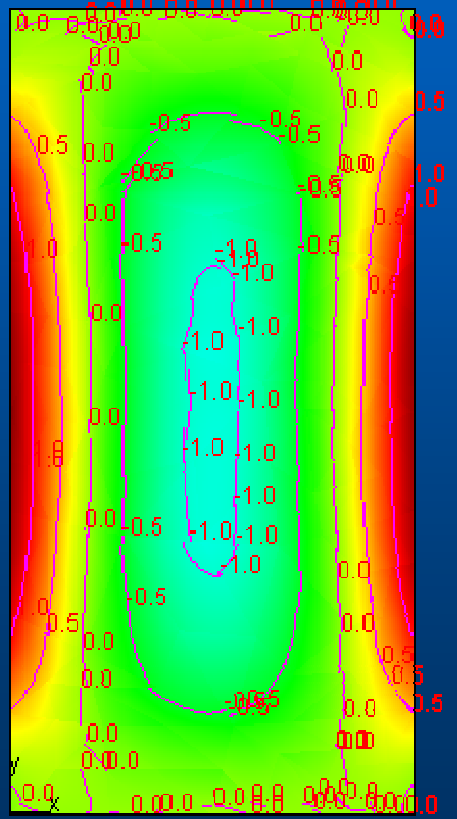




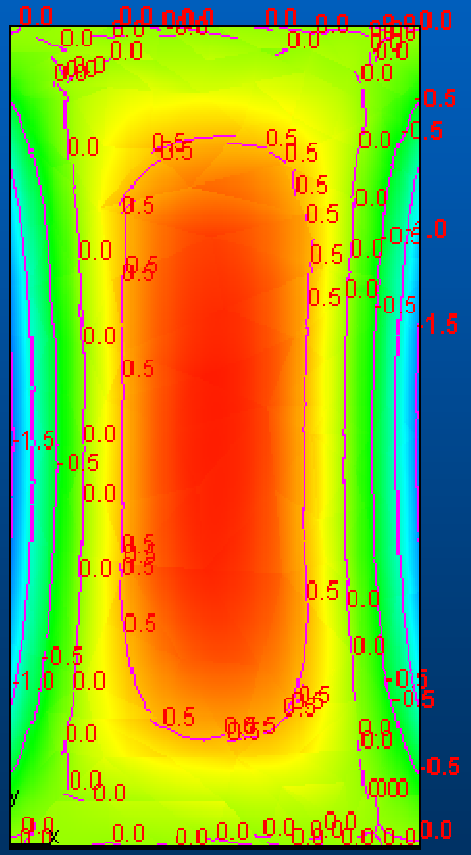


Internal restraining

Max. temperature

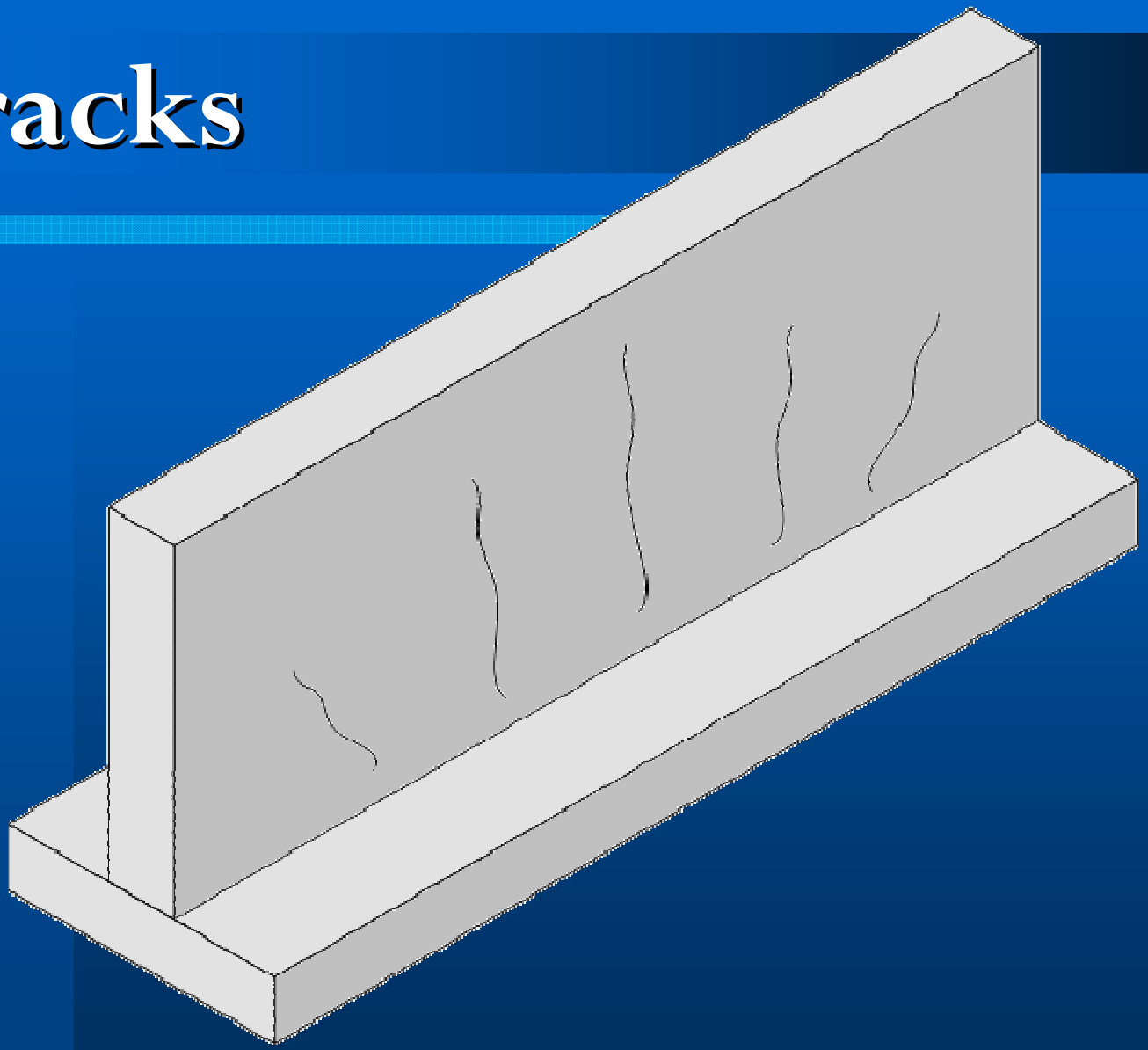


T = 24h



T = 120h

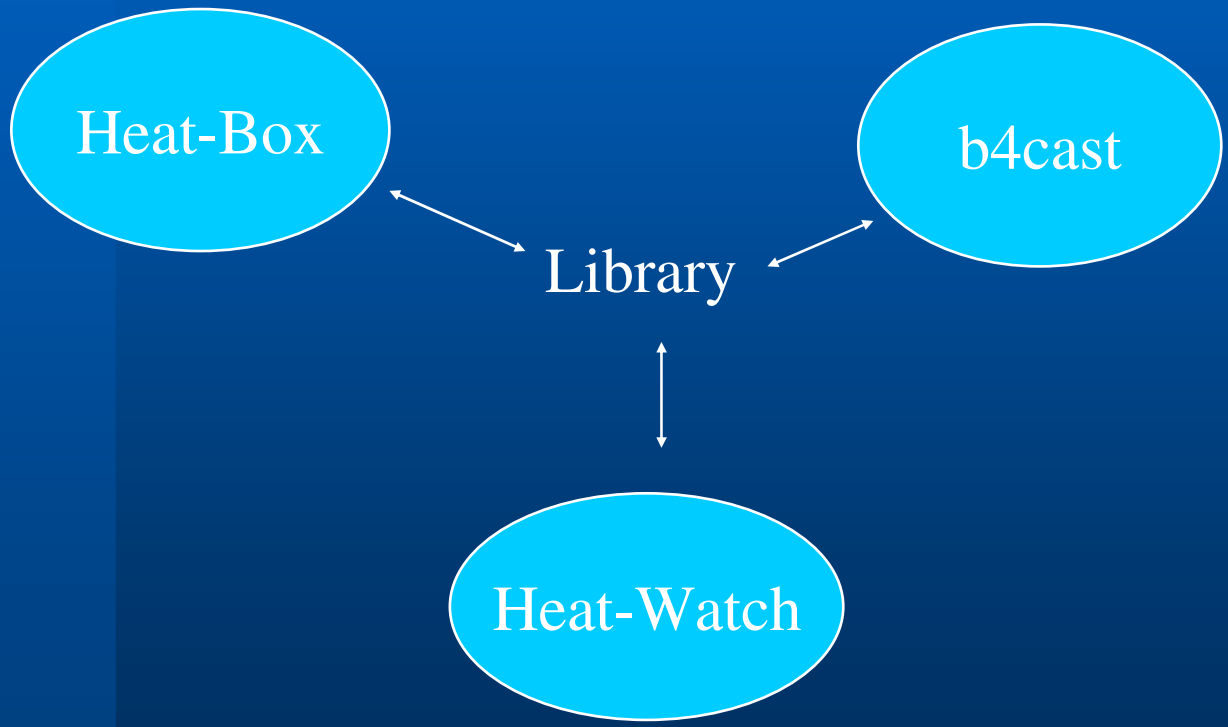
Cracks



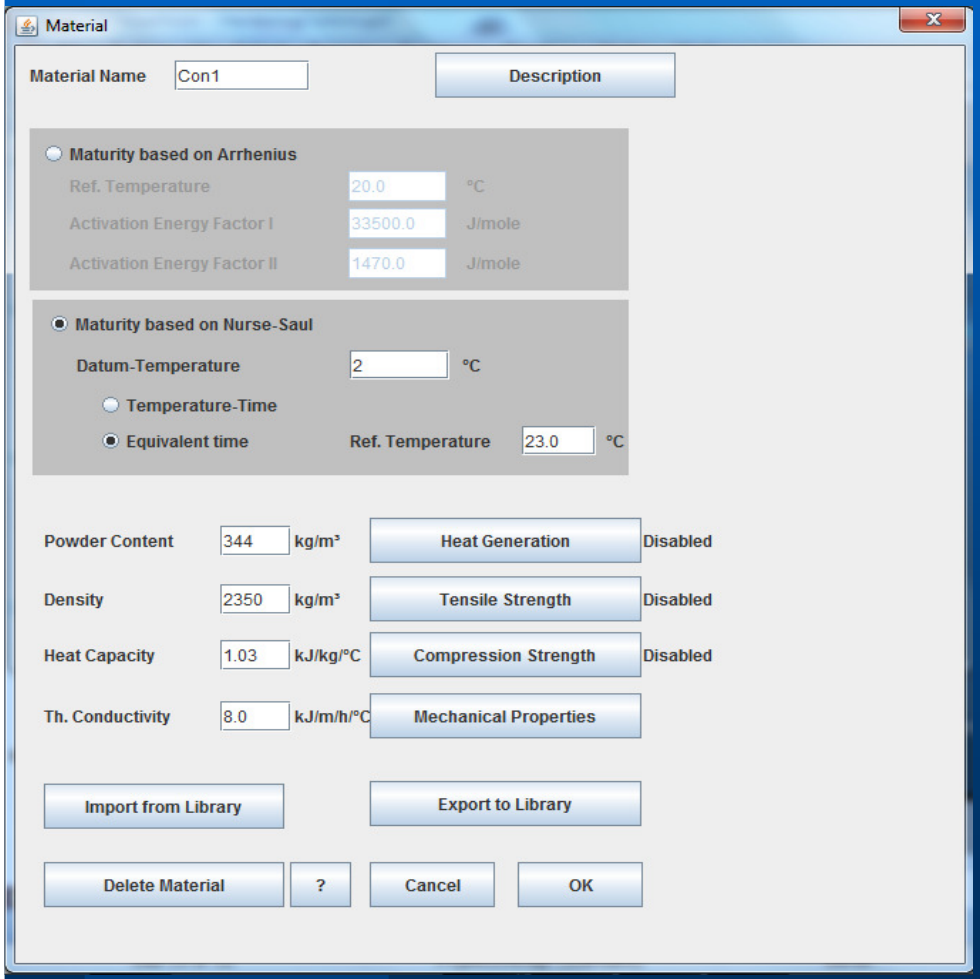
Improving Construction Method

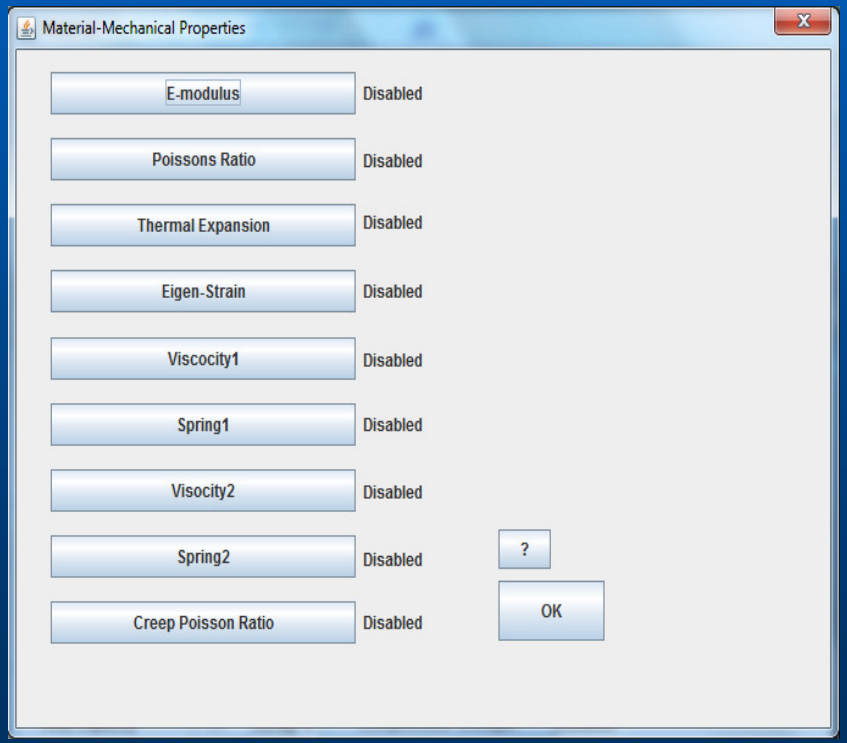
- Location of construction joint
- Placement sequence
- Casting schedule
- Selection of form materials
- Times at which formwork is removed
- Use of insulation
- Use of cooling pipes/heating cables
- Use of cold/warm concrete
- On-site monitoring of temperatures

Materials

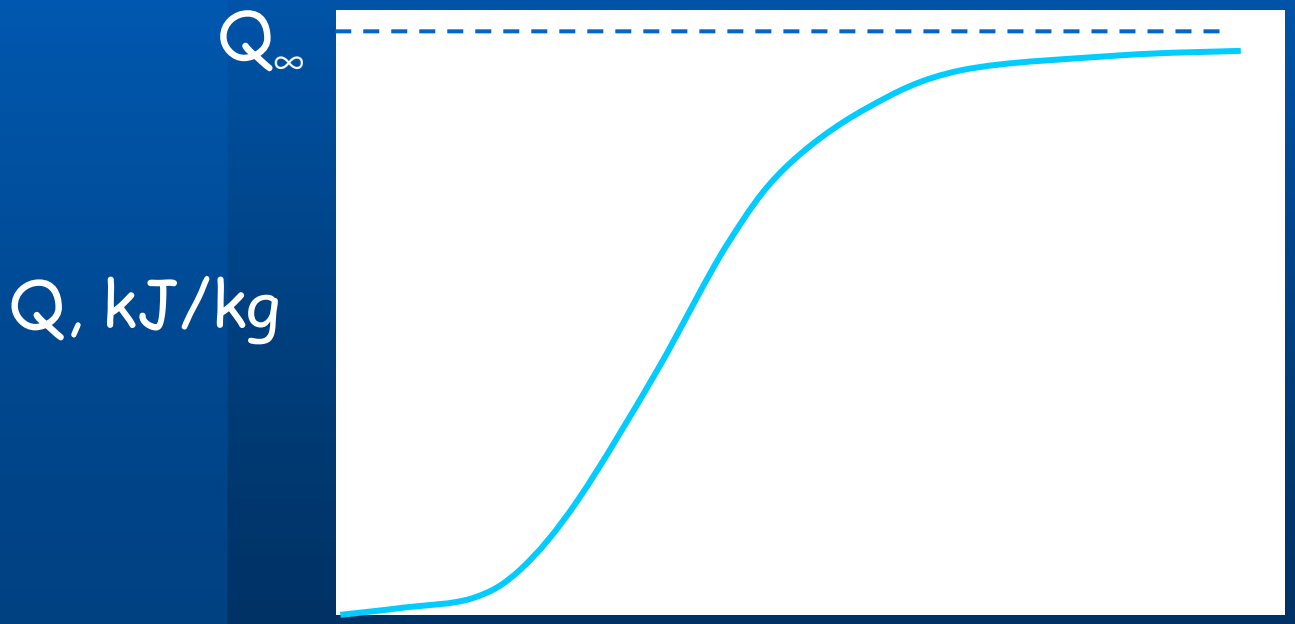


Material Properties



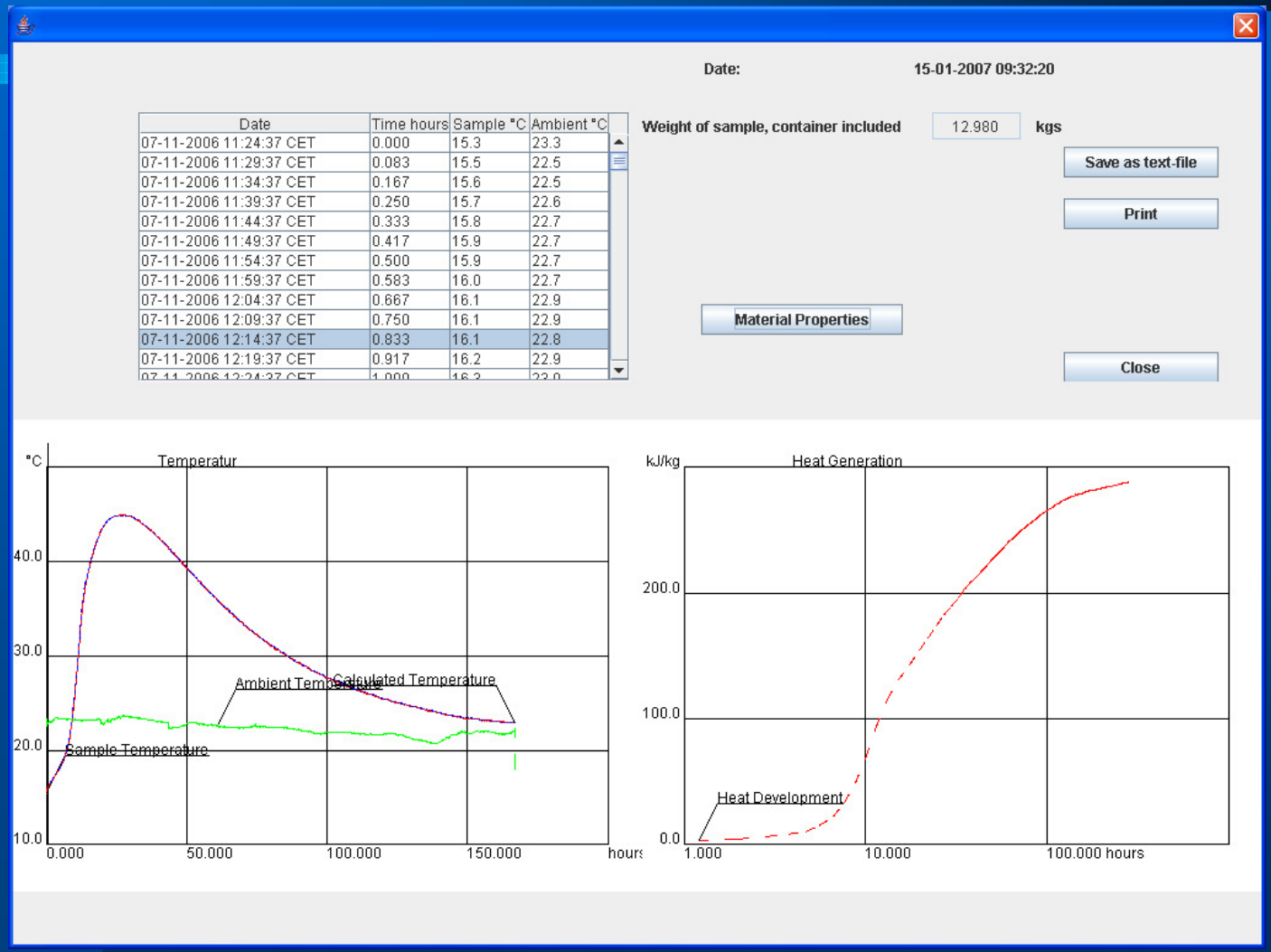


Heat Development



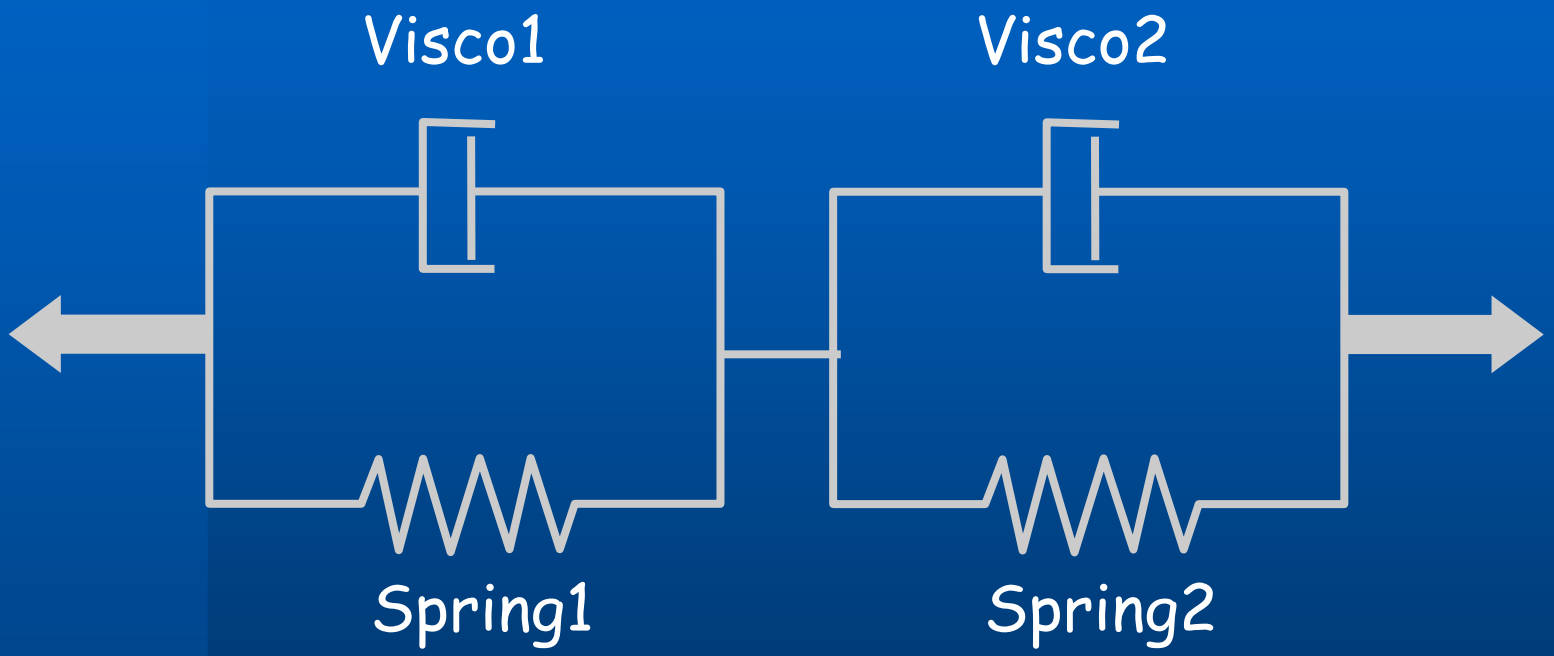
Semi-adiabatic calorimetry Heat-Box

Heat-Box



Date	Time hours	Sample °C	Ambient °C
07-11-2006 11:24:37 CET	0.000	15.3	23.3
07-11-2006 11:29:37 CET	0.083	15.5	22.5
07-11-2006 11:34:37 CET	0.167	15.6	22.5
07-11-2006 11:39:37 CET	0.250	15.7	22.6
07-11-2006 11:44:37 CET	0.333	15.8	22.7
07-11-2006 11:49:37 CET	0.417	15.9	22.7
07-11-2006 11:54:37 CET	0.500	15.9	22.7
07-11-2006 11:59:37 CET	0.583	16.0	22.7
07-11-2006 12:04:37 CET	0.667	16.1	22.9
07-11-2006 12:09:37 CET	0.750	16.1	22.9
07-11-2006 12:14:37 CET	0.833	16.1	22.8
07-11-2006 12:19:37 CET	0.917	16.2	22.9

Creep Model

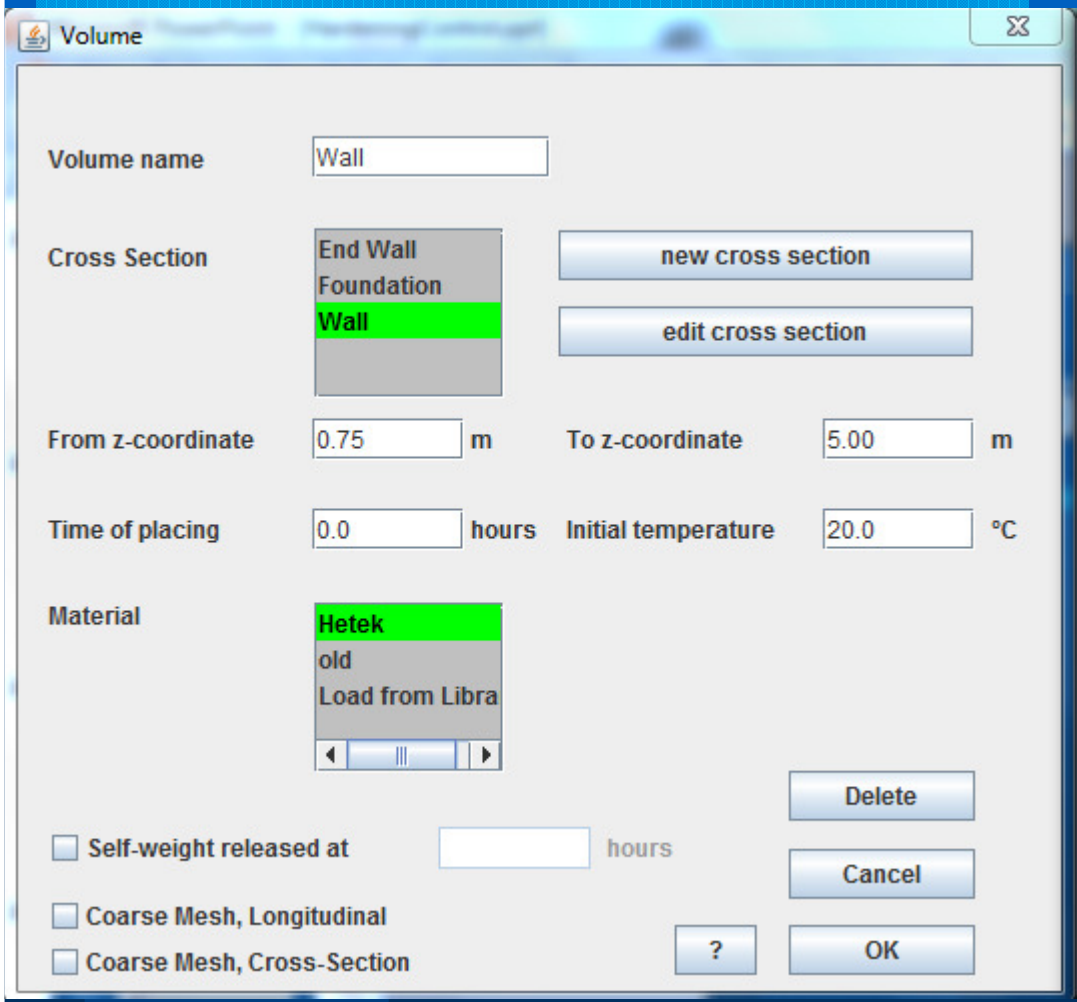


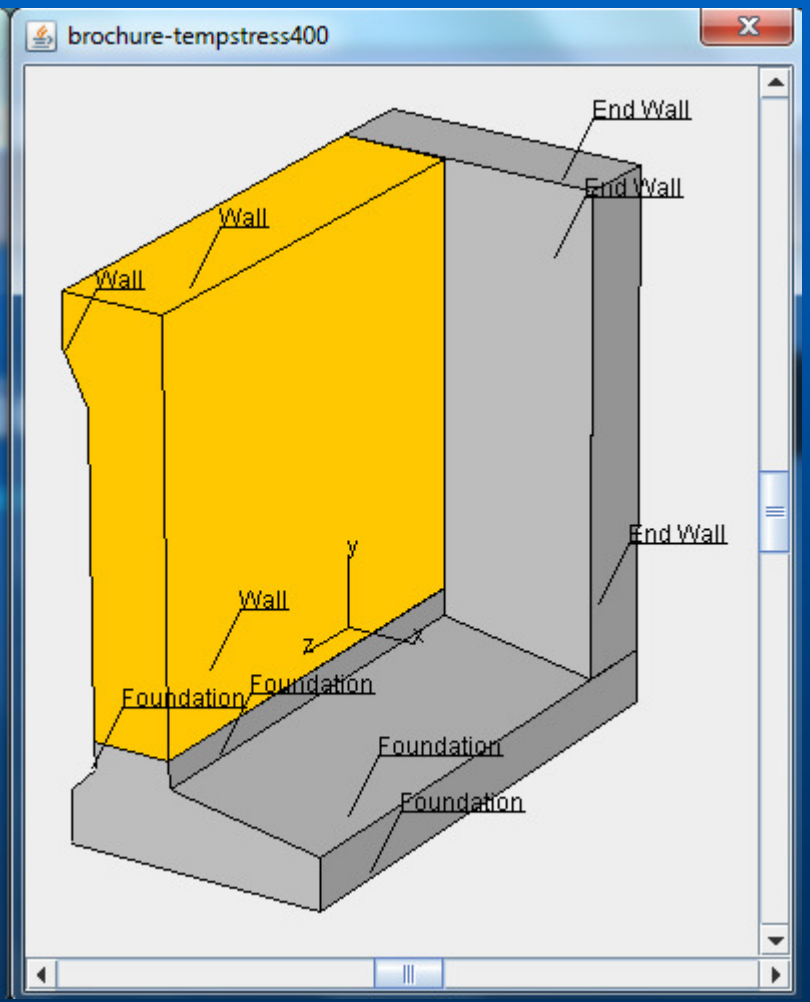
- Values specified as function of maturity

Construction Method

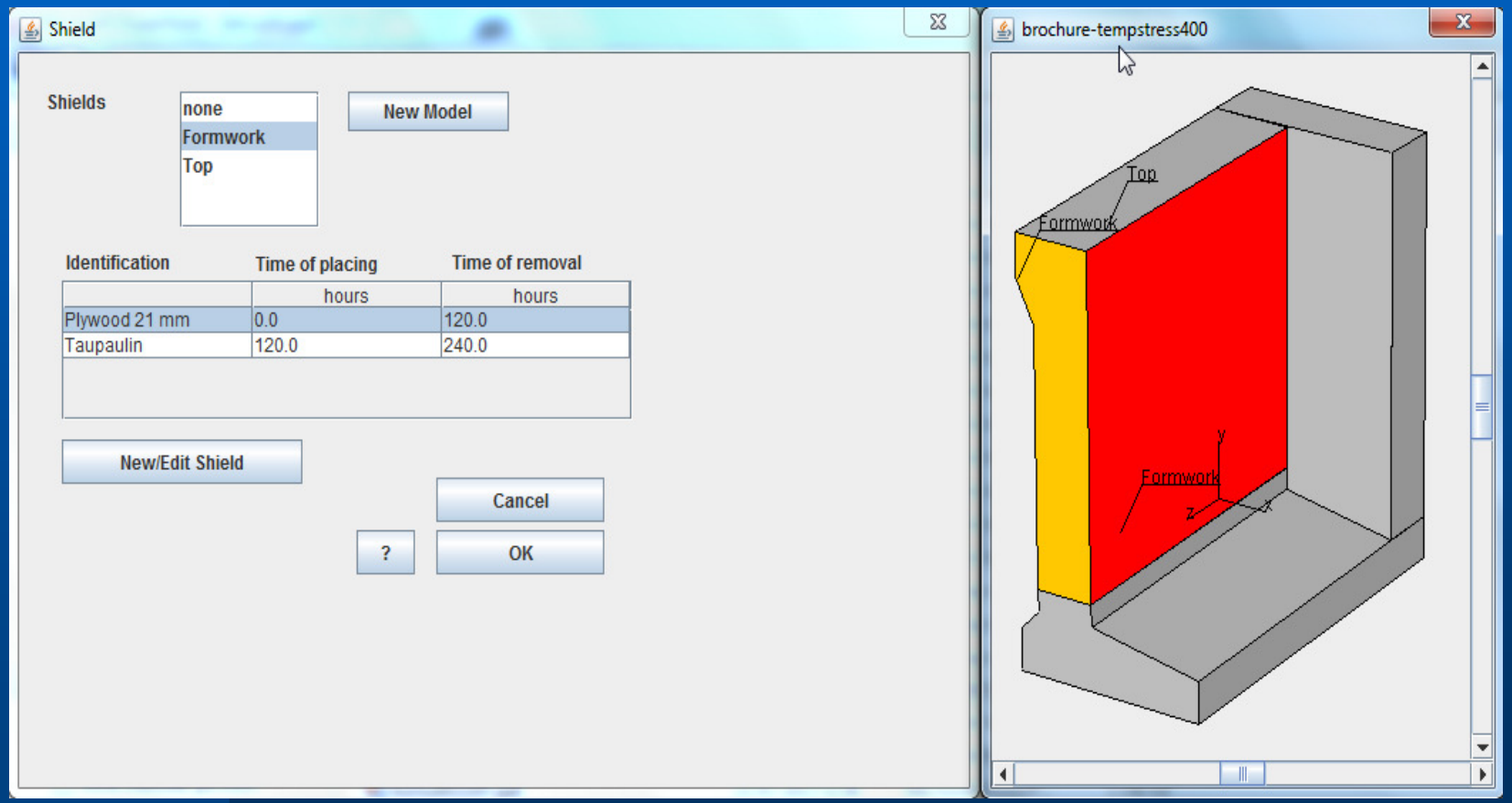
- Define volumes corresponding to different placements
- Specify times of placement of each volume
- Boundary conditions for surface of volumes
  - Insulation properties of formwork (database)
  - Ambient conditions (time histories)
  - Presence of cooling pipes (database)

Definition of Castings

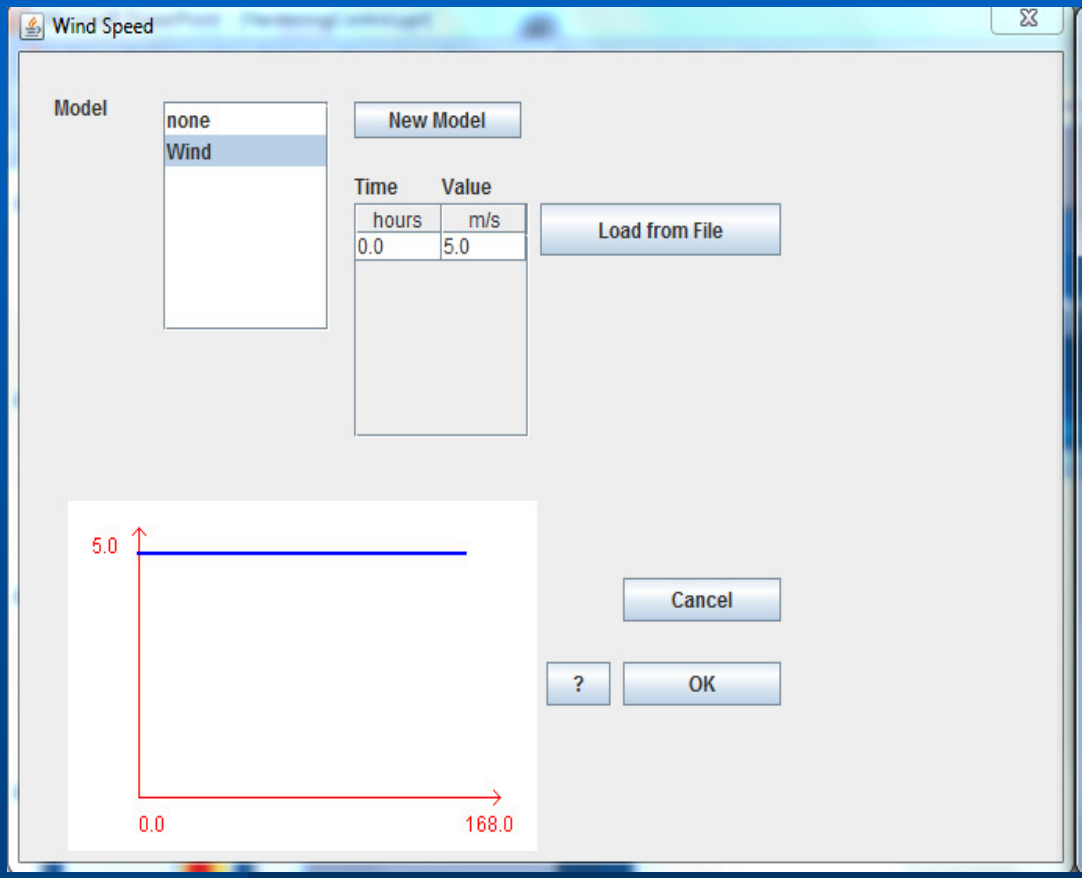


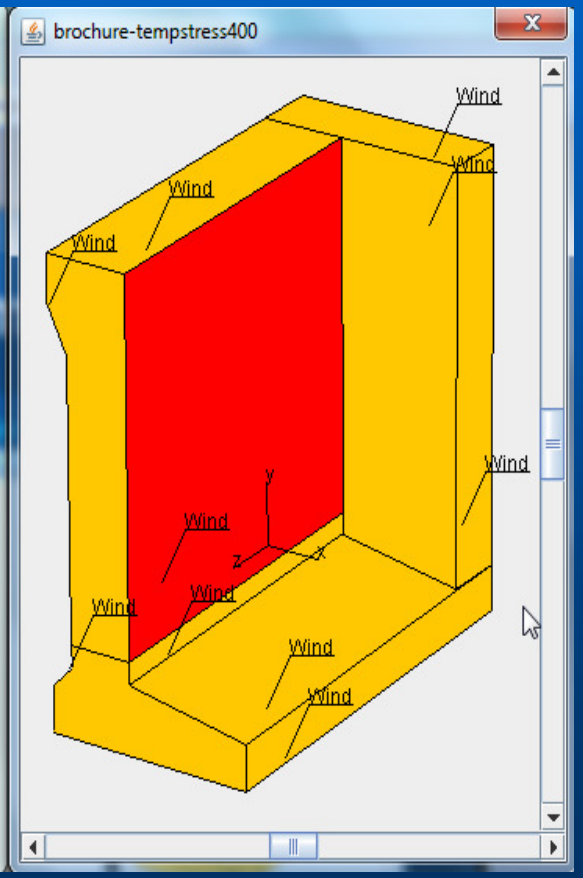


Definition of Formwork

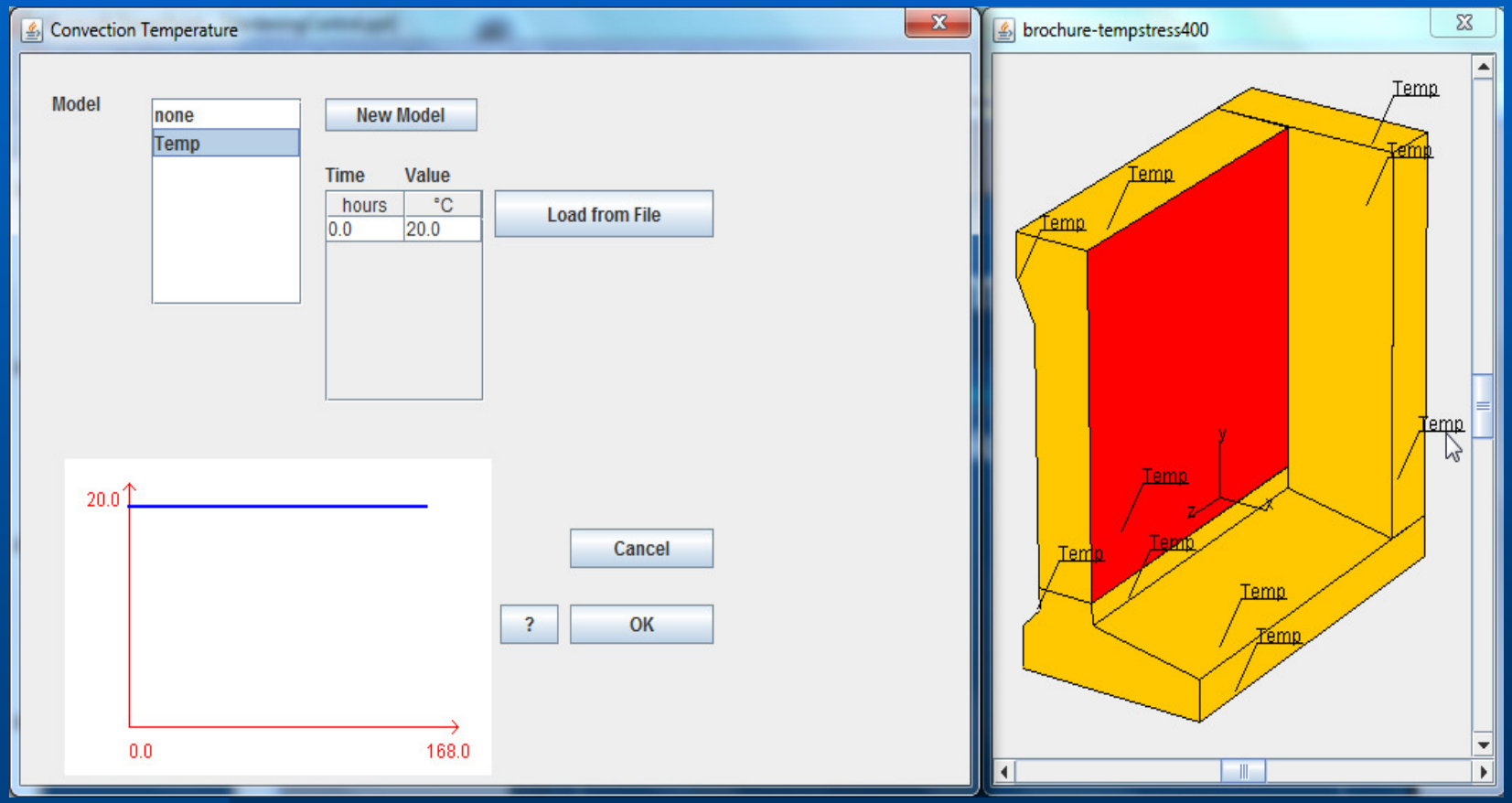


Definition of wind-speeds

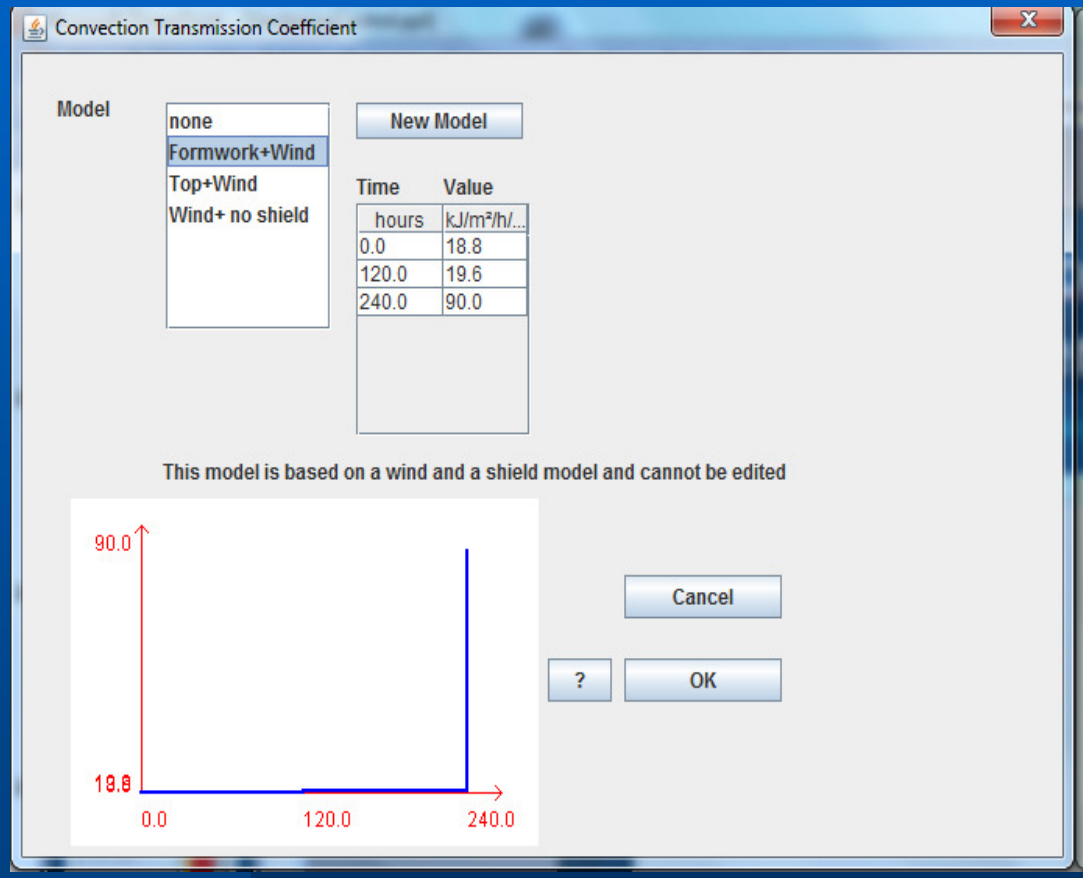


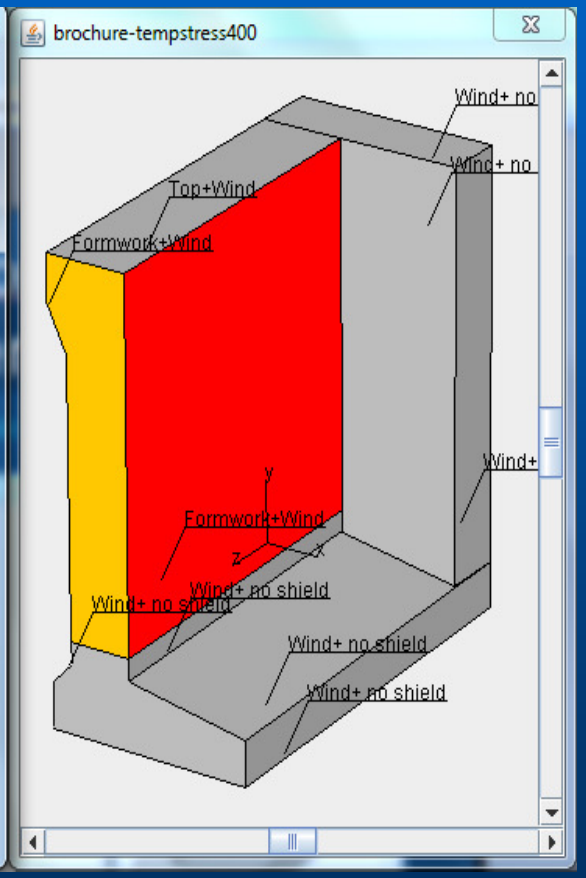


Definition of ambient temperatures

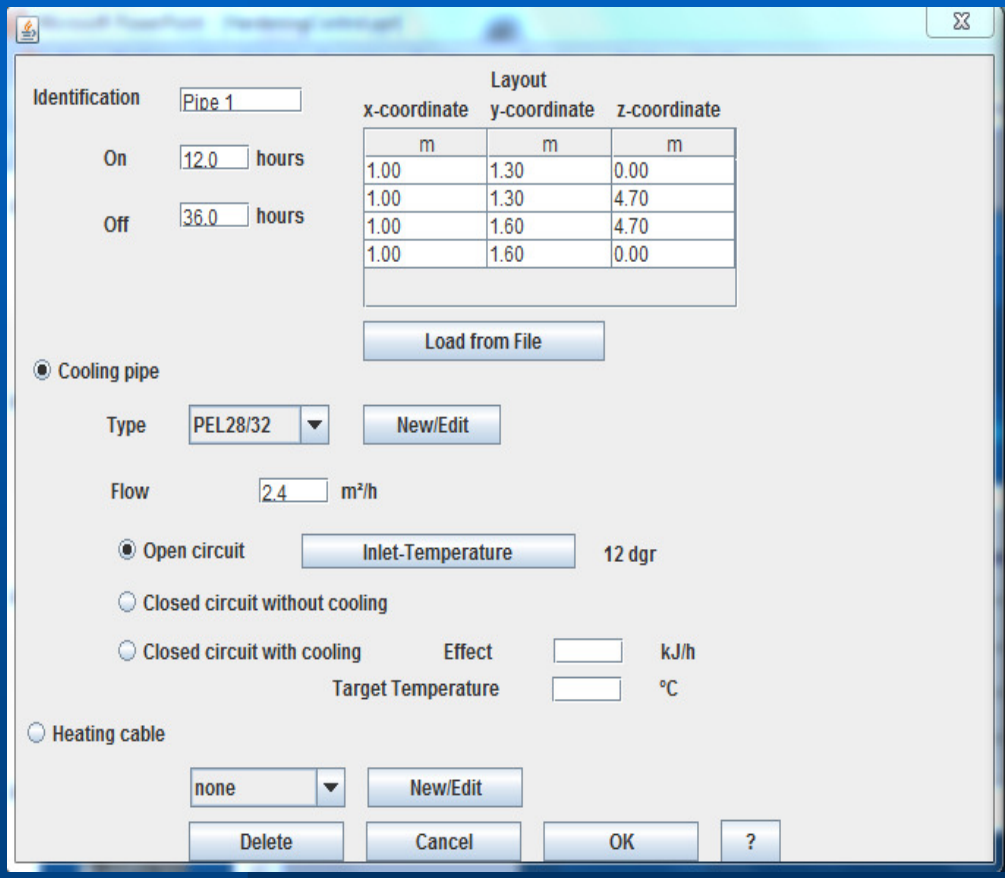


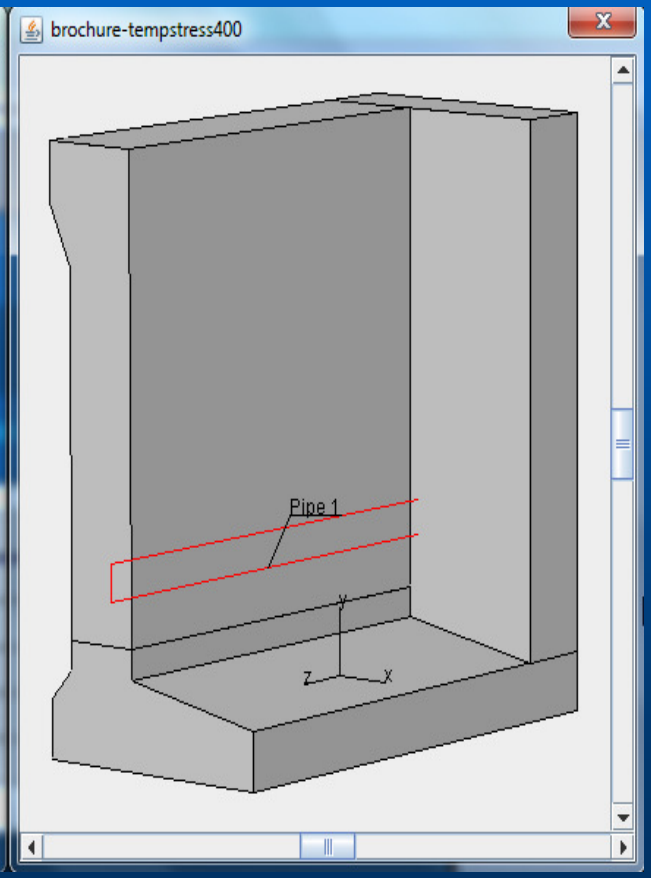
Transmission coefficients





Cooling/Heating pipes/wires

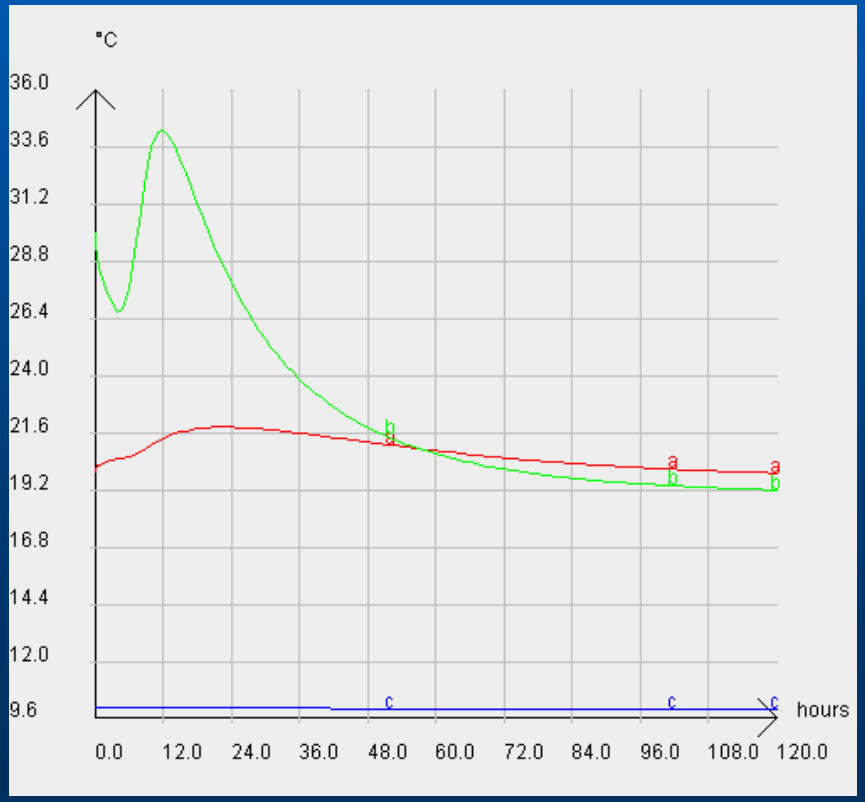




Open circuit

New Concrete

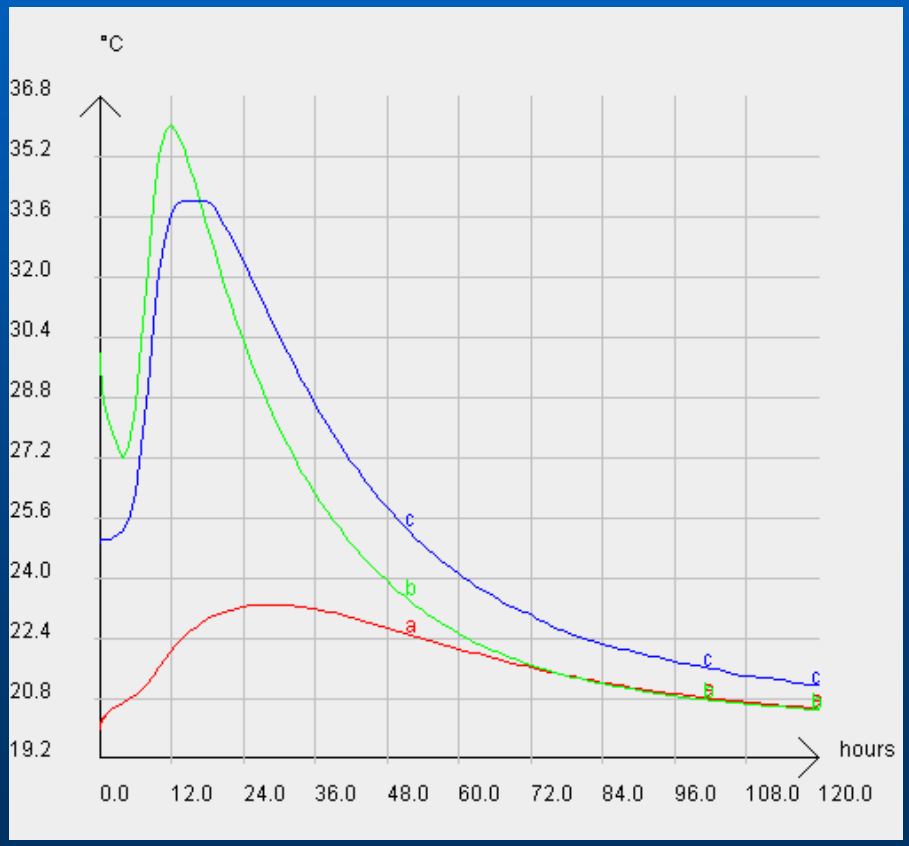
T_{inlet}



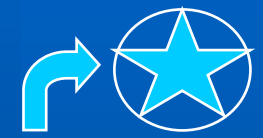
Closed circuit

New Concrete

Old Concrete



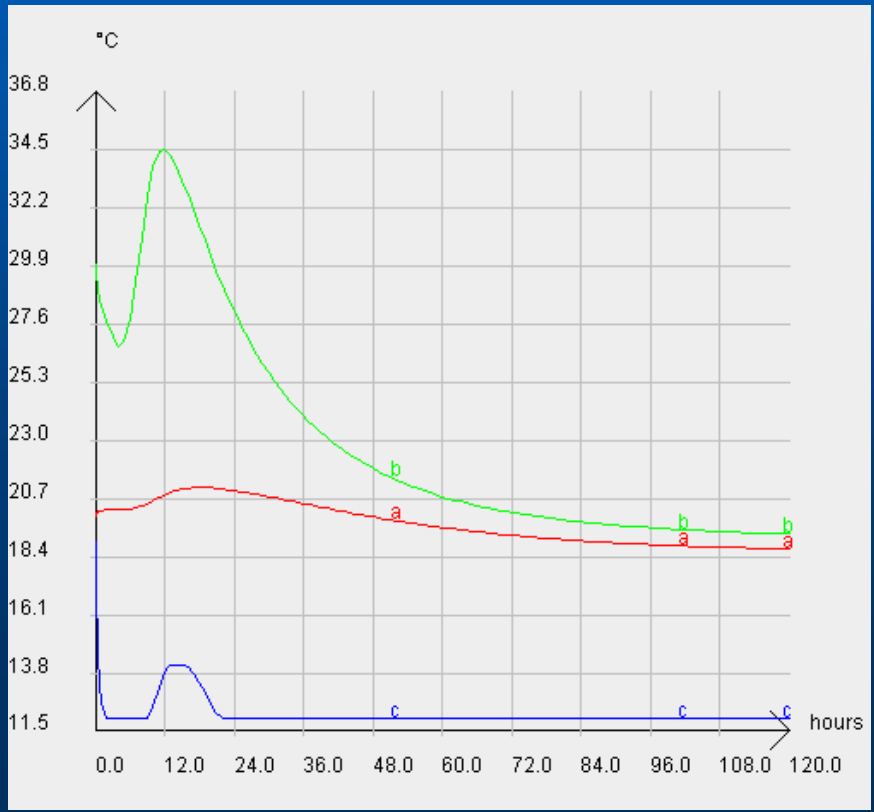
Closed circuit with cooling plant



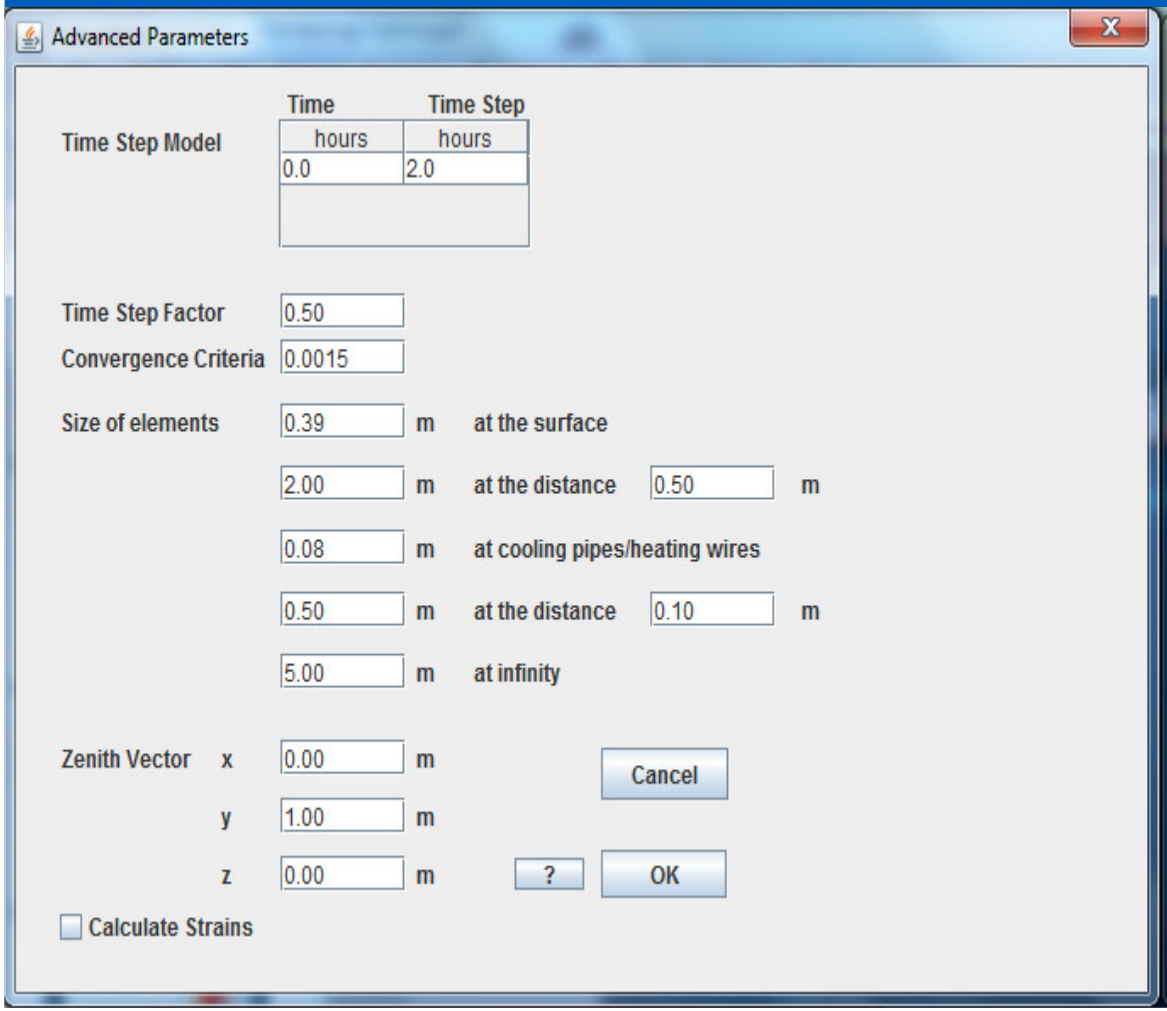
New Concrete

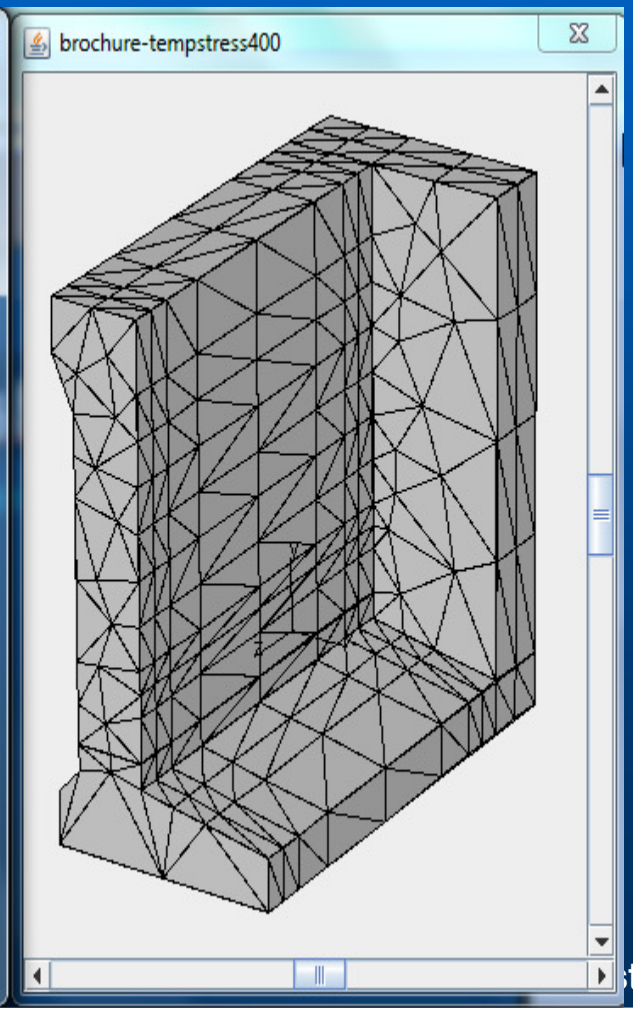
Old Concrete

T_{target}
Max. effect



Automatic meshing

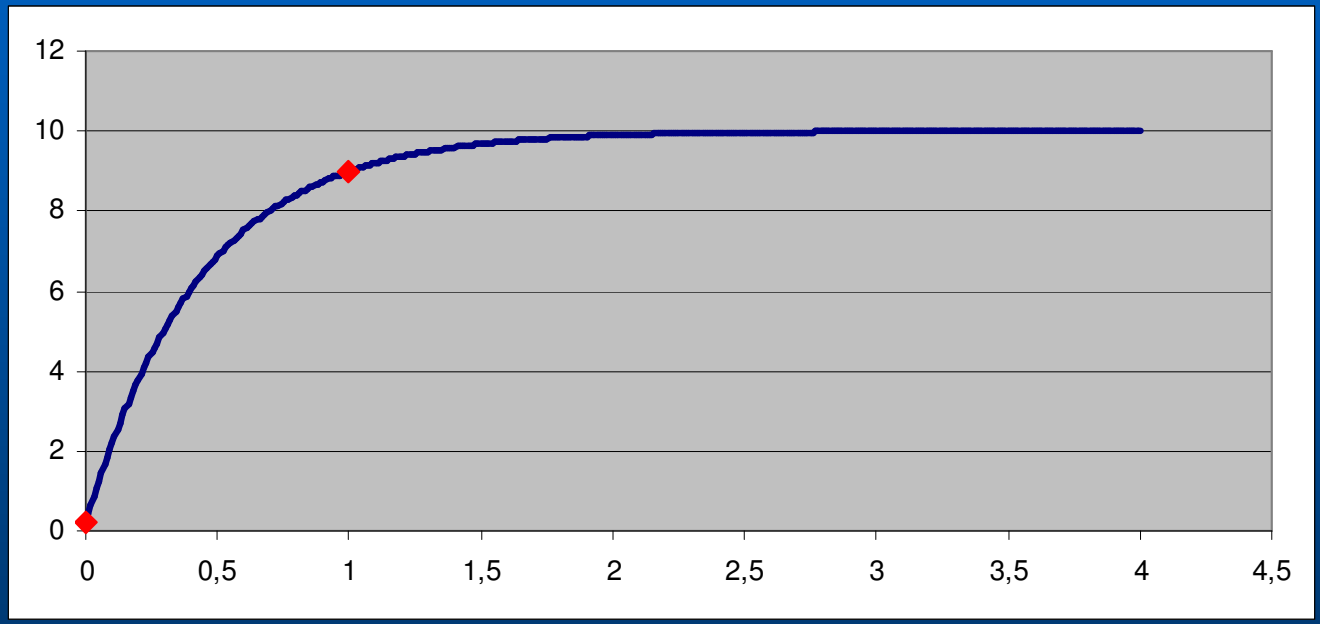




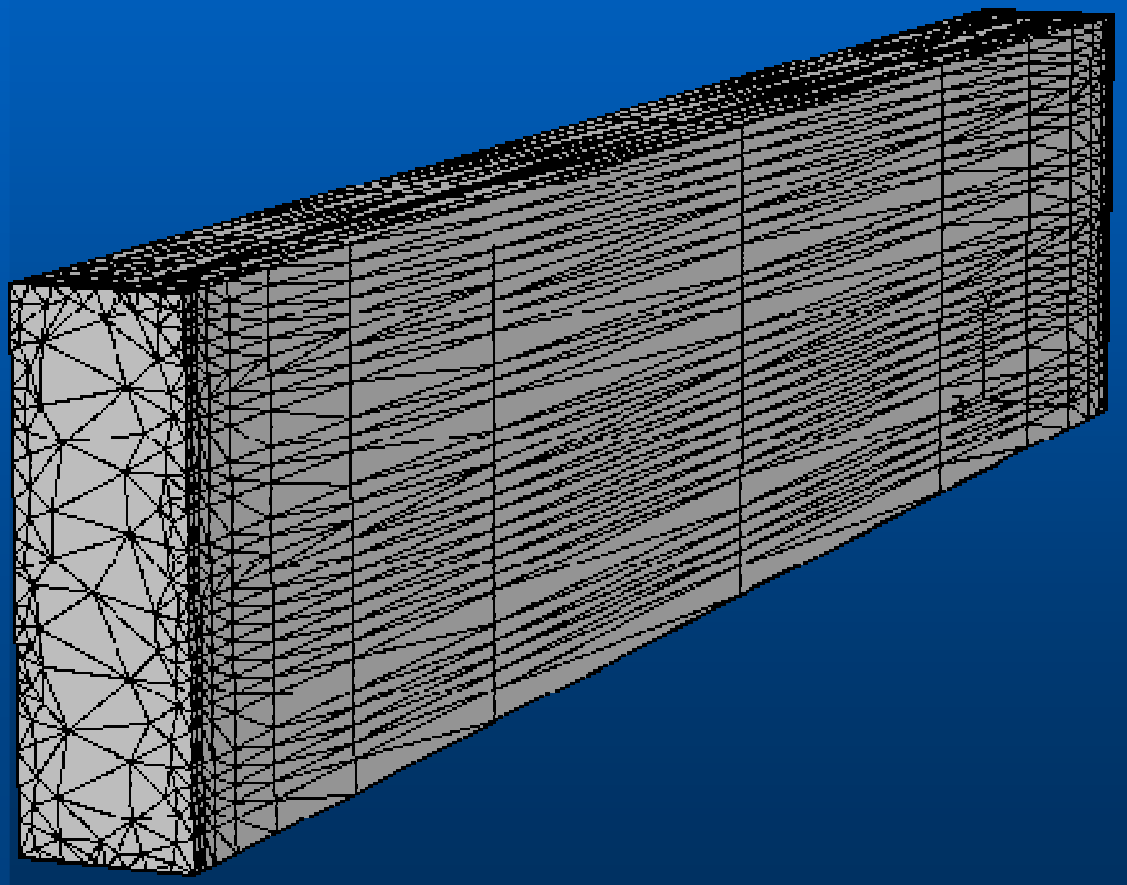
Meshing

Density:

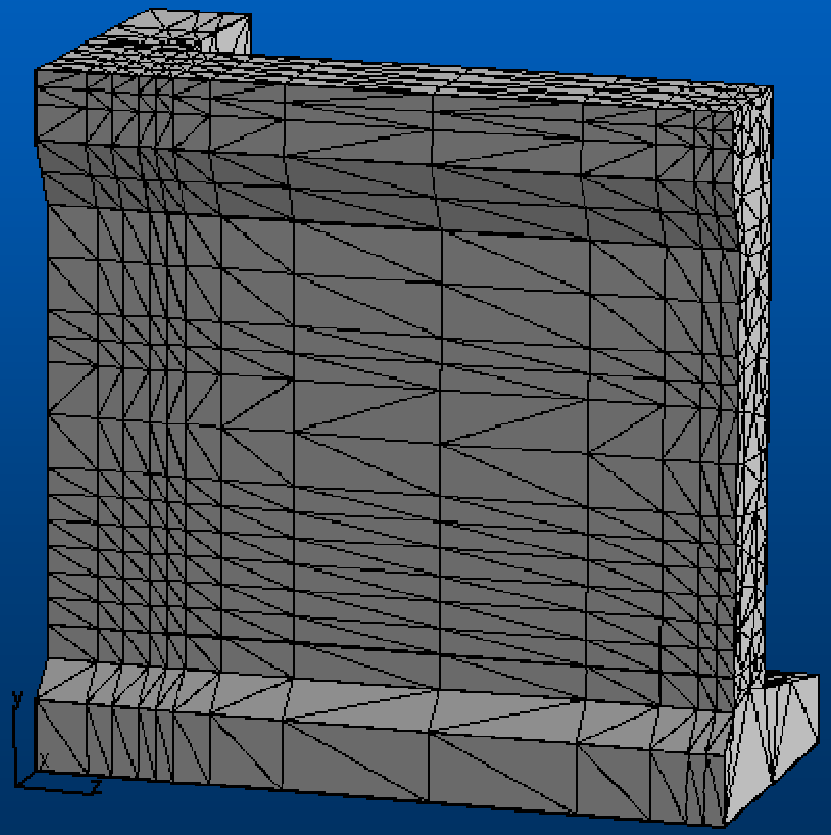
- at surface
- at distance x
- at infinity



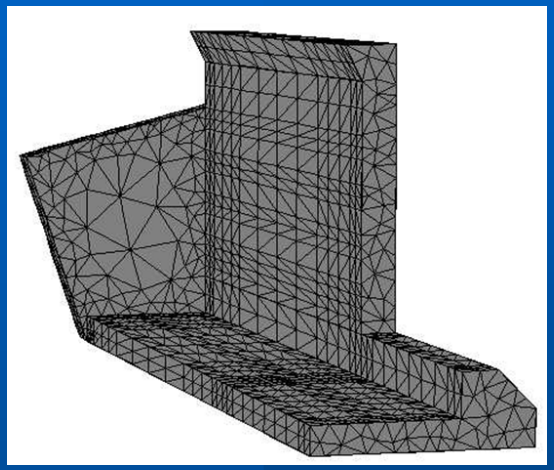
Density of mesh

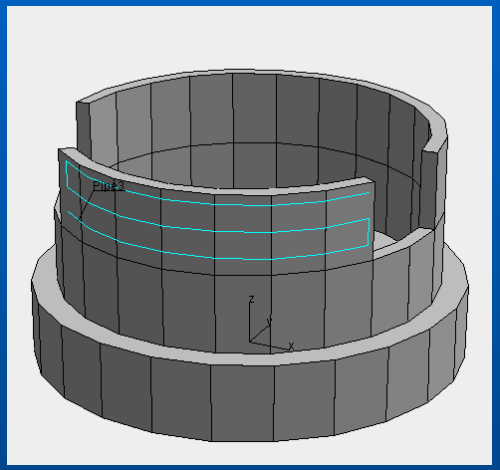


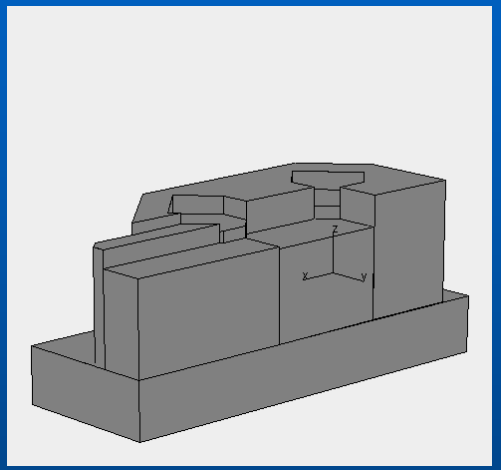
Meshing



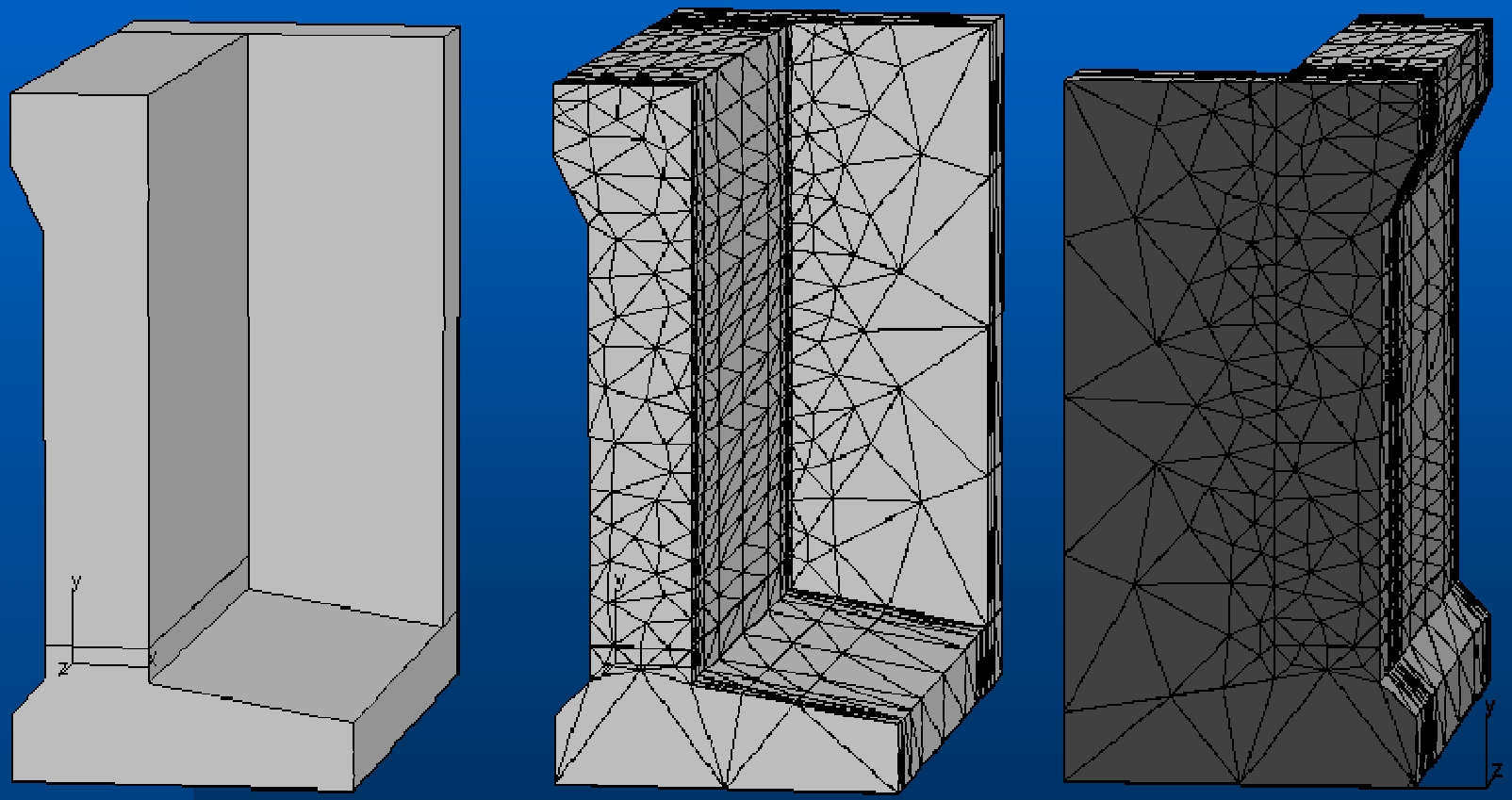
Examples



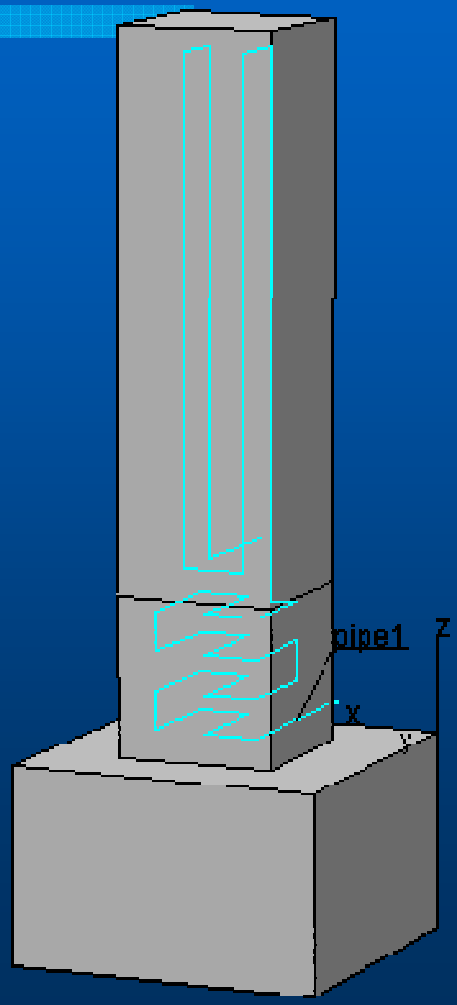




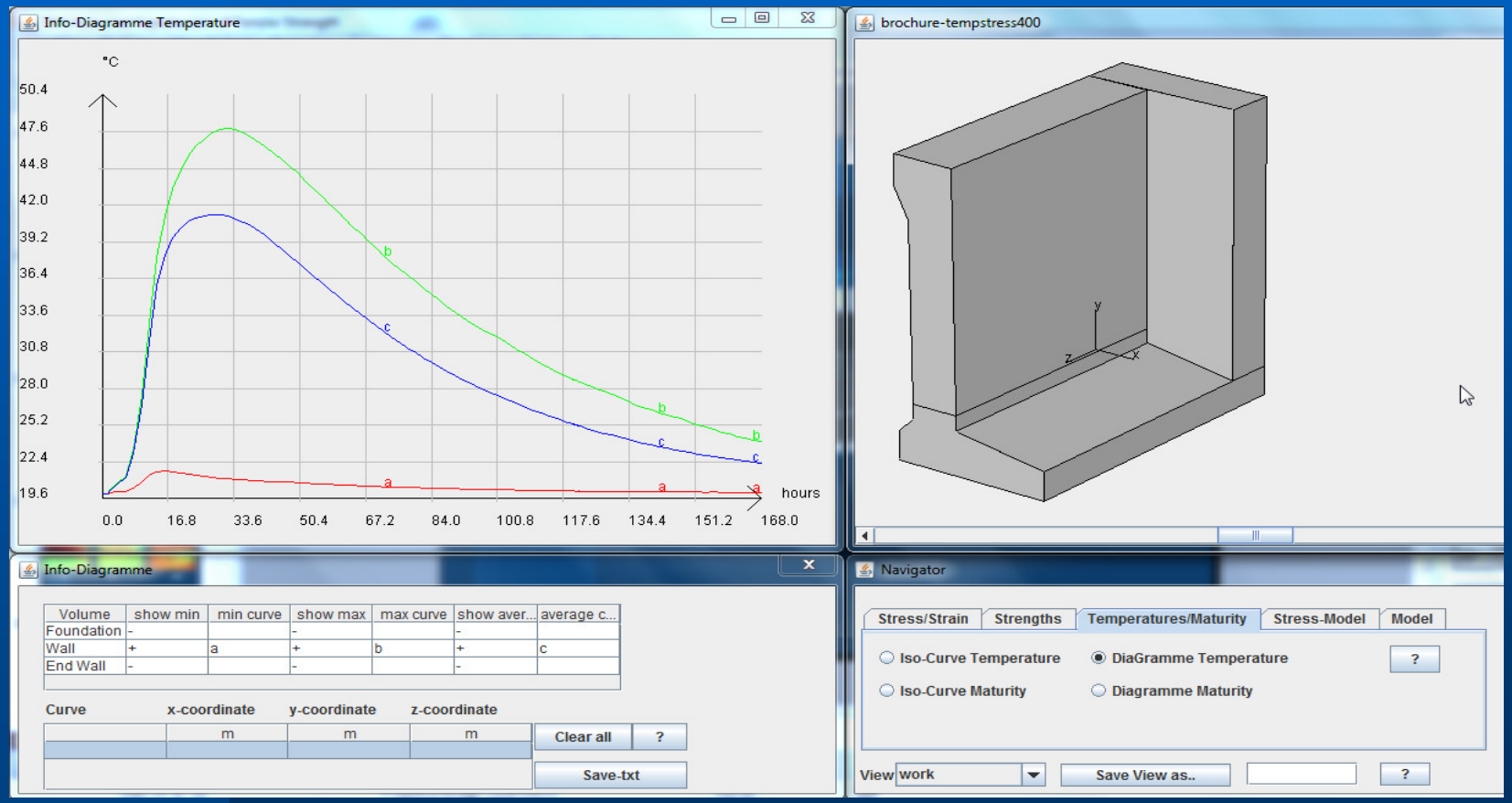
Examples



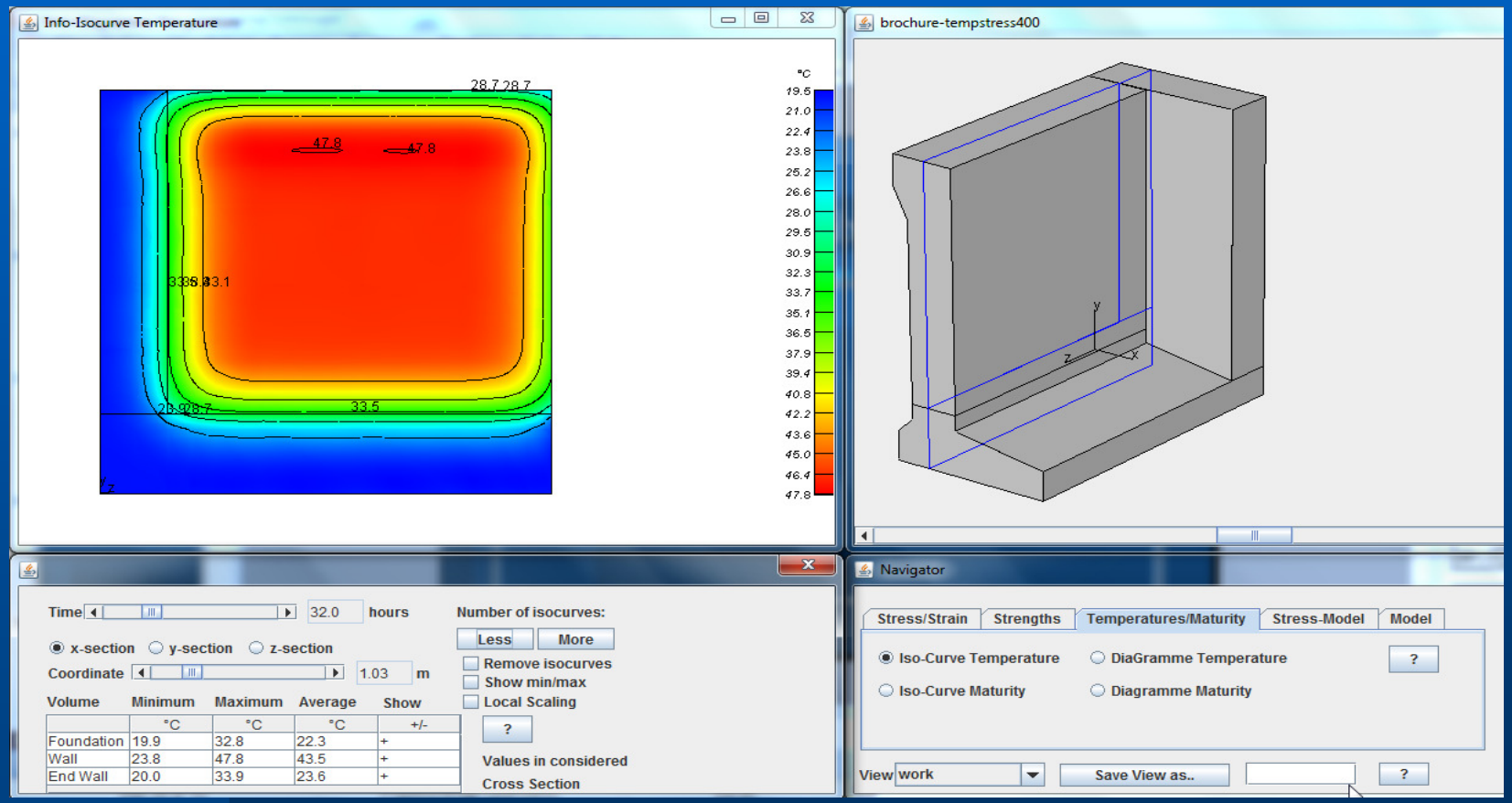
Cooling



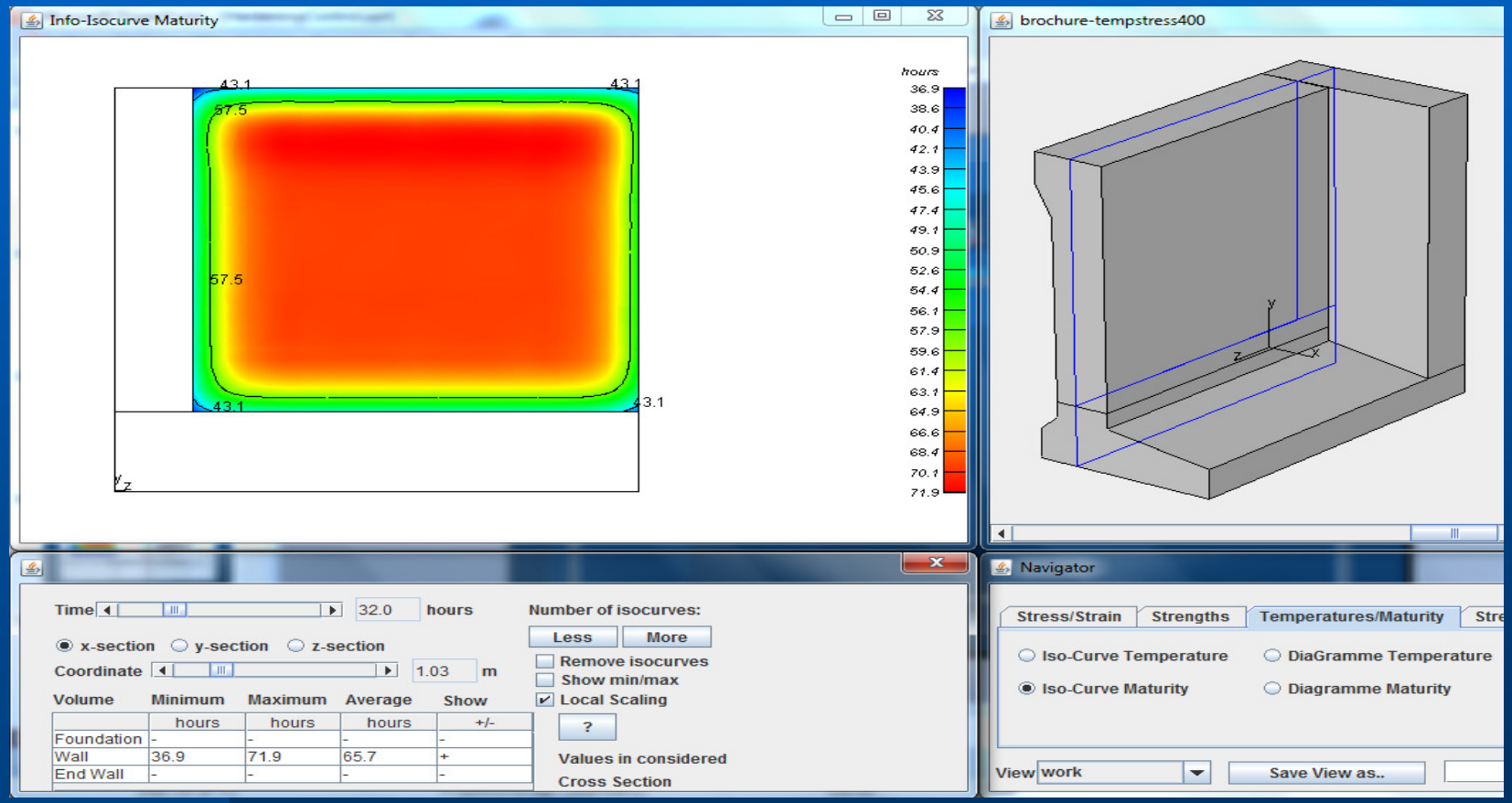
Temperature histories



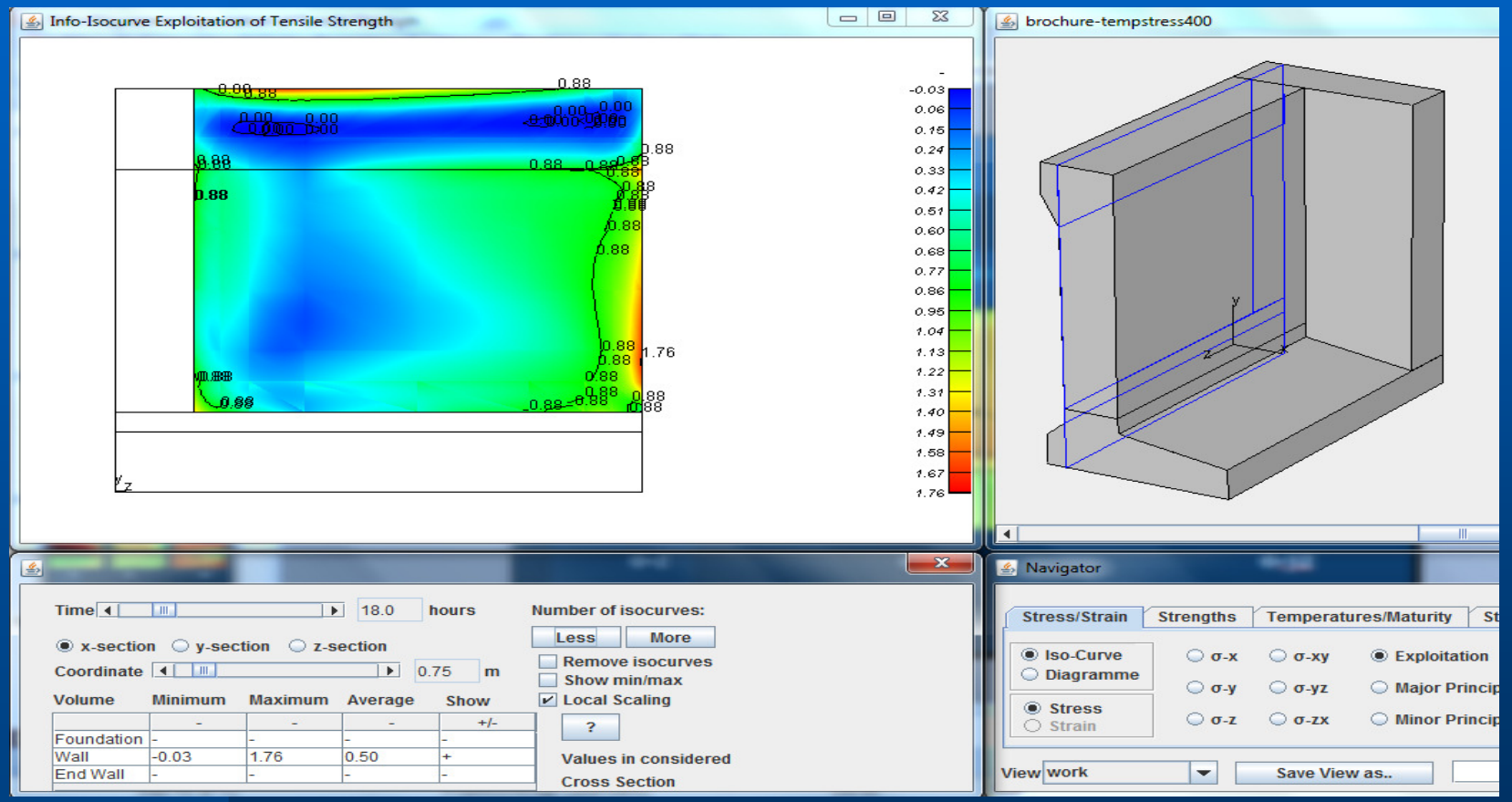
Temperature distribution



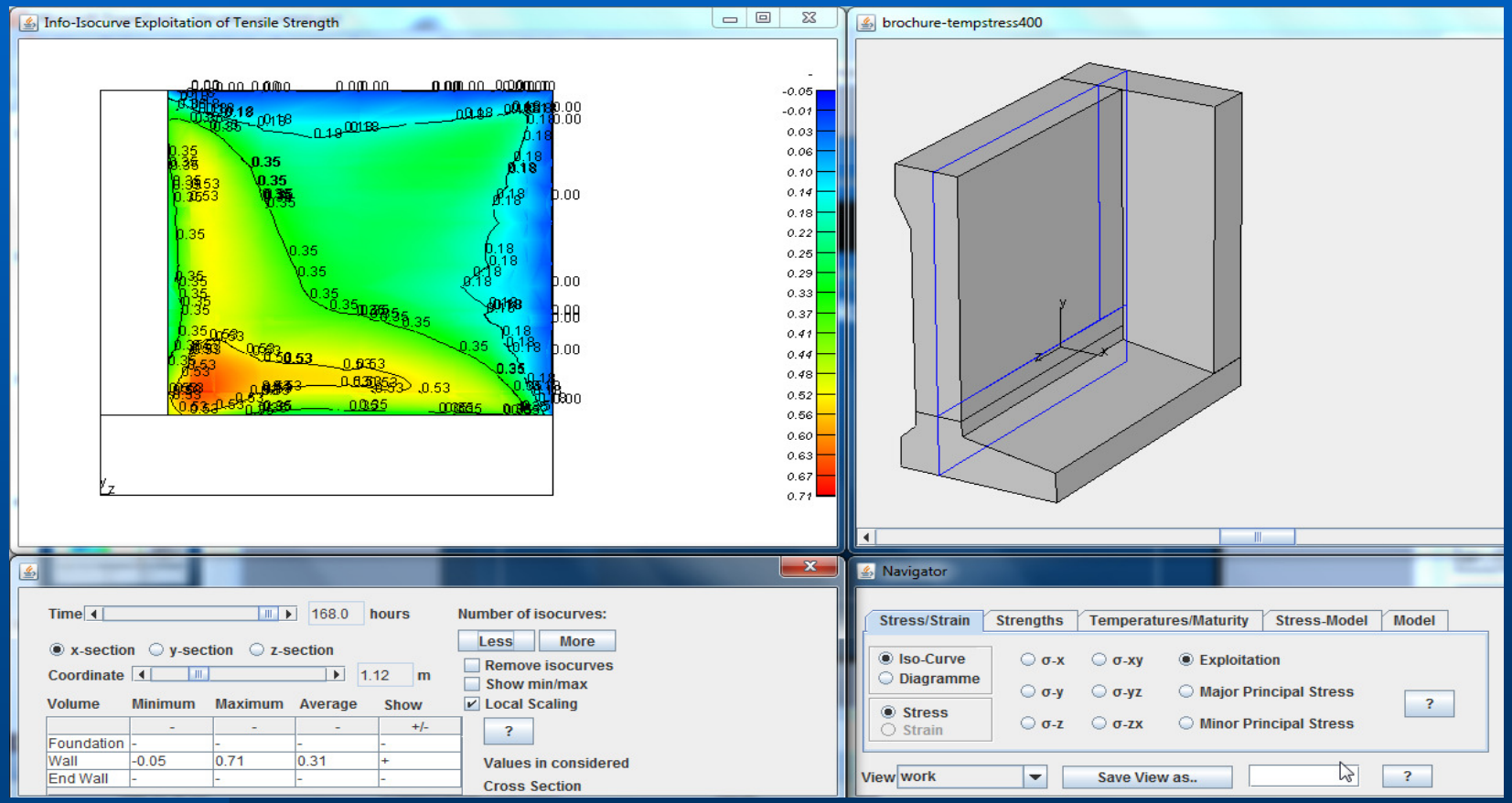
Same for maturity and strength



Early exploitation at surface

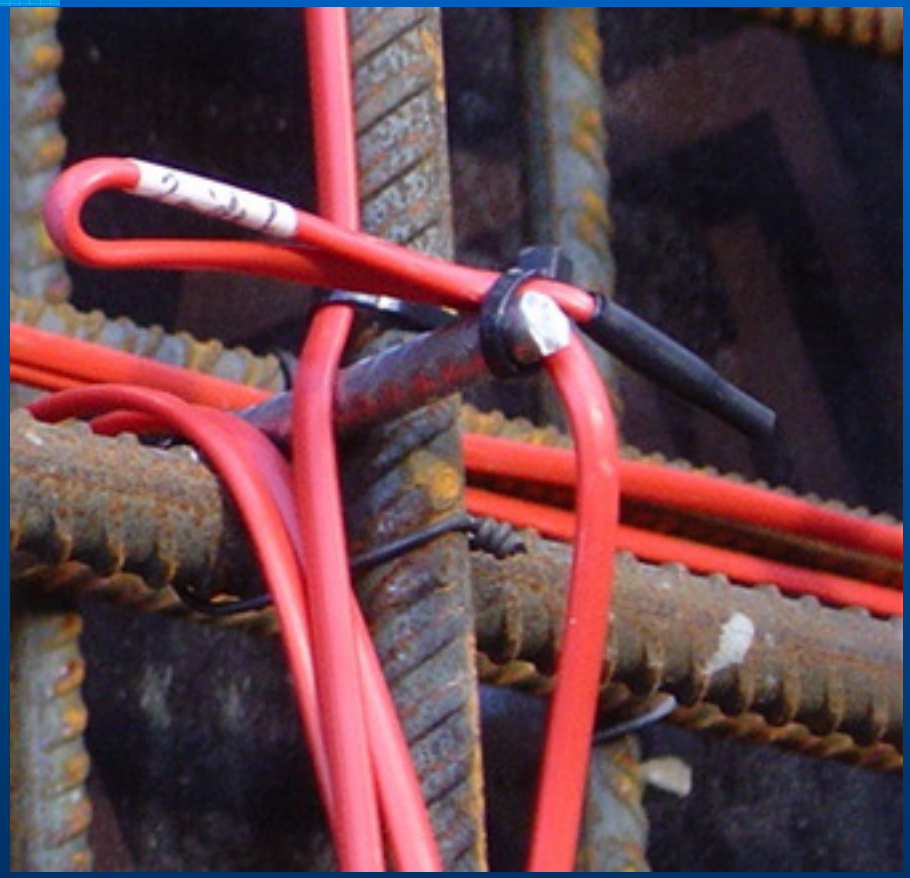


Exploitation at core after hardening



Verification on site: HeatWatch

- Monitoring and logging temperatures
- Calculating maturity and strengths based on user-input
- Fulfilling the requirements concerning freezing, evaporation, differences in temperature, maximum temperature level and strength.

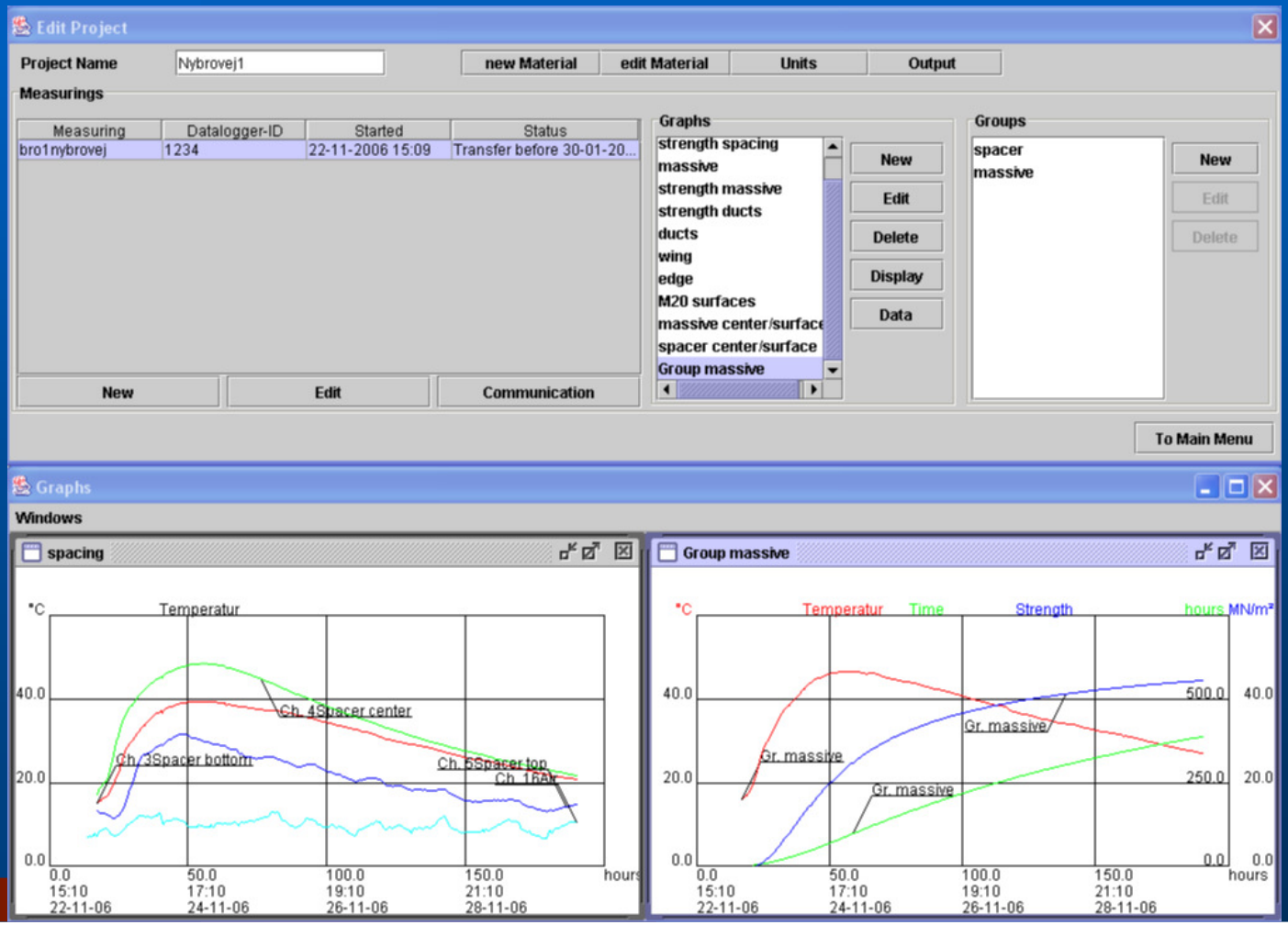


HeatWatch

- 10-30 Thermocouples
- Connected by Internet or wireless local network
- Also mV and mA can be monitored and logged
- Warnings by SMS or e-mail
- Web-interface showing instant values

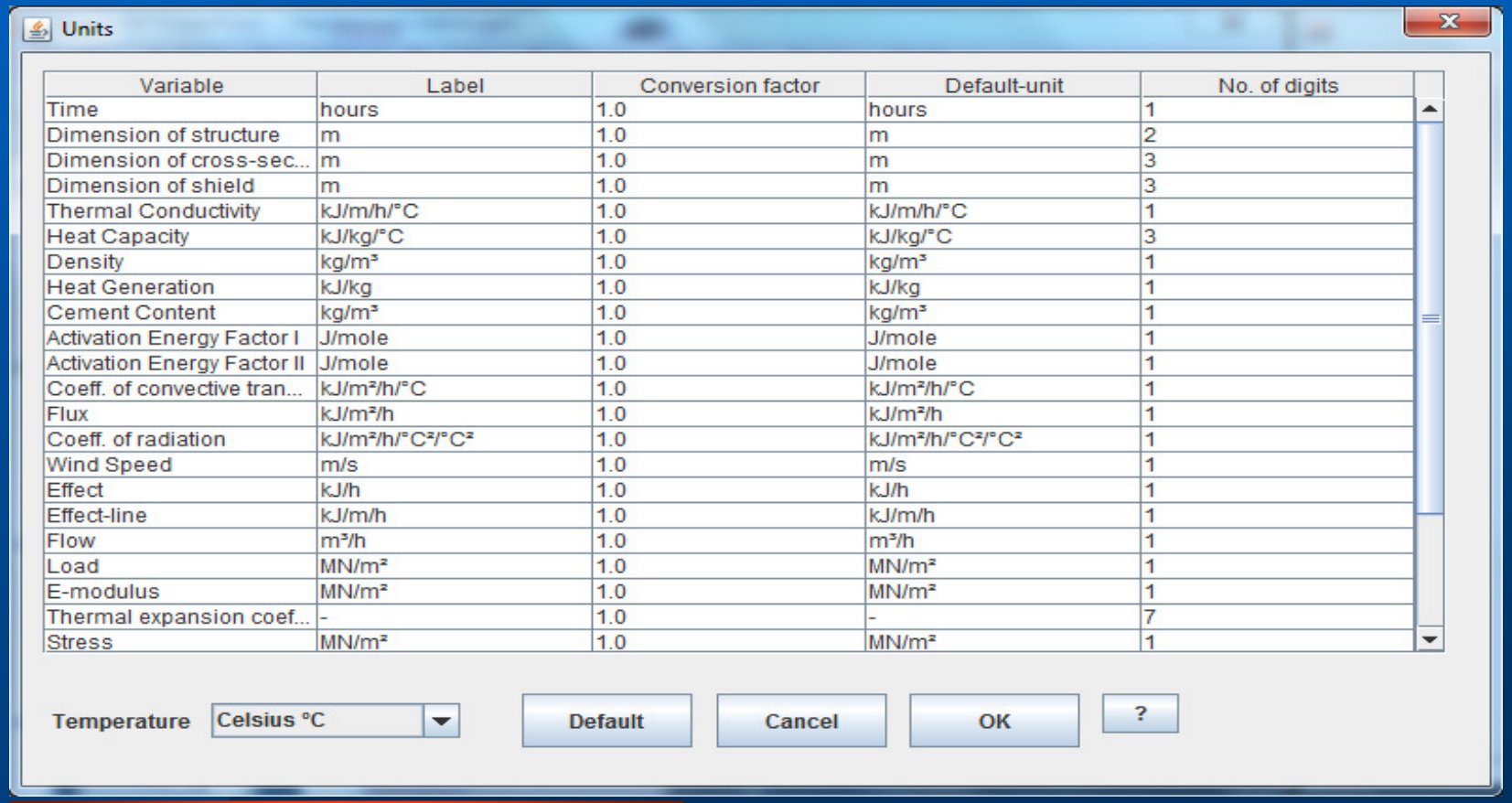
HeatWatch

Averages and differences on measured data can be defined by the user



Units

User-defined units



Reports

All software delivers printed reports